



UNIVERSIDADE FEDERAL DE CAMPINA GRANDE
CENTRO DE ENGENHARIA ELÉTRICA E INFORMÁTICA
UNIDADE ACADÊMICA DE SISTEMAS E COMPUTAÇÃO
CURSO DE BACHARELADO EM CIÊNCIA DA COMPUTAÇÃO

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ROTEIRO 8

Programa 1

```
addi s2, zero, 4  
addi s3, zero, 3  
addi s4, zero, 7  
addi s5, zero, 5  
addi s6, zero, 6  
add s7, s2, s3
```

1.a) Conteúdo da Memória de Instruções (“Instruction Memory”) e dos Registradores (“Registers”), no início e no final da execução do programa.

No início da execução o conteúdo da memória de instruções contém as seguintes instruções:

Endereço	Instrução	Código de máquina em binário	Código de máquina em hexadecimal
Endereço 0	addi s2, zero, 4	00000000010000000000100100010011	0x00400913
Endereço 4	addi s3, zero, 3	00000000001100000000100110010011	0x00300993
Endereço 8	addi s4, zero, 7	00000000011100000000101000010011	0x00700a13
Endereço 12	addi s5, zero, 5	00000000010100000000101010010011	0x00500a93
Endereço 16	addi s6, zero, 6	00000000011000000000101100010011	0x00600b13
Endereço 20	add s7, s2, s3	00000001001110010000101110110011	0x01390bb3

E os registradores têm valores inicializados com zero:

Registradores	Valores
s2	0
s3	0
s4	0
s5	0
s6	0
s7	0
zero	0

Conteúdo da memória de instruções no início da execução

EXECUTION STATUS															
handwritten.s			current cycle: -												
EXECUTION TABLE		CONSOLE													
Empty IF stage															
Empty ID stage															
Empty EX stage															
Empty MEM stage															
Empty WB stage															
Instruction Memory	Data Memory	Registers													
Address 0 (0x0) I-type Instruction: addi s2, x0, 4 00000000001000000000100100010011															
4	0	0	18	19											
0000000000100	00000	000	10010	00000001											
IMMEDIATE	RS1	FUNCT3	RD	OP											
Address 4 (0x4) I-type Instruction: addi s3, x0, 3 000000000001100000000100110010011															
3	0	0	19	19											
0000000000111	00000	000	10011	00000001											
IMMEDIATE	RS1	FUNCT3	RD	OP											
Address 8 (0x8) I-type Instruction: addi s4, x0, 7 000000000011100000000101000010011															
7	0	0	20	19											
0000000000111	00000	000	10100	00000001											
IMMEDIATE	RS1	FUNCT3	RD	OP											
Address 12 (0xc) I-type Instruction: addi s5, x0, 5 000000000010100000000101010010011															
5	0	0	21	19											
0000000000101	00000	000	10101	00000001											
IMMEDIATE	RS1	FUNCT3	RD	OP											
Address 16 (0x10) I-type Instruction: addi s6, x0, 6 000000000011000000000101100010011															
6	0	0	22	19											
0000000000110	00000	000	10110	00000001											
IMMEDIATE	RS1	FUNCT3	RD	OP											
Address 20 (0x14) R-type Instruction: add s7, s2, s3 00000000100111001000010111010011															
0	19	18	0	23	51										
0000000	10011	10010	000	10111	0110011										
FUNCT7	RS2	RS1	FUNCT3	RD	OP										

Conteúdo dos registradores no início da execução

EXECUTION STATUS															
handwritten.s			current cycle: -												
EXECUTION TABLE		CONSOLE													
Empty IF stage															
Empty ID stage															
Empty EX stage															
Empty MEM stage															
Empty WB stage															
Instruction Memory	Data Memory	Registers													
R.No.	Reg.Id.	Dec.Val	Binary Value (32 bit)												
0	x0	0	00000000000000000000000000000000												
1	ra	0	00000000000000000000000000000000												
2	sp	5120	00000000000000000000000000000000												
3	gp	1024	00000000000000000000000000000000												
4	tp	0	00000000000000000000000000000000												
5	t0	0	00000000000000000000000000000000												
6	t1	0	00000000000000000000000000000000												
7	t2	0	00000000000000000000000000000000												
8	s0/fp	5120	00000000000000000000000000000000												
9	s1	0	00000000000000000000000000000000												
10	a0	0	00000000000000000000000000000000												
11	a1	0	00000000000000000000000000000000												
12	a2	0	00000000000000000000000000000000												
13	a3	0	00000000000000000000000000000000												
14	a4	0	00000000000000000000000000000000												
15	a5	0	00000000000000000000000000000000												
16	a6	0	00000000000000000000000000000000												
17	a7	0	00000000000000000000000000000000												
18	s2	0	00000000000000000000000000000000												
19	s3	0	00000000000000000000000000000000												
20	s4	0	00000000000000000000000000000000												
21	s5	0	00000000000000000000000000000000												
22	s6	0	00000000000000000000000000000000												
23	s7	0	00000000000000000000000000000000												
24	s8	0	00000000000000000000000000000000												
25	s9	0	00000000000000000000000000000000												
26	s10	0	00000000000000000000000000000000												
27	s11	0	00000000000000000000000000000000												
28	t3	0	00000000000000000000000000000000												
29	t4	0	00000000000000000000000000000000												
30	t5	0	00000000000000000000000000000000												
31	t6	0	00000000000000000000000000000000												

No final da execução o conteúdo da memória de instruções permanece inalterada

Endereço	Instrução	Código de máquina em binário	Código de máquina em hexadecimal
Endereço 0	addi s2, zero, 4	00000000010000000000100100010011	0x00400913
Endereço 4	addi s3, zero, 3	00000000011000000000100110010011	0x00300993
Endereço 8	addi s4, zero, 7	00000000011100000000101000010011	0x00700a13
Endereço 12	addi s5, zero, 5	00000000010100000000101010010011	0x00500a93
Endereço 16	addi s6, zero, 6	00000000011000000000101100010011	0x00600b13
Endereço 20	add s7, s2, s3	00000001001110010000101110110011	0x01390bb3

E os registradores possuem os seguintes valores:

Registradores	Valores
s2	4
s3	3
s4	7
s5	5
s6	6
s7	7 (resultado da soma de s2 e s3)
zero	0

- Conteúdo da Memória de Instruções no início e no final da execução do programa:
 - No início da execução, o conteúdo da Memória de Instruções corresponde às instruções carregadas nela, que são as instruções do programa fornecido.
 - No final da execução, a Memória de Instruções permanece inalterada, pois não houve modificações nela durante a execução do programa.
- Conteúdo dos Registradores no início e no final da execução do programa:
 - No início da execução, todos os registradores possuem o valor zero, pois foram inicializados com zero.
 - Durante a execução do programa, as instruções de soma imediata (addi) atribuem valores específicos a determinados registradores. Por exemplo, a instrução "addi s2, zero, 4" atribui o valor 4 ao registrador s2.
 - No final da execução do programa, os registradores têm os valores resultantes das instruções executadas. Por exemplo, a instrução "add s7, s2, s3" realiza a soma dos valores contidos nos registradores s2 e s3 e armazena o resultado no registrador s7.

Conteúdo da memória de instruções no final da execução

EXECUTION STATUS									
handwritten.s									
EXECUTION TABLE				CONSOLE					
EXECUTION COMPLETED IN 10 CLOCK CYCLES									
Empty IF stage Empty ID stage Empty EX stage Empty MEM stage Empty WB stage									
Instruction Memory	Data Memory	Registers							
Address 0 (0x0) I-type Instruction: addi s2, x0, 4 00000000001000000000100100010011									
4	0	0	18	19					
0000000000100	00000	000	10010	0010011					
IMMEDIATE	R51	FUNCT3	RD	OP					
Address 4 (0x4) I-type Instruction: addi s3, x0, 3 0000000000011000000000100110010011									
3	0	0	19	19					
0000000000111	00000	000	10011	0010011					
IMMEDIATE	R51	FUNCT3	RD	OP					
Address 8 (0x8) I-type Instruction: addi s4, x0, 7 0000000000111000000000101000010011									
7	0	0	20	19					
0000000000111	00000	000	10100	0010011					
IMMEDIATE	R51	FUNCT3	RD	OP					
Address 12 (0xc) I-type Instruction: addi s5, x0, 5 000000000010100000000101010010011									
5	0	0	21	19					
0000000000101	00000	000	10101	0010011					
IMMEDIATE	R51	FUNCT3	RD	OP					
Address 16 (0x10) I-type Instruction: addi s6, x0, 6 000000000011000000000101100010011									
6	0	0	22	19					
0000000000110	00000	000	10110	0010011					
IMMEDIATE	R51	FUNCT3	RD	OP					
Address 20 (0x14) R-type Instruction: add s7, s2, s3 000000001001110010000101110110011									
0	19	18	0	23	51				
0000000010011	10011	10010	000	10111	0110011				
FUNCT7	RS2	RS1	FUNCT3	RD	OP				

Conteúdo dos registradores no final da execução

1.b) Passagem em três estágios representativos do Pipeline (“SCHEMA LAYOUT”)

Estágio 1 - Busca de Instrução (IF): Nesse estágio, a instrução é buscada da memória de instruções com base no contador de programa (PC) atual.

Ciclo 1: IF: addi s2, zero, 4
Ciclo 2: IF: addi s3, zero, 3
Ciclo 3: IF: addi s4, zero, 7
Ciclo 4: IF: addi s5, zero, 5
Ciclo 5: IF: addi s6, zero, 6
Ciclo 6: IF: add s7, s2, s3

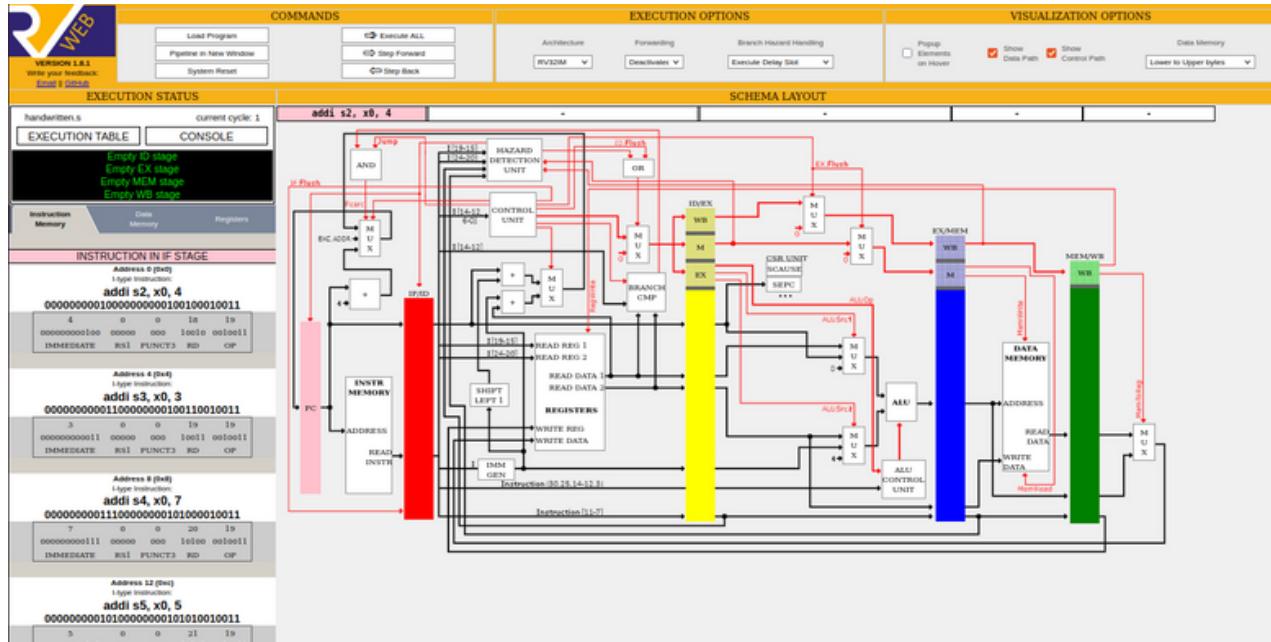
Estágio 2 - Decodificação e Busca de Operandos (ID): Nesse estágio, a instrução é decodificada, os registradores necessários são lidos da memória de registradores (registraror de origem) e os operandos são buscados.

Ciclo 2: ID: addi s2, zero, 4
Ciclo 3: ID: addi s3, zero, 3
Ciclo 4: ID: addi s4, zero, 7
Ciclo 5: ID: addi s5, zero, 5
Ciclo 6: ID: addi s6, zero, 6
Ciclo 7: ID: add s7, s2, s3

Estágio 3 - Execução e Cálculo de Endereço (EX): Nesse estágio, a instrução é executada e o resultado é calculado.

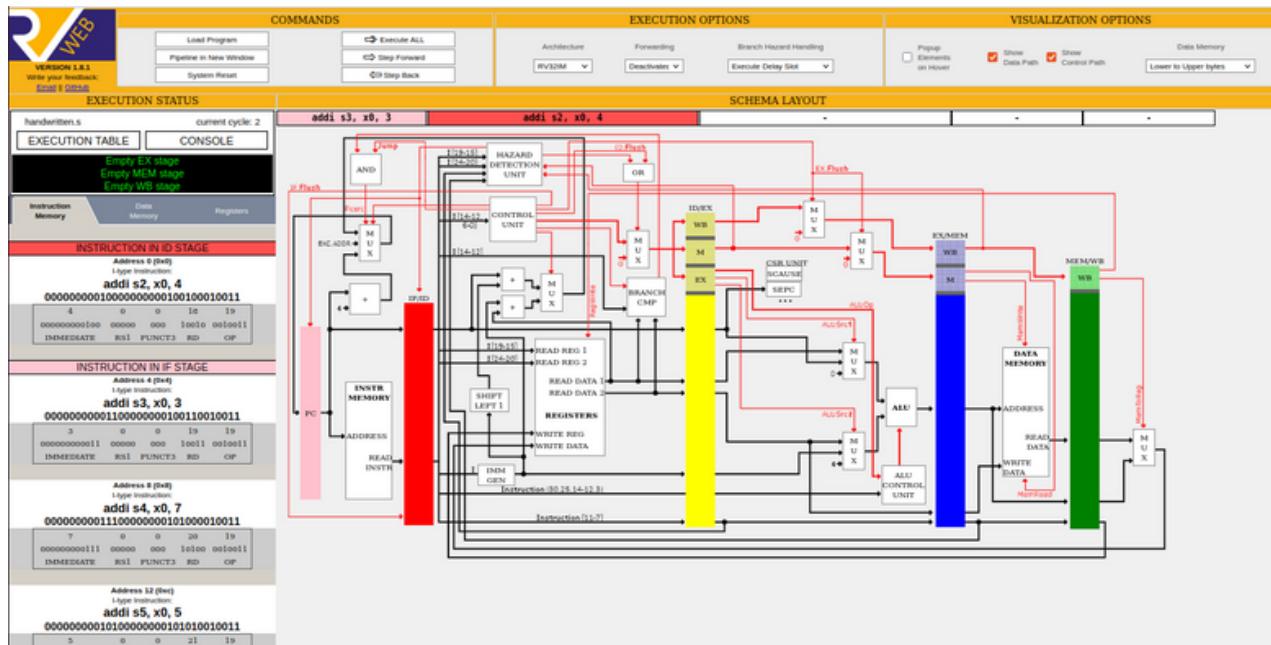
Ciclo 3: EX: addi s2, zero, 4
Ciclo 4: EX: addi s3, zero, 3
Ciclo 5: EX: addi s4, zero, 7
Ciclo 6: EX: addi s5, zero, 5
Ciclo 7: EX: addi s6, zero, 6
Ciclo 8: EX: add s7, s2, s3

Ciclo 1: IF: addi s2, zero, 4



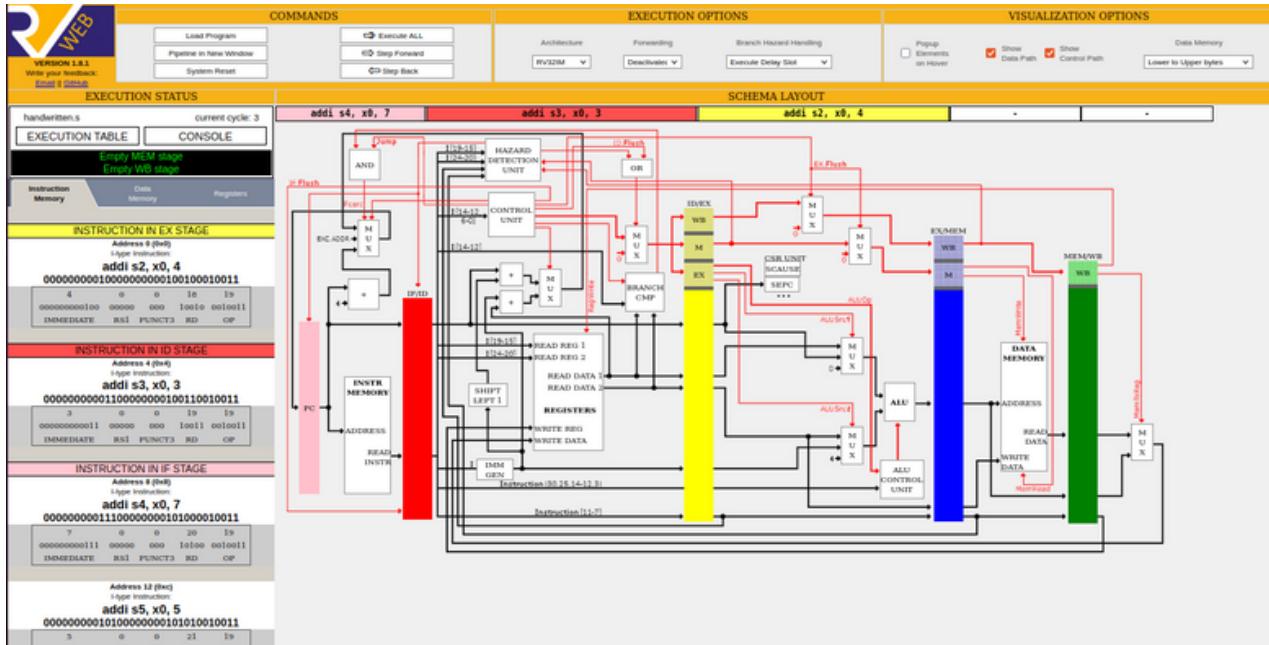
Ciclo 2:

- IF: addi s3, zero, 3
- ID: addi s2, zero, 4



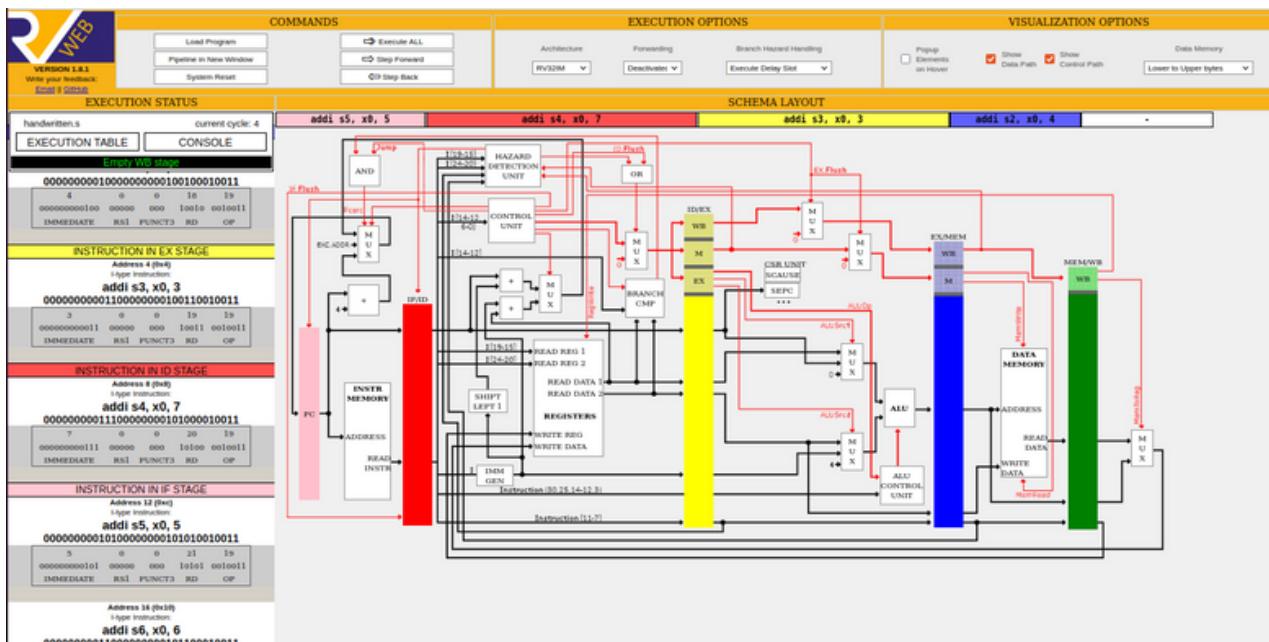
Ciclo 3:

- IF: addi s4, zero, 7
- ID: addi s3, zero, 3
- EX: addi s2, zero, 4



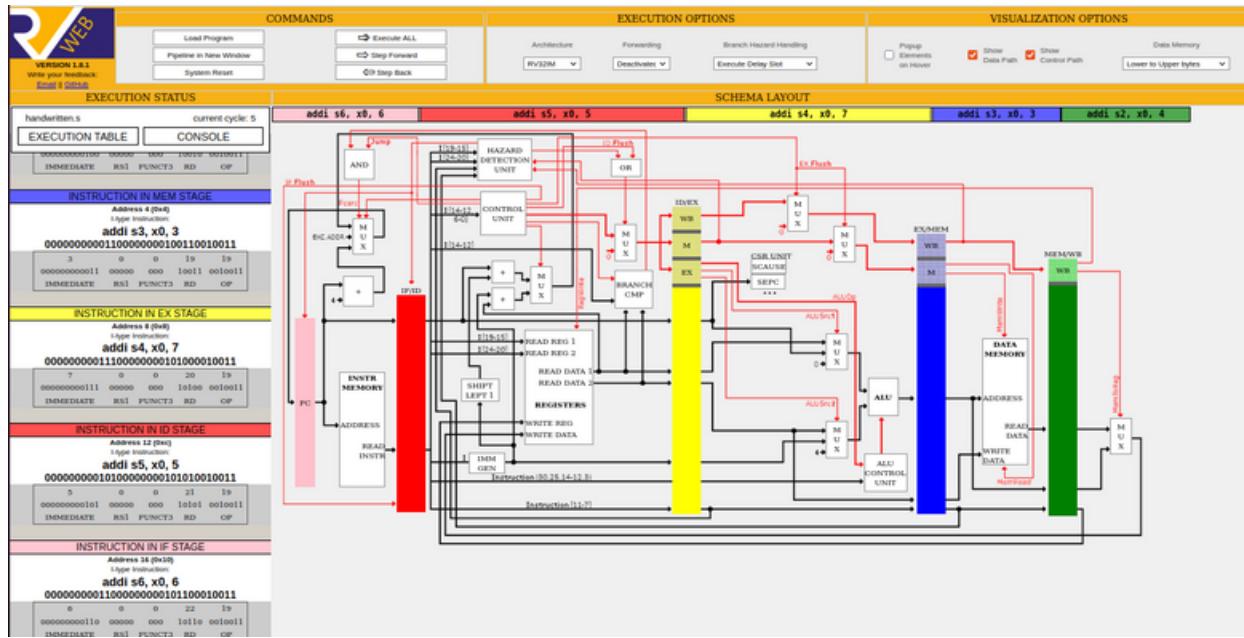
Ciclo 4:

- IF: addi s5, zero, 5
- ID: addi s4, zero, 7
- EX: addi s3, zero, 3



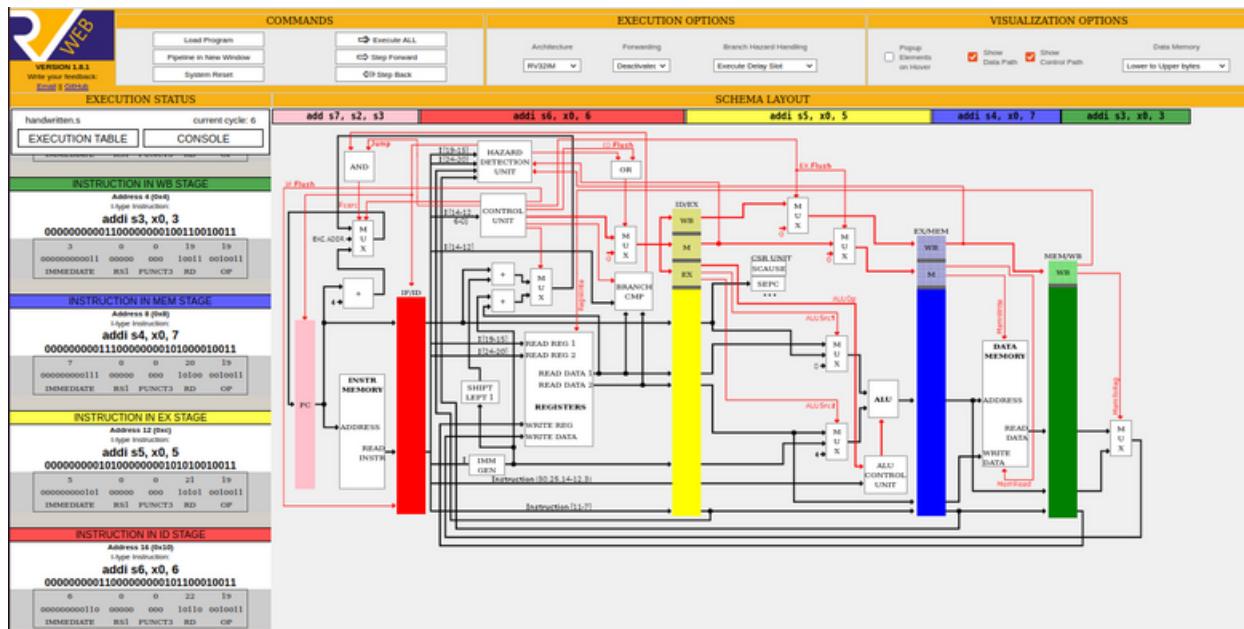
Ciclo 5:

- IF: addi s6, zero, 6
- ID: addi s5, zero, 5
- EX: addi s4, zero, 7



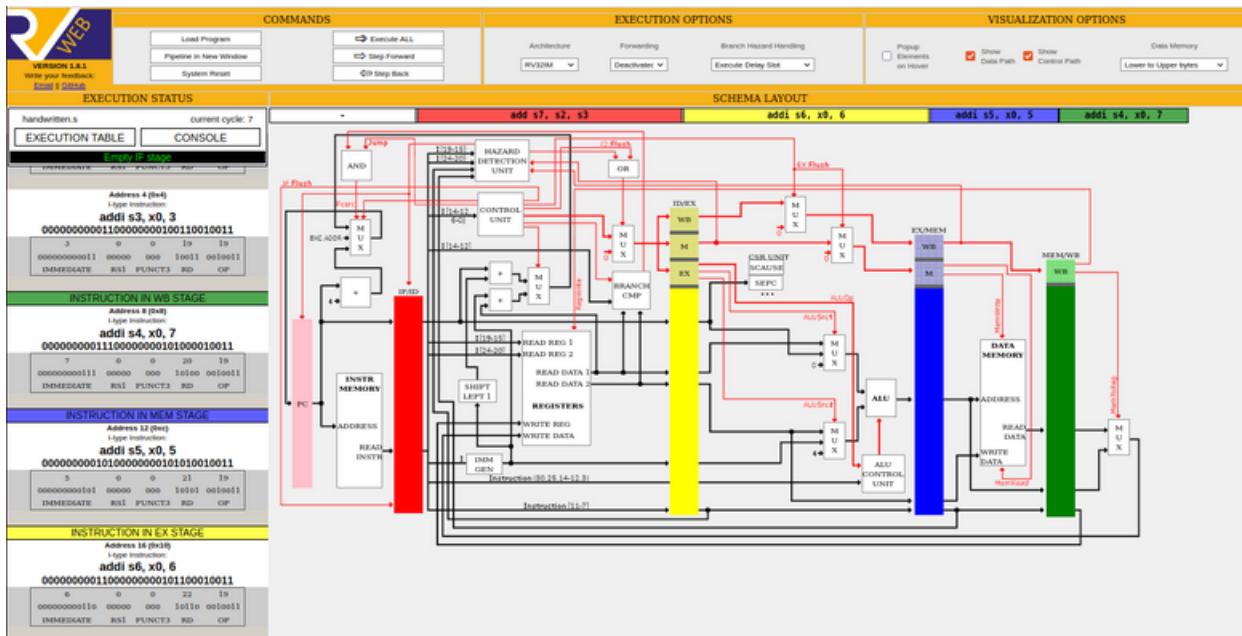
Ciclo 6:

- IF: add s7, s2, s3
- ID: addi s6, zero, 6
- EX: addi s5, zero, 5



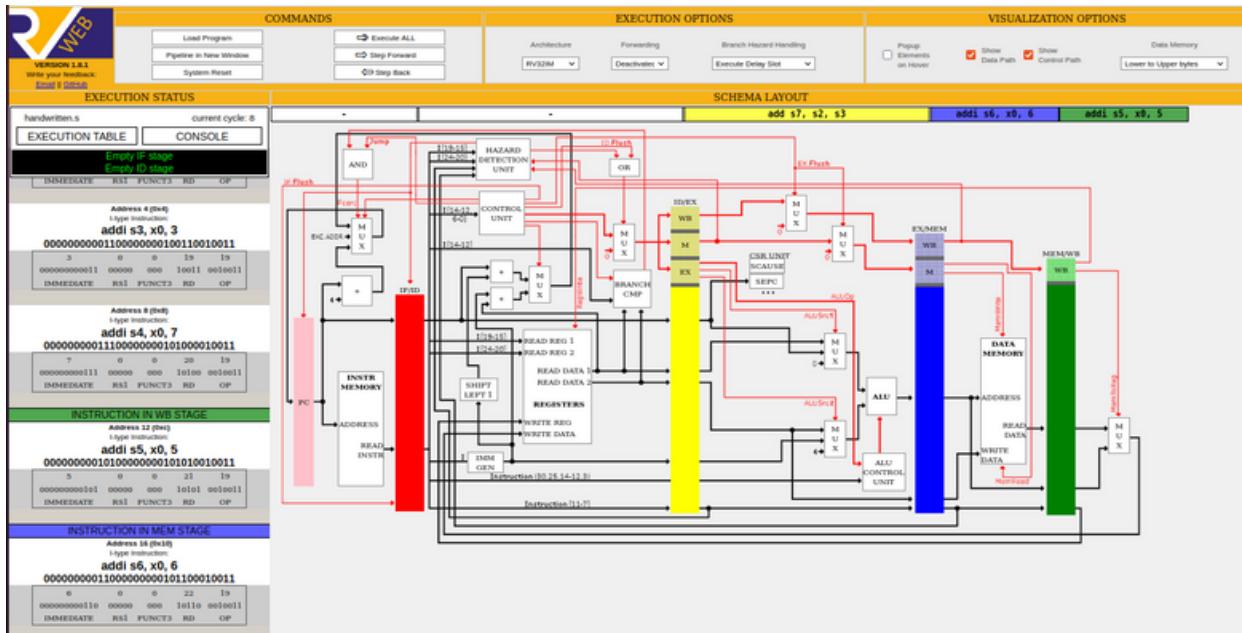
Ciclo 7:

- ID: add s7, s2, s3
- EX: addi s6, zero, 6



Ciclo 8:

- EX: add s7, s2, s3



1.c) Resultado final da execução em Pipeline, por meio da Tabela da Execução do Programa (“EXECUTION TABLE”).

EXECUTION TABLE										
FULL LOOPS	CPU Cycles									
Instruction	1	2	3	4	5	6	7	8	9	10
addi s2, x0, 4	F	D	X	M	W					
addi s3, x0, 3		F	D	X	M	W				
addi s4, x0, 7			F	D	X	M	W			
addi s5, x0, 5				F	D	X	M	W		
addi s6, x0, 6					F	D	X	M	W	
add s7, s2, s3						F	D	X	M	W

1.d) Ciclos de CPU necessários para executar esse programa.

Total de ciclos da CPU = 10

2.a) Conteúdo da Memória de Instruções (“Instruction Memory”) e dos Registradores (“Registers”), no início e no final da execução do programa.

No início da execução o conteúdo da memória de instruções são os mesmos da questão anterior, contendo as seguintes instruções:

Endereço	Instrução	Código de máquina em binário	Código de máquina em hexadecimal
Endereço 0	addi s2, zero, 4	00000000010000000000100100010011	0x00400913
Endereço 4	addi s3, zero, 3	00000000011000000000100110010011	0x00300993
Endereço 8	addi s4, zero, 7	00000000011100000000101000010011	0x00700a13
Endereço 12	addi s5, zero, 5	00000000010100000000101010010011	0x00500a93
Endereço 16	addi s6, zero, 6	00000000011000000000101100010011	0x00600b13
Endereço 20	add s7, s2, s3	00000001001110010000101110110011	0x01390bb3

E os registradores têm valores inicializados com zero:

Registradores	Valores
s2	0
s3	0
s4	0
s5	0
s6	0
s7	0
zero	0

Conteúdo da memória de instruções no início da execução

EXECUTION STATUS																							
handwritten.s			current cycle: -																				
EXECUTION TABLE			CONSOLE																				
Empty IF stage Empty ID stage Empty EX stage Empty MEM stage Empty WB stage																							
Instruction Memory		Data Memory		Registers																			
Address 0 (0x0) I-type Instruction: addi s2, x0, 4 00000000010000000000100100010011 <table border="1"> <tr> <td>4</td><td>0</td><td>0</td><td>18</td><td>19</td></tr> <tr> <td>00000000100</td><td>00000</td><td>000</td><td>10010</td><td>0010011</td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td></tr> </table>						4	0	0	18	19	00000000100	00000	000	10010	0010011	IMMEDIATE	RS1	FUNCT3	RD	OP			
4	0	0	18	19																			
00000000100	00000	000	10010	0010011																			
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Address 4 (0x4) I-type Instruction: addi s3, x0, 3 00000000011000000000100110010011 <table border="1"> <tr> <td>3</td><td>0</td><td>0</td><td>19</td><td>19</td></tr> <tr> <td>00000000011</td><td>00000</td><td>000</td><td>10011</td><td>0010011</td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td></tr> </table>						3	0	0	19	19	00000000011	00000	000	10011	0010011	IMMEDIATE	RS1	FUNCT3	RD	OP			
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6	0	0	22	19																			
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0	19	18	0	23	51																		
0000000	10011	10010	000	10111	0110011																		
FUNCT7	RS2	RS1	FUNCT3	RD	OP																		

Conteúdo dos registradores no início da execução

No final da execução o conteúdo da memória de instruções permanece inalterada

Endereço	Instrução	Código de máquina em binário	Código de máquina em hexadecimal
Endereço 0	addi s2, zero, 4	00000000010000000000100100010011	0x00400913
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Endereço 16	addi s6, zero, 6	00000000011000000000101100010011	0x00600b13
Endereço 20	add s7, s2, s3	00000001001110010000101110110011	0x01390bb3

E os registradores possuem os seguintes valores:

Registradores	Valores
s2	4
s3	3
s4	7
s5	5
s6	6
s7	7 (resultado da soma de s2 e s3)
zero	0

Conteúdo da memória de instruções no final da execução

EXECUTION STATUS																									
handwritten.s																									
EXECUTION TABLE		CONSOLE																							
EXECUTION COMPLETED IN 10 CLOCK CYCLES																									
Empty IF stage Empty ID stage Empty EX stage Empty MEM stage Empty WB stage																									
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000000000101	00000	000	10101	0010011																					
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Address 16 (0x10) I-type Instruction: addi s6, x0, 6 00000000011000000000101100010011 <table border="1"> <tr> <td>6</td><td>0</td><td>0</td><td>22</td><td>19</td></tr> <tr> <td>000000000110</td><td>00000</td><td>000</td><td>10110</td><td>0010011</td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td></tr> </table>								6	0	0	22	19	000000000110	00000	000	10110	0010011	IMMEDIATE	RS1	FUNCT3	RD	OP			
6	0	0	22	19																					
000000000110	00000	000	10110	0010011																					
IMMEDIATE	RS1	FUNCT3	RD	OP																					
Address 20 (0x14) R-type Instruction: add s7, s2, s3 00000001001110010000101110110011 <table border="1"> <tr> <td>0</td><td>19</td><td>18</td><td>0</td><td>23</td><td>51</td></tr> <tr> <td>0000000</td><td>10011</td><td>10010</td><td>000</td><td>10111</td><td>0110011</td></tr> <tr> <td>FUNCT7</td><td>RS2</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td></tr> </table>								0	19	18	0	23	51	0000000	10011	10010	000	10111	0110011	FUNCT7	RS2	RS1	FUNCT3	RD	OP
0	19	18	0	23	51																				
0000000	10011	10010	000	10111	0110011																				
FUNCT7	RS2	RS1	FUNCT3	RD	OP																				

Conteúdo dos registradores no final da execução

EXECUTION STATUS													
handwritten.s													
EXECUTION TABLE		CONSOLE											
EXECUTION COMPLETED IN 10 CLOCK CYCLES													
Empty IF stage Empty ID stage Empty EX stage Empty MEM stage Empty WB stage													
Instruction Memory	Data Memory	Registers											
R.No.	Reg.Id.	Dec.Val	Binary Value (32 bit)										
0	x0	0	00000000000000000000000000000000										
1	ra	0	00000000000000000000000000000000										
2	sp	5120	00000000000000000000000000000000										
3	gp	1024	00000000000000000000000000000000										
4	tp	0	00000000000000000000000000000000										
5	t0	0	00000000000000000000000000000000										
6	t1	0	00000000000000000000000000000000										
7	t2	0	00000000000000000000000000000000										
8	s0/fp	5120	00000000000000000000000000000000										
9	s1	0	00000000000000000000000000000000										
10	a0	0	00000000000000000000000000000000										
11	a1	0	00000000000000000000000000000000										
12	a2	0	00000000000000000000000000000000										
13	a3	0	00000000000000000000000000000000										
14	a4	0	00000000000000000000000000000000										
15	a5	0	00000000000000000000000000000000										
16	a6	0	00000000000000000000000000000000										
17	a7	0	00000000000000000000000000000000										
18	s2	4	00000000000000000000000000000000										
19	s3	3	00000000000000000000000000000000										
20	s4	7	00000000000000000000000000000000										
21	s5	5	00000000000000000000000000000000										
22	s6	6	00000000000000000000000000000000										
23	s7	7	00000000000000000000000000000000										
24	s8	0	00000000000000000000000000000000										
25	s9	0	00000000000000000000000000000000										
26	s10	0	00000000000000000000000000000000										
27	s11	0	00000000000000000000000000000000										
28	t3	0	00000000000000000000000000000000										
29	t4	0	00000000000000000000000000000000										
29	t4	0	00000000000000000000000000000000										
30	t5	0	00000000000000000000000000000000										
31	t6	0	00000000000000000000000000000000										

2.b) Passagem em três estágios representativos do Pipeline (“SCHEMA LAYOUT”)

A passagem das instruções do programa pelos três estágios do Pipeline permanece inalterada em relação à questão 1, exceto pelas ilustrações, uma vez que o simulador online WebRISC-V não exibe as passagens do pipeline quando o encaminhamento (forwarding) está ativado.

Estágio 1 - Busca de Instrução (IF): Nesse estágio, a instrução é buscada da memória de instruções com base no contador de programa (PC) atual.

Ciclo 1: IF: addi s2, zero, 4
Ciclo 2: IF: addi s3, zero, 3
Ciclo 3: IF: addi s4, zero, 7
Ciclo 4: IF: addi s5, zero, 5
Ciclo 5: IF: addi s6, zero, 6
Ciclo 6: IF: add s7, s2, s3

Estágio 2 - Decodificação e Busca de Operandos (ID): Nesse estágio, a instrução é decodificada, os registradores necessários são lidos da memória de registradores (registraror de origem) e os operandos são buscados.

Ciclo 2: ID: addi s2, zero, 4
Ciclo 3: ID: addi s3, zero, 3
Ciclo 4: ID: addi s4, zero, 7
Ciclo 5: ID: addi s5, zero, 5
Ciclo 6: ID: addi s6, zero, 6
Ciclo 7: ID: add s7, s2, s3

Estágio 3 - Execução e Cálculo de Endereço (EX): Nesse estágio, a instrução é executada e o resultado é calculado.

Ciclo 3: EX: addi s2, zero, 4
Ciclo 4: EX: addi s3, zero, 3
Ciclo 5: EX: addi s4, zero, 7
Ciclo 6: EX: addi s5, zero, 5
Ciclo 7: EX: addi s6, zero, 6
Ciclo 8: EX: add s7, s2, s3

Ciclo 1: IF: addi s2, zero, 4

EXECUTION STATUS

current cycle: 1

COMMANDS

- Load Program
- Pipeline in New Window
- System Reset
- Execute All
- Step Forward
- Step Back

EXECUTION OPTIONS

- Architecture: RV32IM
- Branch Hazard Handling: Activated
- Execute Delay Set

VISUALIZATION OPTIONS

- Show Elements on Hover
- Show Data Path
- Show Control Path
- Data Memory
- Lower to Upper bytes

EXECUTION TABLE

FULL LOOPS	CPU Cycles
Instruction	1
addi s2, x0, 4	F

Ciclo 2:

- IF: addi s3, zero, 3
- ID: addi s2, zero, 4

EXECUTION STATUS

current cycle: 2

COMMANDS

- Load Program
- Pipeline in New Window
- System Reset
- Execute All
- Step Forward
- Step Back

EXECUTION OPTIONS

- Architecture: RV32IM
- Branch Hazard Handling: Activated
- Execute Delay Set

VISUALIZATION OPTIONS

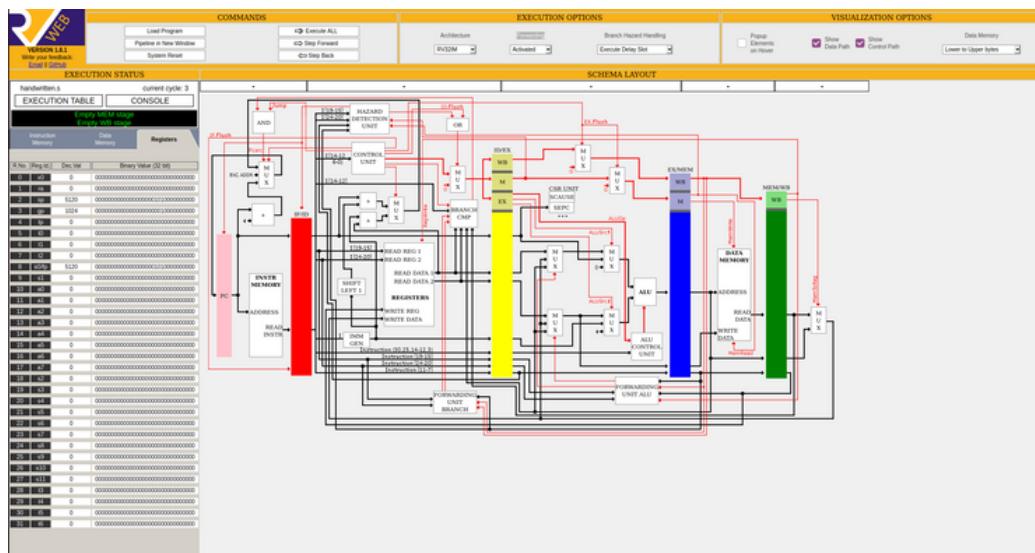
- Show Elements on Hover
- Show Data Path
- Show Control Path
- Data Memory
- Lower to Upper bytes

EXECUTION TABLE

FULL LOOPS	CPU Cycles
Instruction	1 2
addi s2, x0, 4	F D
addi s3, x0, 3	F

Ciclo 3:

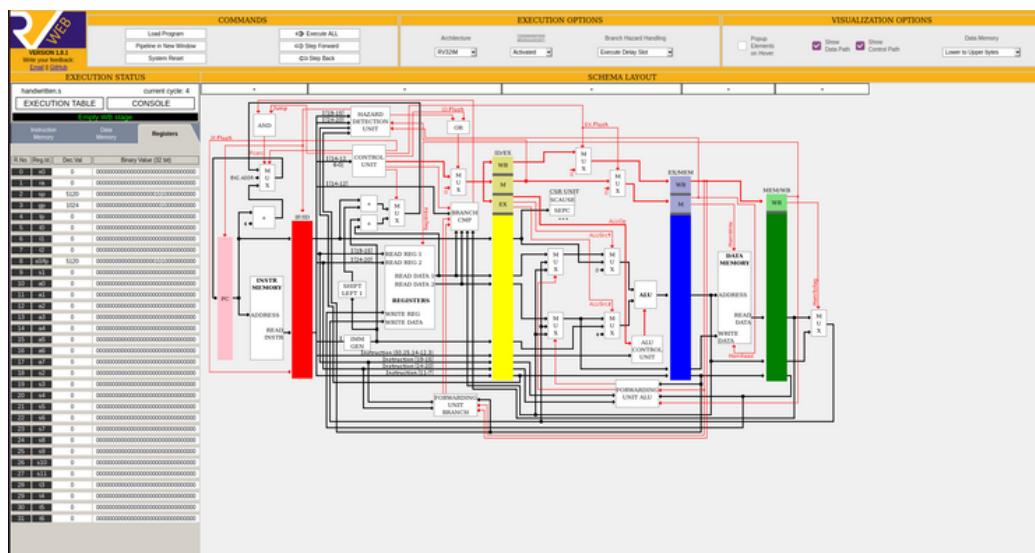
- IF: addi s4, zero, 7
- ID: addi s3, zero, 3
- EX: addi s2, zero, 4



EXECUTION TABLE				
FULL LOOPS	CPU Cycles	1	2	3
Instruction				
addi s2, x0, 4	F D X			
addi s3, x0, 3		F D X		
addi s4, x0, 7			F D	

Ciclo 4:

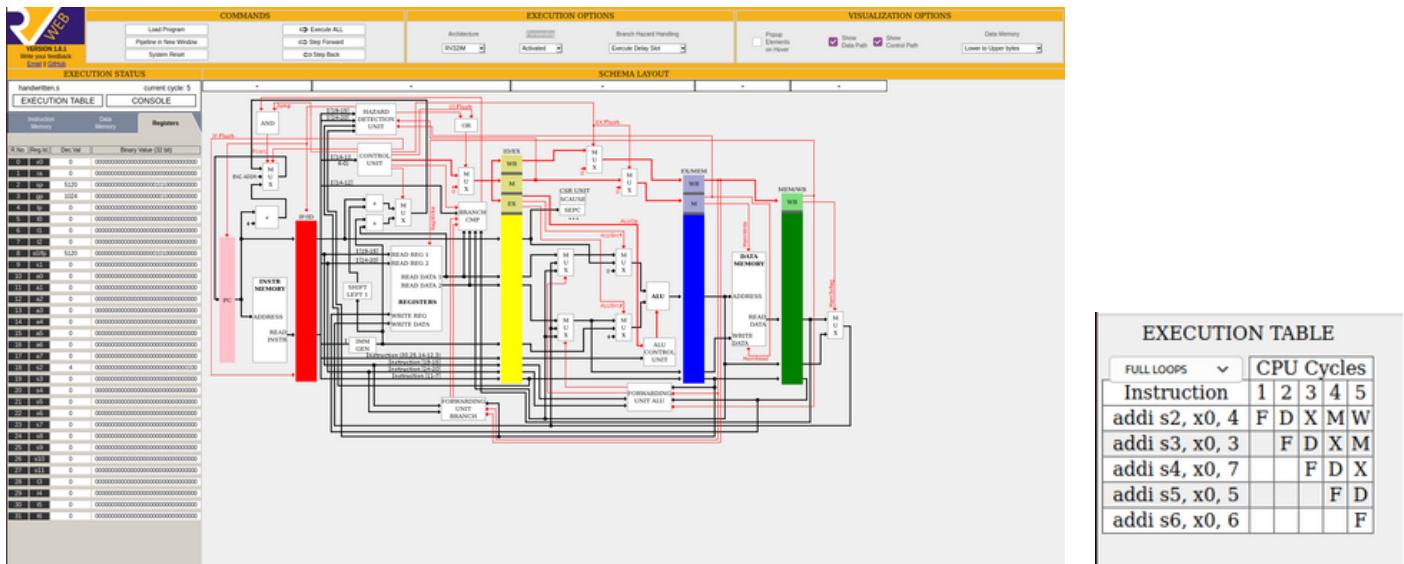
- IF: addi s5, zero, 5
- ID: addi s4, zero, 7
- EX: addi s3, zero, 3



EXECUTION TABLE					
FULL LOOPS	CPU Cycles	1	2	3	4
Instruction					
addi s2, x0, 4	F D X M				
addi s3, x0, 3		F D X			
addi s4, x0, 7			F D		
addi s5, x0, 5				F	

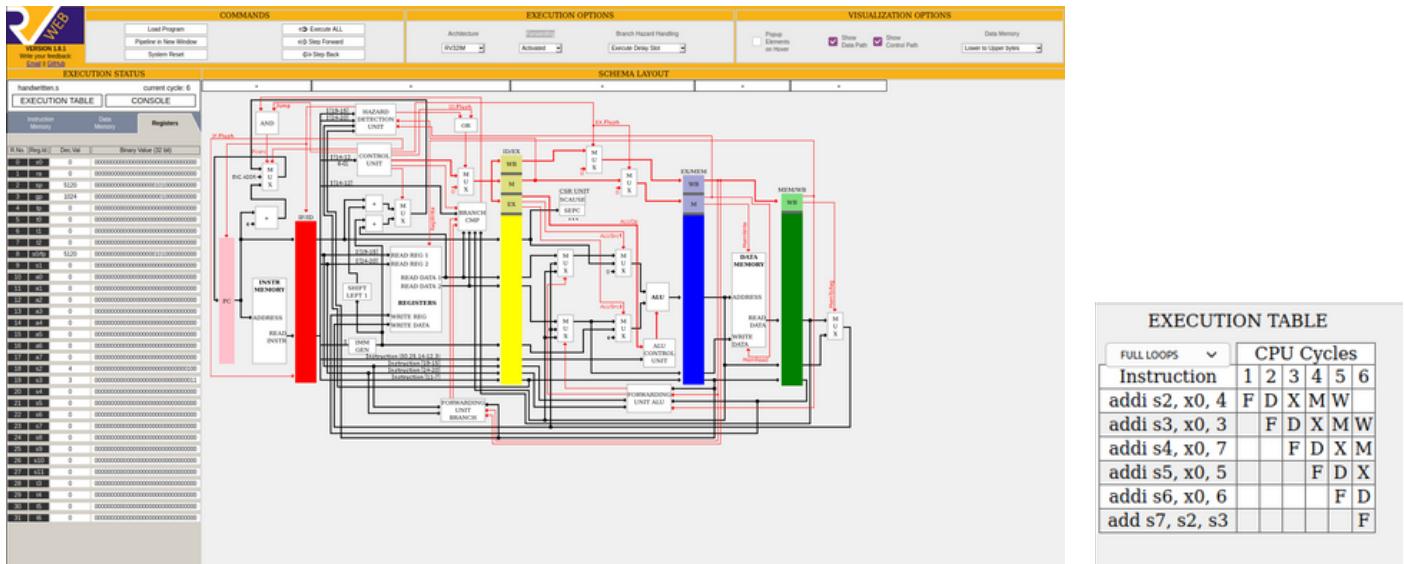
Ciclo 5:

- IF: addi s6, zero, 6
- ID: addi s5, zero, 5
- EX: addi s4, zero, 7



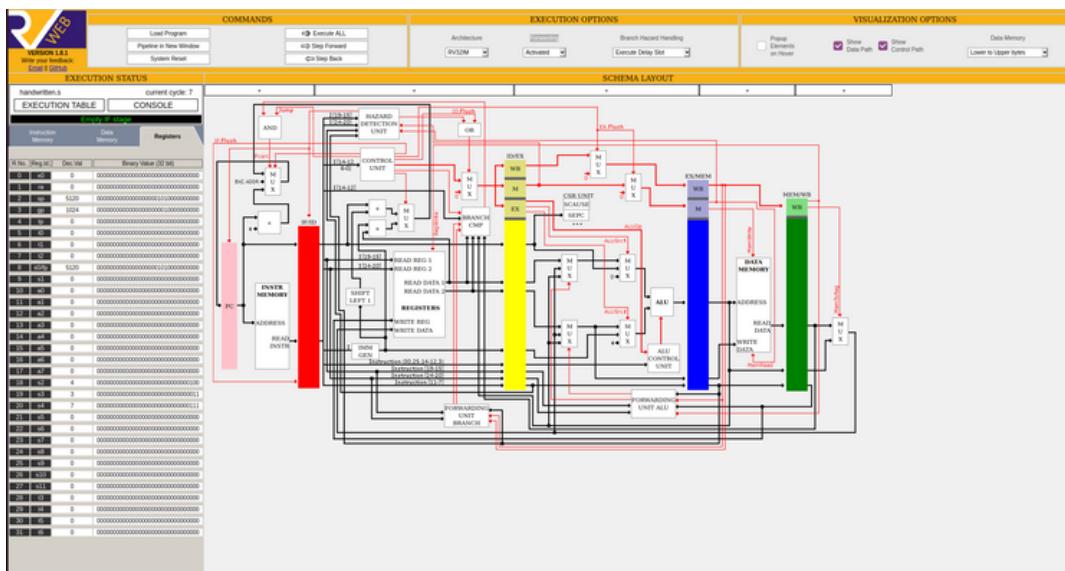
Ciclo 6:

- IF: add s7, s2, s3
- ID: addi s6, zero, 6
- EX: addi s5, zero, 5



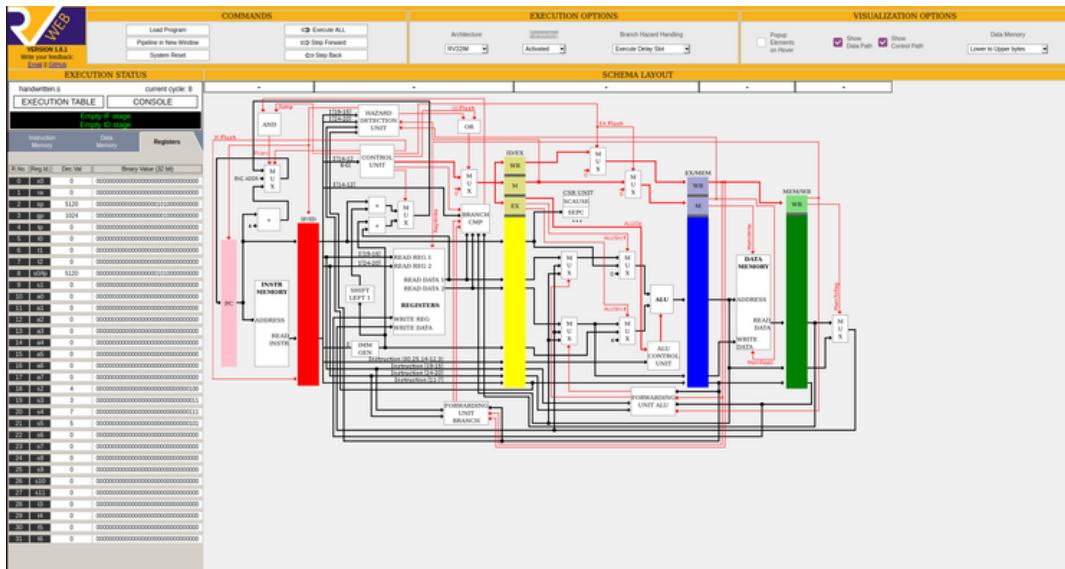
Ciclo 7:

- ID: add s7, s2, s3
- EX: addi s6, zero, 6



Ciclo 8:

- EX: add s7, s2, s3



2.c) Resultado final da execução em Pipeline, por meio da Tabela da Execução do Programa (“EXECUTION TABLE”).

EXECUTION TABLE		CPU Cycles									
FULL LOOPS	▼	1	2	3	4	5	6	7	8	9	10
Instruction											
addi s2, x0, 4		F	D	X	M	W					
addi s3, x0, 3		F	D	X	M	W					
addi s4, x0, 7			F	D	X	M	W				
addi s5, x0, 5				F	D	X	M	W			
addi s6, x0, 6					F	D	X	M	W		
add s7, s2, s3						F	D	X	M	W	

2.d) Ciclos de CPU necessários para executar esse programa.

Total de ciclos da CPU = 10

Programa 2

```
addi s2, zero, 4  
add s3, zero, s2  
addi s4, zero, 7  
addi s5, zero, 5  
addi s6, zero, 6  
add s7, s6, s1
```

1.a) Conteúdo da Memória de Instruções (“Instruction Memory”) e dos Registradores (“Registers”), no início e no final da execução do programa.

No início da execução o conteúdo da memória de instruções contém as seguintes instruções:

Endereço	Instrução	Código de máquina em binário	Código de máquina em hexadecimal
Endereço 0	addi s2, zero, 4	00000000010000000000100100010011	0x00400913
Endereço 4	add s3, zero, s2	00000001001000000000100110110011	0x012009b3
Endereço 8	addi s4, zero, 7	00000000011100000000101000010011	0x00700a13
Endereço 12	addi s5, zero, 5	00000000010100000000101010010011	0x00500a93
Endereço 16	addi s6, zero, 6	00000000011000000000101100010011	0x00600b13
Endereço 20	add s7, s6, s1	00000000100110110000101110110011	0x009b0bb3

E os registradores têm valores inicializados com zero:

Registradores	Valores
s1	0
s2	0
s3	0
s4	0
s5	0
s6	0
s7	0
zero	0

Conteúdo da memória de instruções no início da execução

EXECUTION STATUS																																																																																																																	
handwritten.s			current cycle: -																																																																																																														
EXECUTION TABLE		CONSOLE																																																																																																															
Empty IF stage Empty ID stage Empty EX stage Empty MEM stage Empty WB stage																																																																																																																	
Instruction Memory	Data Memory	Registers																																																																																																															
Address 0 (0x0) I-type Instruction: addi s2, x0, 4 00000000010000000000100100010011 <table border="1"> <tr> <td>4</td><td>0</td><td>0</td><td>1e</td><td>19</td><td></td></tr> <tr> <td>000000000100</td><td>00000</td><td>000</td><td>10010</td><td>0010011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table> Address 4 (0x4) R-type Instruction: add s3, x0, s2 00000001001000000000100110110011 <table border="1"> <tr> <td>0</td><td>1e</td><td>0</td><td>0</td><td>19</td><td>51</td></tr> <tr> <td>0000000</td><td>10010</td><td>00000</td><td>000</td><td>10011</td><td>0110011</td></tr> <tr> <td>FUNCT7</td><td>RS2</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td></tr> </table> Address 8 (0x8) I-type Instruction: addi s4, x0, 7 00000000011100000000101000010011 <table border="1"> <tr> <td>7</td><td>0</td><td>0</td><td>20</td><td>19</td><td></td></tr> <tr> <td>000000000111</td><td>00000</td><td>000</td><td>10100</td><td>0010011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table> Address 12 (0xc) I-type Instruction: addi s5, x0, 5 00000000010100000000101010010011 <table border="1"> <tr> <td>5</td><td>0</td><td>0</td><td>21</td><td>19</td><td></td></tr> <tr> <td>000000000101</td><td>00000</td><td>000</td><td>10101</td><td>0010011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table> Address 16 (0x10) I-type Instruction: addi s6, x0, 6 00000000011000000000101100010011 <table border="1"> <tr> <td>6</td><td>0</td><td>0</td><td>22</td><td>19</td><td></td></tr> <tr> <td>000000000110</td><td>00000</td><td>000</td><td>10110</td><td>0010011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table> Address 20 (0x14) R-type Instruction: add s7, s6, s1 000000000100110110000101110110011 <table border="1"> <tr> <td>0</td><td>9</td><td>22</td><td>0</td><td>23</td><td>51</td></tr> <tr> <td>0000000</td><td>01001</td><td>10110</td><td>000</td><td>10111</td><td>0110011</td></tr> <tr> <td>FUNCT7</td><td>RS2</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td></tr> </table>	4	0	0	1e	19		000000000100	00000	000	10010	0010011		IMMEDIATE	RS1	FUNCT3	RD	OP		0	1e	0	0	19	51	0000000	10010	00000	000	10011	0110011	FUNCT7	RS2	RS1	FUNCT3	RD	OP	7	0	0	20	19		000000000111	00000	000	10100	0010011		IMMEDIATE	RS1	FUNCT3	RD	OP		5	0	0	21	19		000000000101	00000	000	10101	0010011		IMMEDIATE	RS1	FUNCT3	RD	OP		6	0	0	22	19		000000000110	00000	000	10110	0010011		IMMEDIATE	RS1	FUNCT3	RD	OP		0	9	22	0	23	51	0000000	01001	10110	000	10111	0110011	FUNCT7	RS2	RS1	FUNCT3	RD	OP					
4	0	0	1e	19																																																																																																													
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0	1e	0	0	19	51																																																																																																												
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Conteúdo dos registradores no início da execução

EXECUTION STATUS																																																																																																																																																																																																											
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15	a5	0	00000000000000000000000000000000																																																																																																																																																																																																								
16	a6	0	00000000000000000000000000000000																																																																																																																																																																																																								
17	a7	0	00000000000000000000000000000000																																																																																																																																																																																																								
18	s2	0	00000000000000000000000000000000																																																																																																																																																																																																								
19	s3	0	00000000000000000000000000000000																																																																																																																																																																																																								
20	s4	0	00000000000000000000000000000000																																																																																																																																																																																																								
21	s5	0	00000000000000000000000000000000																																																																																																																																																																																																								
22	s6	0	00000000000000000000000000000000																																																																																																																																																																																																								
23	s7	0	00000000000000000000000000000000																																																																																																																																																																																																								
24	s8	0	00000000000000000000000000000000																																																																																																																																																																																																								
25	s9	0	00000000000000000000000000000000																																																																																																																																																																																																								
26	s10	0	00000000000000000000000000000000																																																																																																																																																																																																								
27	s11	0	00000000000000000000000000000000																																																																																																																																																																																																								
28	t3	0	00000000000000000000000000000000																																																																																																																																																																																																								
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31	t6	0	00000000000000000000000000000000																																																																																																																																																																																																								

No final da execução o conteúdo da memória de instruções permanece inalterada

Endereço	Instrução	Código de máquina em binário	Código de máquina em hexadecimal
Endereço 0	addi s2, zero, 4	00000000010000000000100100010011	0x00400913
Endereço 4	add s3, zero, s2	00000001001000000000100110110011	0x012009b3
Endereço 8	addi s4, zero, 7	00000000011100000000101000010011	0x00700a13
Endereço 12	addi s5, zero, 5	00000000010100000000101010010011	0x00500a93
Endereço 16	addi s6, zero, 6	00000000011000000000101100010011	0x00600b13
Endereço 20	add s7, s6, s1	00000000100110110000101110110011	0x009b0bb3

E os registradores possuem os seguintes valores:

Registradores	Valores
s1	0
s2	4
s3	4
s4	7
s5	5
s6	6
s7	6 (resultado da soma de s6 e s1)
zero	0

- Conteúdo da Memória de Instruções no início e no final da execução do programa:
 - No início da execução, o conteúdo da Memória de Instruções corresponde às instruções carregadas nela, que são as instruções do programa fornecido.
 - No final da execução, a Memória de Instruções permanece inalterada, pois não houve modificações nela durante a execução do programa.
- Conteúdo dos Registradores no início e no final da execução do programa:
 - No início da execução, todos os registradores possuem o valor zero, pois foram inicializados com zero.
 - Durante a execução do programa, as instruções de soma imediata (addi) atribuem valores específicos a determinados registradores. Por exemplo, a instrução "addi s4, zero, 7" atribui o valor 7 ao registrador s4.
 - No final da execução do programa, os registradores têm os valores resultantes das instruções executadas. Por exemplo, a instrução "add s7, s6, s1" realiza a soma dos valores contidos nos registradores s1 e s6 e armazena o resultado no registrador s7.

Conteúdo da memória de instruções no final da execução

Conteúdo dos registradores no final da execução

EXECUTION STATUS																							
handwritten.s																							
EXECUTION TABLE			CONSOLE																				
EXECUTION COMPLETED IN 14 CLOCK CYCLES																							
Instruction Memory	Data Memory	Registers																					
Address 0 (0x0) I-type Instruction: addi s2, x0, 4 <code>00000000010000000000100100010011</code> <table border="1"> <tr> <td>4</td><td>0</td><td>0</td><td>1e</td><td>19</td><td></td></tr> <tr> <td>000000000100</td><td>00000</td><td>000</td><td>10010</td><td>0010011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>R\$1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table>						4	0	0	1e	19		000000000100	00000	000	10010	0010011		IMMEDIATE	R\$1	FUNCT3	RD	OP	
4	0	0	1e	19																			
000000000100	00000	000	10010	0010011																			
IMMEDIATE	R\$1	FUNCT3	RD	OP																			
Address 4 (0x4) R-type Instruction: add s3, x0, s2 <code>00000001001000000000100110110011</code> <table border="1"> <tr> <td>0</td><td>1e</td><td>0</td><td>0</td><td>19</td><td>51</td></tr> <tr> <td>00000000</td><td>10010</td><td>00000</td><td>000</td><td>10011</td><td>0110011</td></tr> <tr> <td>FUNCT7</td><td>RS2</td><td>R\$1</td><td>FUNCT3</td><td>RD</td><td>OP</td></tr> </table>						0	1e	0	0	19	51	00000000	10010	00000	000	10011	0110011	FUNCT7	RS2	R\$1	FUNCT3	RD	OP
0	1e	0	0	19	51																		
00000000	10010	00000	000	10011	0110011																		
FUNCT7	RS2	R\$1	FUNCT3	RD	OP																		
Address 8 (0x8) I-type Instruction: addi s4, x0, 7 <code>00000000011100000000101000010011</code> <table border="1"> <tr> <td>7</td><td>0</td><td>0</td><td>20</td><td>19</td><td></td></tr> <tr> <td>000000000111</td><td>00000</td><td>000</td><td>10100</td><td>0010011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>R\$1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table>						7	0	0	20	19		000000000111	00000	000	10100	0010011		IMMEDIATE	R\$1	FUNCT3	RD	OP	
7	0	0	20	19																			
000000000111	00000	000	10100	0010011																			
IMMEDIATE	R\$1	FUNCT3	RD	OP																			
Address 12 (0xc) I-type Instruction: addi s5, x0, 5 <code>00000000010100000000101010010011</code> <table border="1"> <tr> <td>5</td><td>0</td><td>0</td><td>21</td><td>19</td><td></td></tr> <tr> <td>000000000101</td><td>00000</td><td>000</td><td>10101</td><td>0010011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>R\$1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table>						5	0	0	21	19		000000000101	00000	000	10101	0010011		IMMEDIATE	R\$1	FUNCT3	RD	OP	
5	0	0	21	19																			
000000000101	00000	000	10101	0010011																			
IMMEDIATE	R\$1	FUNCT3	RD	OP																			
Address 16 (0x10) I-type Instruction: addi s6, x0, 6 <code>00000000011000000000101100010011</code> <table border="1"> <tr> <td>6</td><td>0</td><td>0</td><td>22</td><td>19</td><td></td></tr> <tr> <td>000000000110</td><td>00000</td><td>000</td><td>10110</td><td>0010011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>R\$1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table>						6	0	0	22	19		000000000110	00000	000	10110	0010011		IMMEDIATE	R\$1	FUNCT3	RD	OP	
6	0	0	22	19																			
000000000110	00000	000	10110	0010011																			
IMMEDIATE	R\$1	FUNCT3	RD	OP																			
Address 20 (0x14) R-type Instruction: add s7, s6, s1 <code>00000000100110110000101110110011</code> <table border="1"> <tr> <td>0</td><td>9</td><td>22</td><td>0</td><td>23</td><td>51</td></tr> <tr> <td>00000000</td><td>01001</td><td>10110</td><td>000</td><td>10111</td><td>0110011</td></tr> <tr> <td>FUNCT7</td><td>RS2</td><td>R\$1</td><td>FUNCT3</td><td>RD</td><td>OP</td></tr> </table>						0	9	22	0	23	51	00000000	01001	10110	000	10111	0110011	FUNCT7	RS2	R\$1	FUNCT3	RD	OP
0	9	22	0	23	51																		
00000000	01001	10110	000	10111	0110011																		
FUNCT7	RS2	R\$1	FUNCT3	RD	OP																		

1.b) Passagem em três estágios representativos do Pipeline (“SCHEMA LAYOUT”)

Estágio 1 - Busca de Instrução (IF): Nesse estágio, a instrução é buscada da memória de instruções com base no contador de programa (PC) atual.

Ciclo 1: IF: addi s2, zero, 4
Ciclo 2: IF: add s3, zero, s2
Ciclo 5: IF: addi s4, zero, 7
Ciclo 6: IF: addi s5, zero, 5
Ciclo 7: IF: addi s6, zero, 6
Ciclo 8: IF: add s7, s6, s1

Estágio 2 - Decodificação e Busca de Operandos (ID): Nesse estágio, a instrução é decodificada, os registradores necessários são lidos da memória de registradores (registraror de origem) e os operandos são buscados.

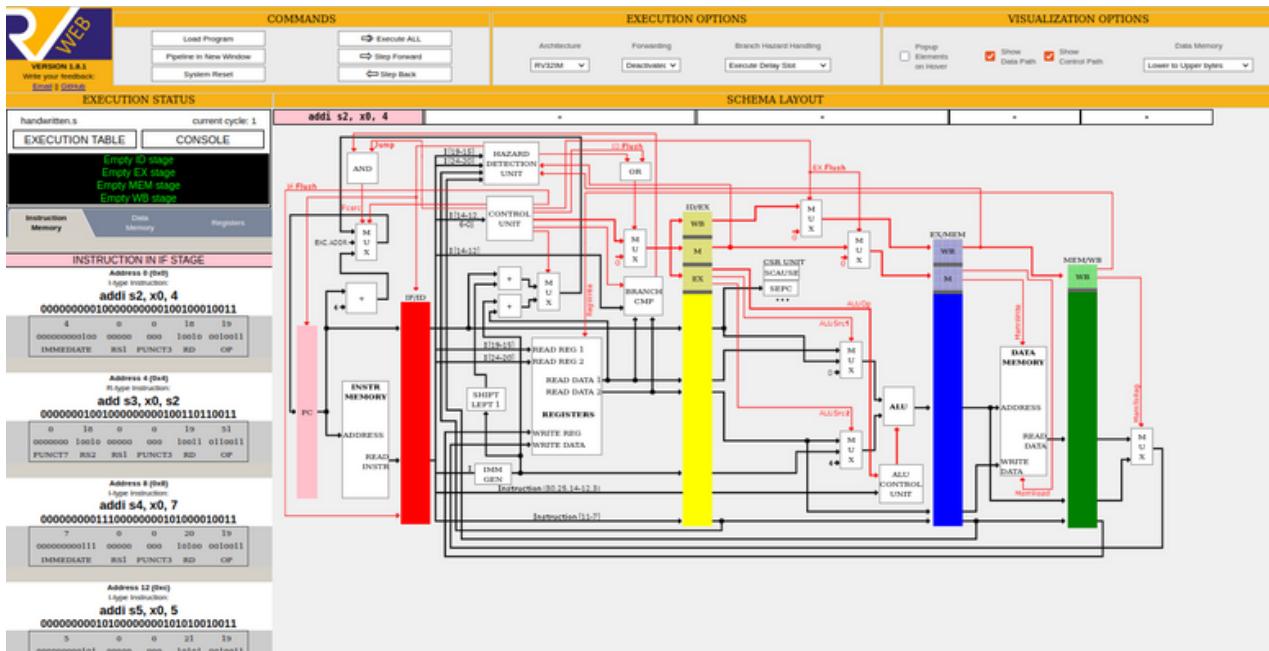
Ciclo 2: ID: addi s2, zero, 4
Ciclo 5: ID: add s3, zero, s2
Ciclo 6: ID: addi s4, zero, 7
Ciclo 7: ID: addi s5, zero, 5
Ciclo 8: ID: addi s6, zero, 6
Ciclo 11: ID: add s7, s6, s1

Estágio 3 - Execução e Cálculo de Endereço (EX): Nesse estágio, a instrução é executada e o resultado é calculado.

Ciclo 3: EX: addi s2, zero, 4
Ciclo 6: EX: add s3, zero, s2
Ciclo 7: EX: addi s4, zero, 7
Ciclo 8: EX: addi s5, zero, 5
Ciclo 9: EX: addi s6, zero, 6
Ciclo 12: EX: add s7, s6, s1

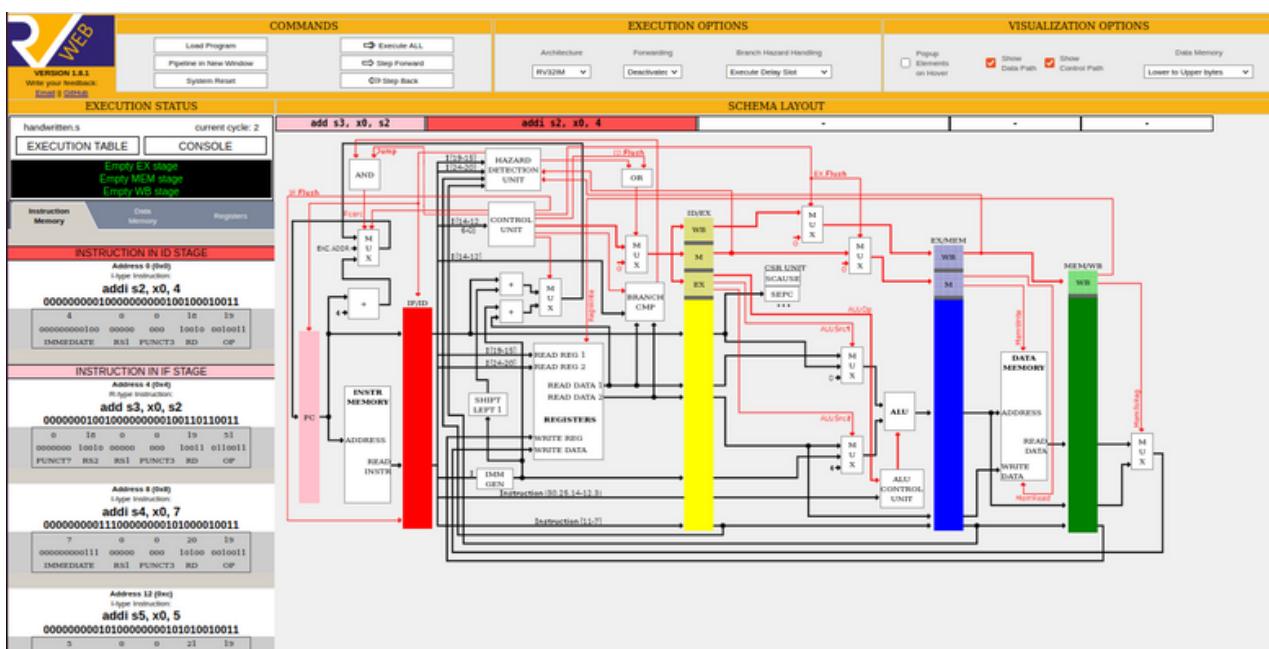
Ciclo 1:

- IF: addi s2, zero, 4



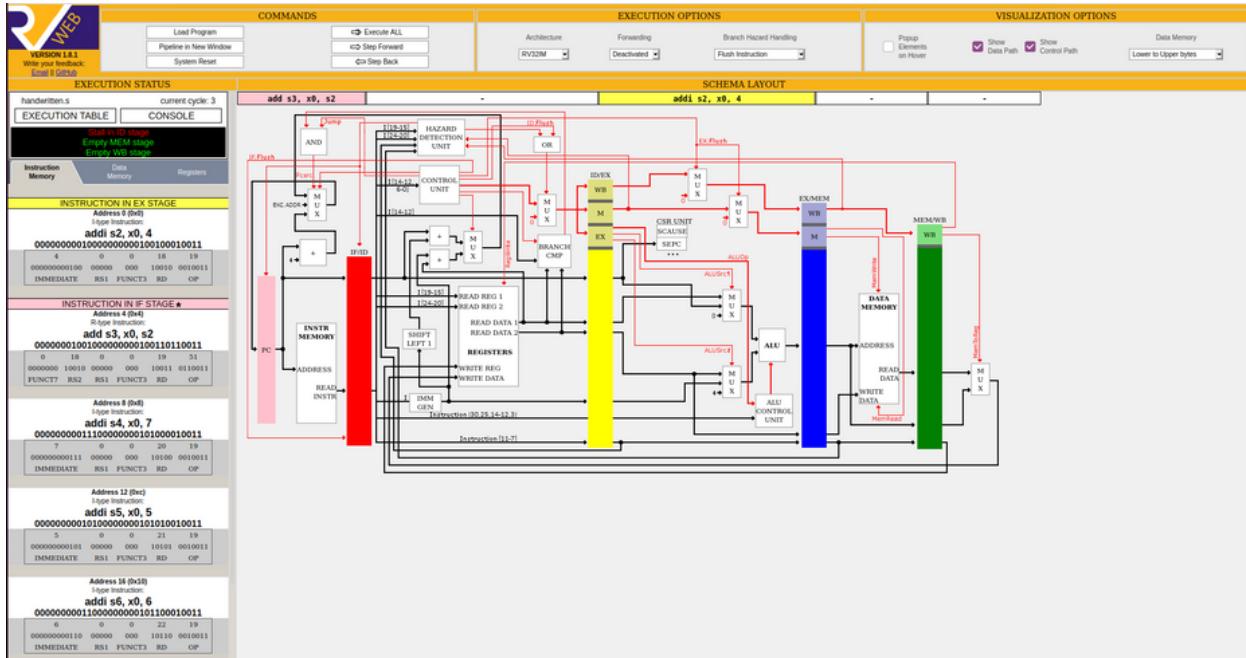
Ciclo 2:

- IF: add s3, zero, s2
- ID: addi s2, zero, 4



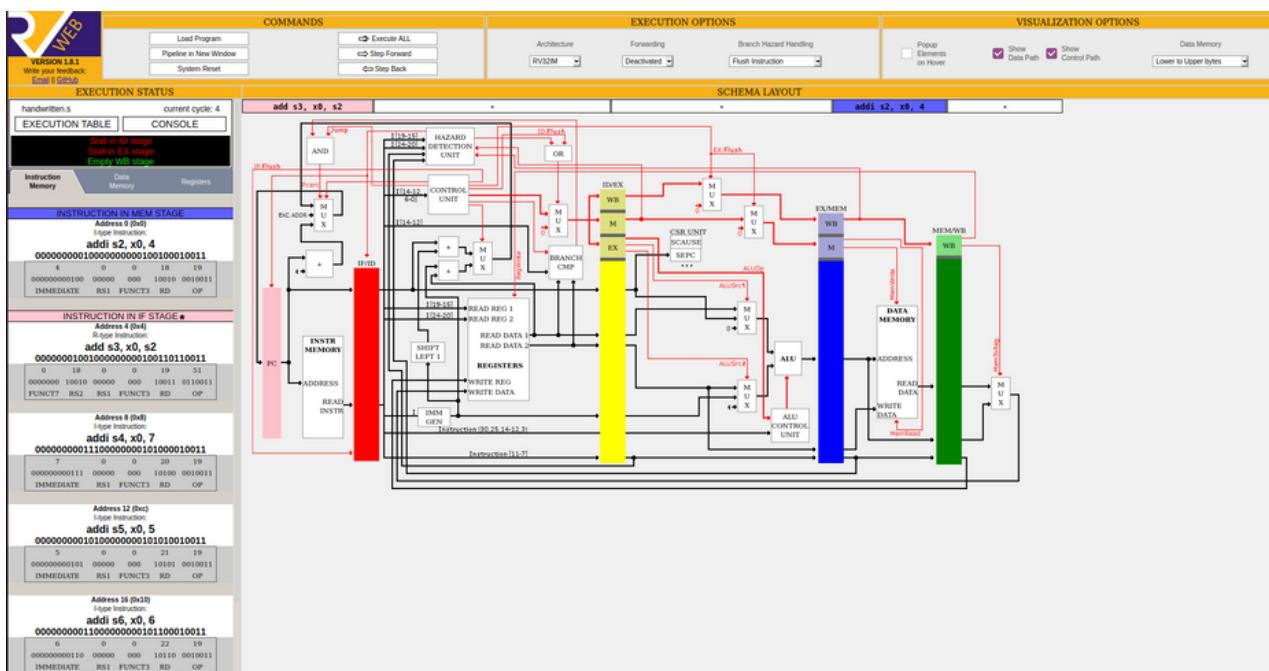
Ciclo 3:

- IF: add s3, zero, s2
- EX: addi s2, zero, 4
- Como a instrução **add s3, zero, s2** necessita do valor de s2 para ser executada. Portanto, o estágio ID (Decodificação e Busca de Operandos) dessa instrução só ocorrerá após o estágio MEM do ciclo em que a instrução "addi s2, zero, 4" é buscada.



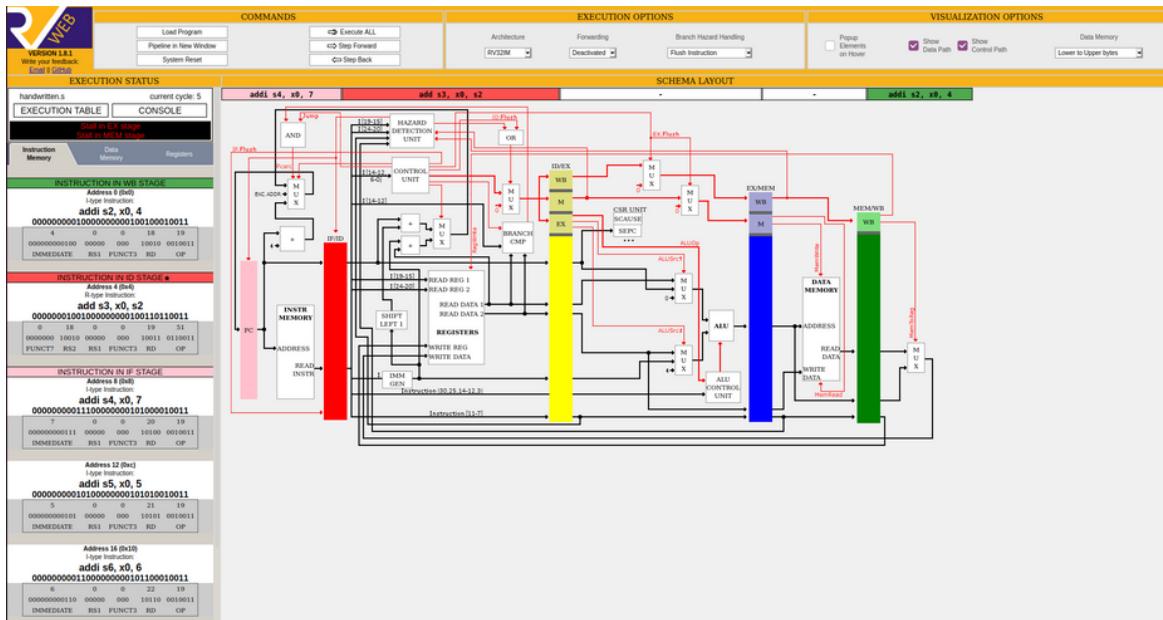
Ciclo 4:

- IF: add s3, zero, s2



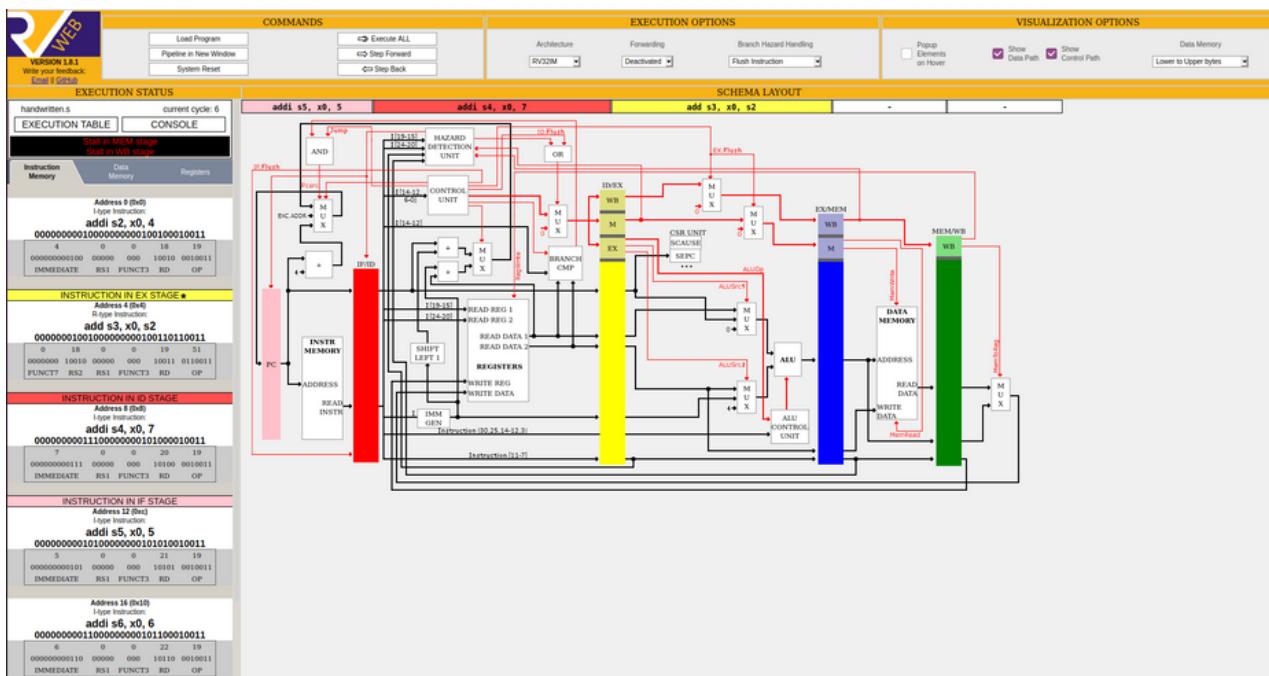
Ciclo 5:

- IF: addi s4, zero, 7
- ID: addi s3, zero, s2



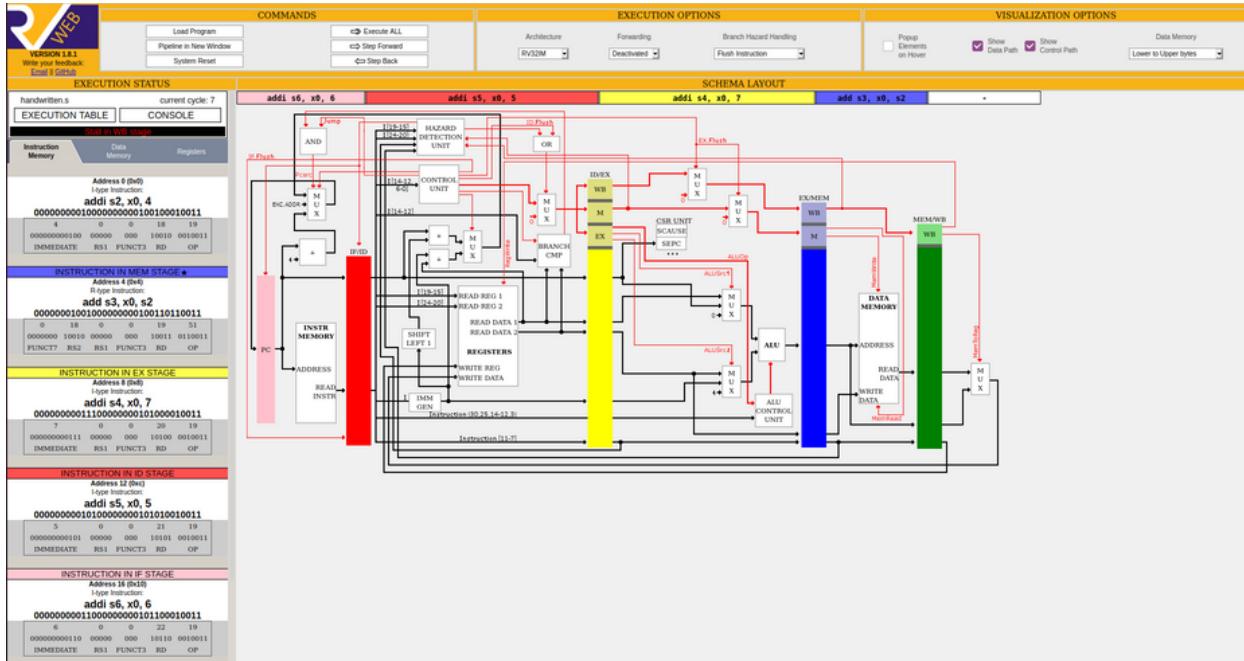
Ciclo 6:

- IF: addi s5, zero, 5
- ID: addi s4, zero, 7
- EX: addi s3, zero, s2



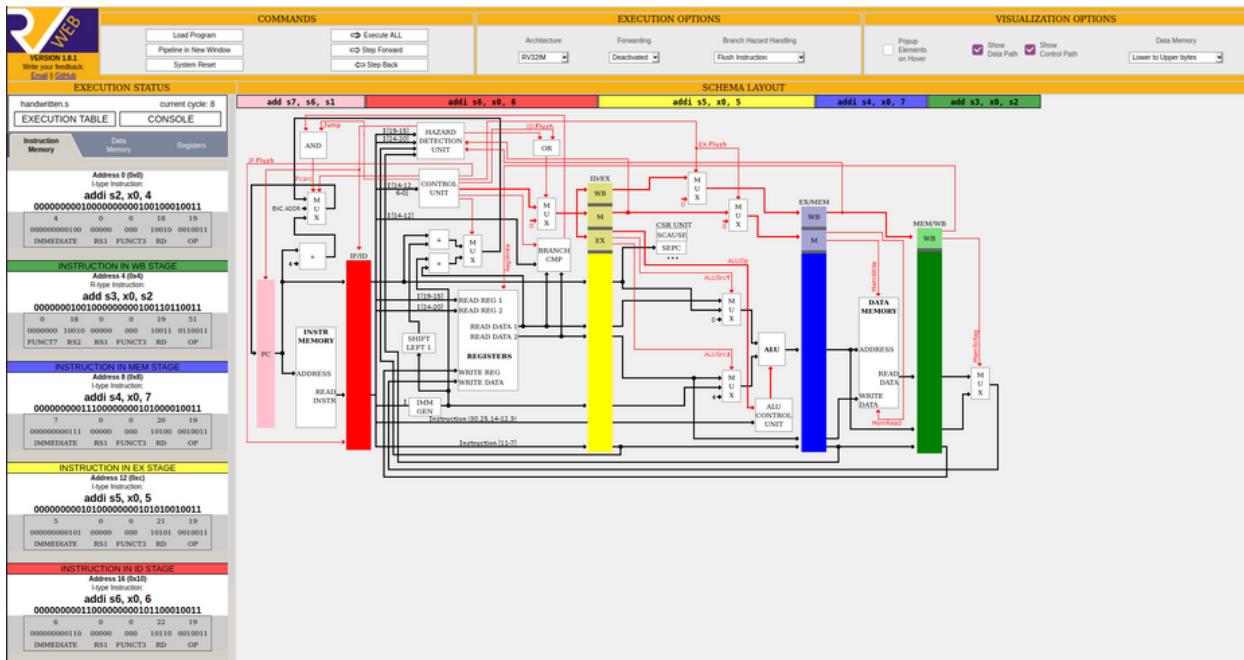
Ciclo 7:

- IF: addi s6, zero, 6
- ID: addi s5, zero, 5
- EX: addi s4, zero, 7



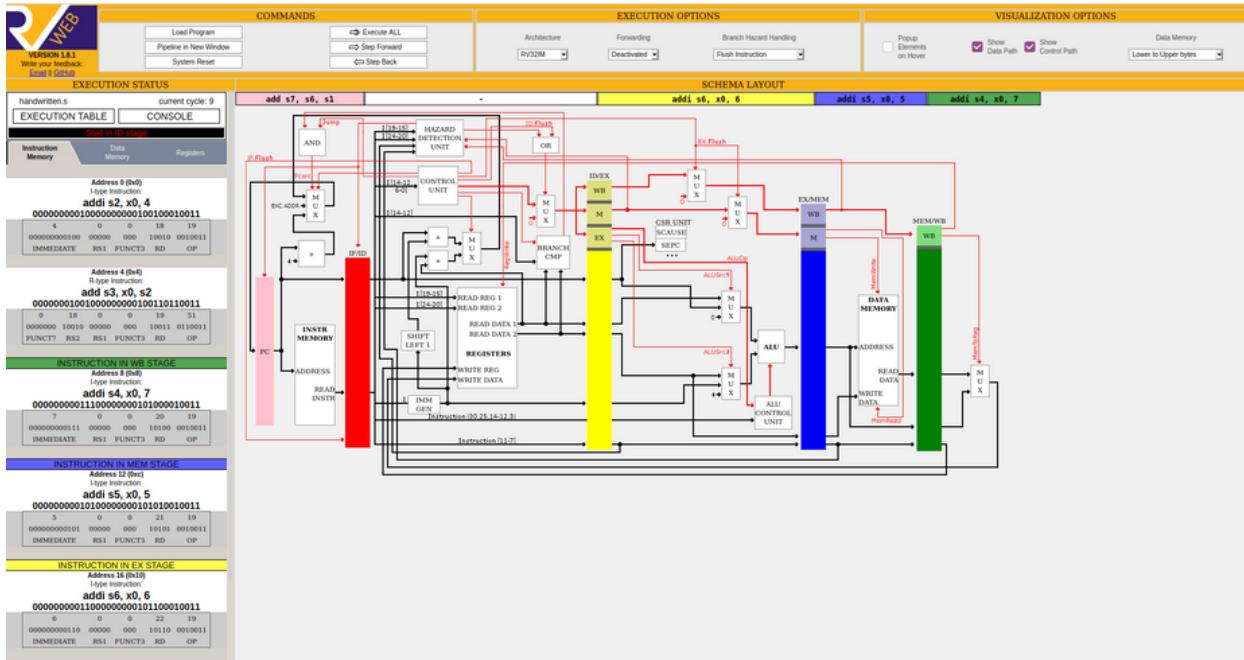
Ciclo 8:

- IF: add s7, s6, s1
- ID: addi s6, zero, 6
- EX: addi s5, zero, 5



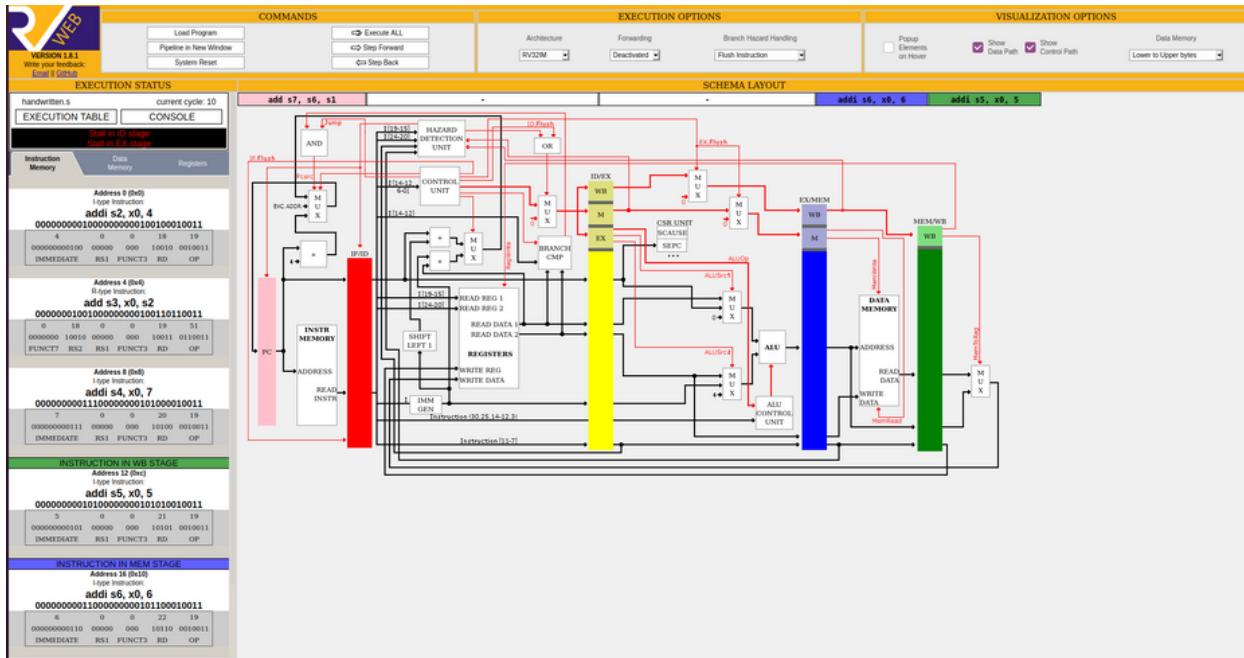
Ciclo 9:

- IF: add s7, s6, s1
- EX: addi s6, zero, 6



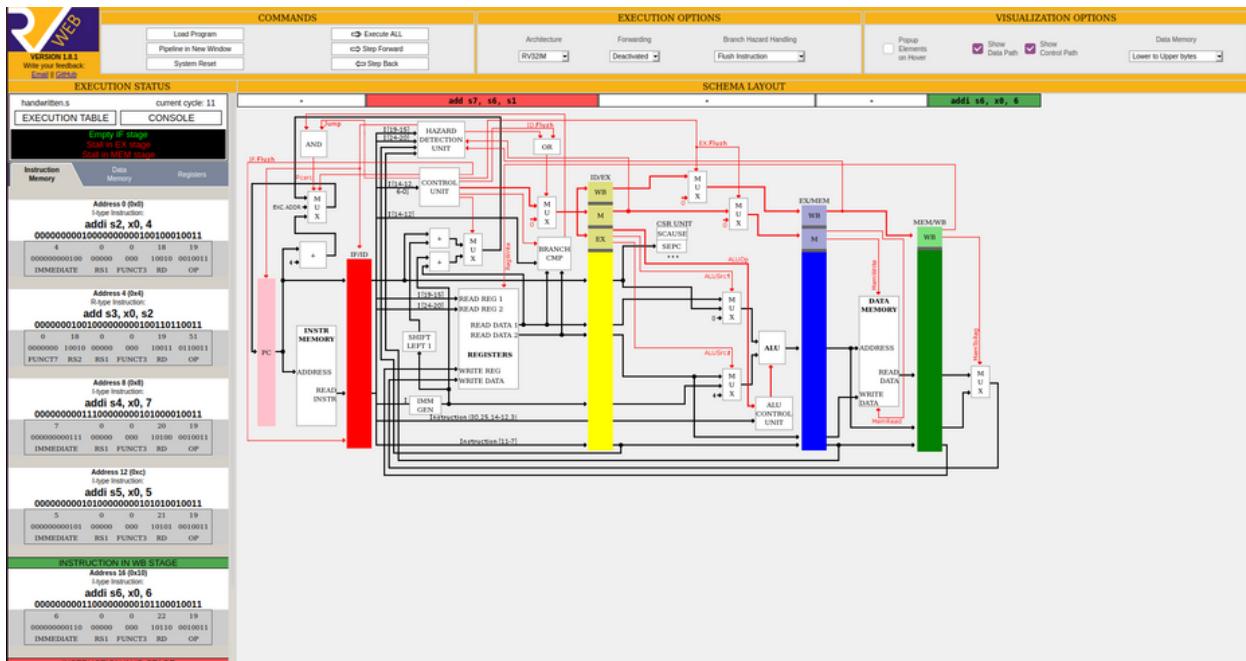
Ciclo 10:

- IF: add s7, s6, s1



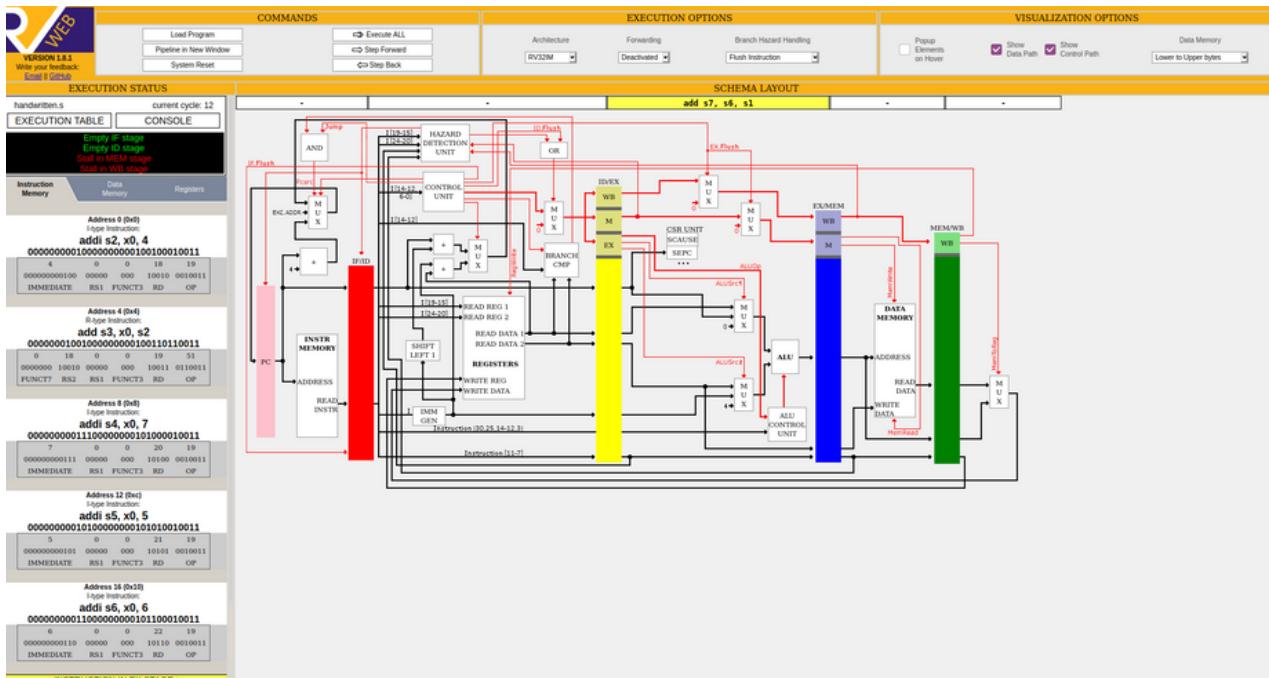
Ciclo 11:

- ID: add s7, s6, s1



Ciclo 12:

- EX: add s7, s6, s1



1.c) Resultado final da execução em Pipeline, por meio da Tabela da Execução do Programa (“EXECUTION TABLE”).

EXECUTION TABLE		CPU Cycles													
FULL LOOPS	▼	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Instruction															
addi s2, x0, 4		F	D	X	M	W									
add s3, x0, s2		F	-	-	D	X	M	W							
addi s4, x0, 7					F	D	X	M	W						
addi s5, x0, 5						F	D	X	M	W					
addi s6, x0, 6							F	D	X	M	W				
add s7, s6, s1								F	-	-	D	X	M	W	

1.d) Ciclos de CPU necessários para executar esse programa.

Total de ciclos da CPU = 14

2.a) Conteúdo da Memória de Instruções (“Instruction Memory”) e dos Registradores (“Registers”), no início e no final da execução do programa.

No início da execução o conteúdo da memória de instruções contém as seguintes instruções (ele não muda em relação a questão 1):

Endereço	Instrução	Código de máquina em binário	Código de máquina em hexadecimal
Endereço 0	addi s2, zero, 4	00000000010000000000100100010011	0x00400913
Endereço 4	add s3, zero, s2	00000001001000000000100110110011	0x012009b3
Endereço 8	addi s4, zero, 7	00000000011100000000101000010011	0x00700a13
Endereço 12	addi s5, zero, 5	00000000010100000000101010010011	0x00500a93
Endereço 16	addi s6, zero, 6	00000000011000000000101100010011	0x00600b13
Endereço 20	add s7, s6, s1	00000000100110110000101110110011	0x009b0bb3

E os registradores têm valores inicializados com zero:

Registradores	Valores
s1	0
s2	0
s3	0
s4	0
s5	0
s6	0
s7	0
zero	0

Conteúdo da memória de instruções no início da execução

Conteúdo dos registradores no início da execução

EXECUTION STATUS				
handwritten.s			current cycle: -	
EXECUTION TABLE			CONSOLE	
Empty IF stage Empty ID stage Empty EX stage Empty MEM stage Empty WB stage				
Instruction Memory		Data Memory	Registers	
R.No.	Reg.Id	Dec.Val	Binary Value (32 bit)	
0	x0	0	00000000000000000000000000000000	
1	ra	0	00000000000000000000000000000000	
2	sp	5120	000000000000000000000000000000001010000000000	
3	gp	1024	000000000000000000000000000000001000000000000	
4	tp	0	00	
5	t0	0	00	
6	t1	0	00	
7	t2	0	00	
8	s0/fp	5120	000000000000000000000000000000001010000000000	
9	s1	0	00	
10	a0	0	00	
11	a1	0	00	
12	a2	0	00	
13	a3	0	00	
14	a4	0	00	
15	a5	0	00	
16	a6	0	00	
17	a7	0	00	
18	s2	0	00	
19	s3	0	00	
20	s4	0	00	
21	s5	0	00	
22	s6	0	00	
23	s7	0	00	
24	s8	0	00	
25	s9	0	00	
26	s10	0	00	
27	s11	0	00	
28	t3	0	00	
29	t4	0	00	
30	t5	0	00	
31	t6	0	00	

No final da execução o conteúdo da memória de instruções permanece inalterada

Endereço	Instrução	Código de máquina em binário	Código de máquina em hexadecIMAL
Endereço 0	addi s2, zero, 4	00000000010000000000100100010011	0x00400913
Endereço 4	add s3, zero, s2	00000001001000000000100110110011	0x012009b3
Endereço 8	addi s4, zero, 7	00000000011100000000101000010011	0x00700a13
Endereço 12	addi s5, zero, 5	00000000010100000000101010010011	0x00500a93
Endereço 16	addi s6, zero, 6	00000000011000000000101100010011	0x00600b13
Endereço 20	add s7, s6, s1	00000000100110110000101110110011	0x009b0bb3

E os registradores possuem os seguintes valores:

Registradores	Valores
s1	0
s2	4
s3	4
s4	7
s5	5
s6	6
s7	6 (resultado da soma de s6 e s1)
zero	0

Conteúdo da memória de instruções no final da execução

EXECUTION STATUS																							
EXECUTION TABLE			CONSOLE																				
EXECUTION COMPLETED IN 10 CLOCK CYCLES																							
Empty IF stage Empty ID stage Empty EX stage Empty MEM stage Empty WB stage																							
Instruction Memory	Data Memory	Registers																					
Address 0 (0x0) I-type Instruction: addi s2, x0, 4 <code>00000000001000000000100100010011</code> <table border="1"> <tr> <td>4</td><td>0</td><td>0</td><td>18</td><td>19</td><td></td></tr> <tr> <td>0000000000100</td><td>00000</td><td>000</td><td>10010</td><td>00100011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table>						4	0	0	18	19		0000000000100	00000	000	10010	00100011		IMMEDIATE	RS1	FUNCT3	RD	OP	
4	0	0	18	19																			
0000000000100	00000	000	10010	00100011																			
IMMEDIATE	RS1	FUNCT3	RD	OP																			
Address 4 (0x4) R-type Instruction: add s3, x0, s2 <code>00000001001000000000100110110011</code> <table border="1"> <tr> <td>0</td><td>18</td><td>0</td><td>0</td><td>19</td><td>51</td></tr> <tr> <td>0000000</td><td>10010</td><td>00000</td><td>000</td><td>10011</td><td>01100011</td></tr> <tr> <td>FUNCT7</td><td>RS2</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td></tr> </table>						0	18	0	0	19	51	0000000	10010	00000	000	10011	01100011	FUNCT7	RS2	RS1	FUNCT3	RD	OP
0	18	0	0	19	51																		
0000000	10010	00000	000	10011	01100011																		
FUNCT7	RS2	RS1	FUNCT3	RD	OP																		
Address 8 (0x8) I-type Instruction: addi s4, x0, 7 <code>0000000000111000000000101000010011</code> <table border="1"> <tr> <td>7</td><td>0</td><td>0</td><td>20</td><td>19</td><td></td></tr> <tr> <td>0000000000111</td><td>00000</td><td>000</td><td>10100</td><td>00100011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table>						7	0	0	20	19		0000000000111	00000	000	10100	00100011		IMMEDIATE	RS1	FUNCT3	RD	OP	
7	0	0	20	19																			
0000000000111	00000	000	10100	00100011																			
IMMEDIATE	RS1	FUNCT3	RD	OP																			
Address 12 (0xc) I-type Instruction: addi s5, x0, 5 <code>000000000010100000000101010010011</code> <table border="1"> <tr> <td>5</td><td>0</td><td>0</td><td>21</td><td>19</td><td></td></tr> <tr> <td>0000000000101</td><td>00000</td><td>000</td><td>10101</td><td>00100011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table>						5	0	0	21	19		0000000000101	00000	000	10101	00100011		IMMEDIATE	RS1	FUNCT3	RD	OP	
5	0	0	21	19																			
0000000000101	00000	000	10101	00100011																			
IMMEDIATE	RS1	FUNCT3	RD	OP																			
Address 16 (0x10) I-type Instruction: addi s6, x0, 6 <code>000000000011000000000101100010011</code> <table border="1"> <tr> <td>6</td><td>0</td><td>0</td><td>22</td><td>19</td><td></td></tr> <tr> <td>0000000000110</td><td>00000</td><td>000</td><td>10110</td><td>00100011</td><td></td></tr> <tr> <td>IMMEDIATE</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td><td></td></tr> </table>						6	0	0	22	19		0000000000110	00000	000	10110	00100011		IMMEDIATE	RS1	FUNCT3	RD	OP	
6	0	0	22	19																			
0000000000110	00000	000	10110	00100011																			
IMMEDIATE	RS1	FUNCT3	RD	OP																			
Address 20 (0x14) R-type Instruction: add s7, s6, s1 <code>0000000000100110110000101110110011</code> <table border="1"> <tr> <td>0</td><td>9</td><td>22</td><td>0</td><td>23</td><td>51</td></tr> <tr> <td>0000000</td><td>01001</td><td>10110</td><td>000</td><td>10111</td><td>01100011</td></tr> <tr> <td>FUNCT7</td><td>RS2</td><td>RS1</td><td>FUNCT3</td><td>RD</td><td>OP</td></tr> </table>						0	9	22	0	23	51	0000000	01001	10110	000	10111	01100011	FUNCT7	RS2	RS1	FUNCT3	RD	OP
0	9	22	0	23	51																		
0000000	01001	10110	000	10111	01100011																		
FUNCT7	RS2	RS1	FUNCT3	RD	OP																		

Conteúdo dos registradores no final da execução

EXECUTION STATUS																																																																																																																																									
EXECUTION TABLE			CONSOLE																																																																																																																																						
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Instruction Memory	Data Memory	Registers																																																																																																																																							
<table border="1"> <thead> <tr> <th>R.No.</th><th>Reg.Id.</th><th>Dec.Val</th><th>Binary Value (32 bit)</th></tr> </thead> <tbody> <tr><td>0</td><td>x0</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>1</td><td>ra</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>2</td><td>sp</td><td>5120</td><td>000000000000000000000000001010000000000</td></tr> <tr><td>3</td><td>gp</td><td>1024</td><td>0000000000000000000000000000000010000000000</td></tr> <tr><td>4</td><td>tp</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>5</td><td>t0</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>6</td><td>t1</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>7</td><td>t2</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>8</td><td>s0/fp</td><td>5120</td><td>000000000000000000000000000000001010000000000</td></tr> <tr><td>9</td><td>s1</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>10</td><td>a0</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>11</td><td>a1</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>12</td><td>a2</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>13</td><td>a3</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>14</td><td>a4</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>15</td><td>a5</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>16</td><td>a6</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>17</td><td>a7</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>18</td><td>s2</td><td>4</td><td>00000000000000000000000000000000100</td></tr> <tr><td>19</td><td>s3</td><td>4</td><td>00000000000000000000000000000000100</td></tr> <tr><td>20</td><td>s4</td><td>7</td><td>00000000000000000000000000000000111</td></tr> <tr><td>21</td><td>s5</td><td>5</td><td>00000000000000000000000000000000101</td></tr> <tr><td>22</td><td>s6</td><td>6</td><td>00000000000000000000000000000000110</td></tr> <tr><td>23</td><td>s7</td><td>6</td><td>00000000000000000000000000000000110</td></tr> <tr><td>24</td><td>s8</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>25</td><td>s9</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>26</td><td>s10</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>27</td><td>s11</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>28</td><td>t3</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>29</td><td>t4</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>30</td><td>t5</td><td>0</td><td>00000000000000000000000000000000</td></tr> <tr><td>31</td><td>t6</td><td>0</td><td>00000000000000000000000000000000</td></tr> </tbody> </table>						R.No.	Reg.Id.	Dec.Val	Binary Value (32 bit)	0	x0	0	00000000000000000000000000000000	1	ra	0	00000000000000000000000000000000	2	sp	5120	000000000000000000000000001010000000000	3	gp	1024	0000000000000000000000000000000010000000000	4	tp	0	00000000000000000000000000000000	5	t0	0	00000000000000000000000000000000	6	t1	0	00000000000000000000000000000000	7	t2	0	00000000000000000000000000000000	8	s0/fp	5120	000000000000000000000000000000001010000000000	9	s1	0	00000000000000000000000000000000	10	a0	0	00000000000000000000000000000000	11	a1	0	00000000000000000000000000000000	12	a2	0	00000000000000000000000000000000	13	a3	0	00000000000000000000000000000000	14	a4	0	00000000000000000000000000000000	15	a5	0	00000000000000000000000000000000	16	a6	0	00000000000000000000000000000000	17	a7	0	00000000000000000000000000000000	18	s2	4	00000000000000000000000000000000100	19	s3	4	00000000000000000000000000000000100	20	s4	7	00000000000000000000000000000000111	21	s5	5	00000000000000000000000000000000101	22	s6	6	00000000000000000000000000000000110	23	s7	6	00000000000000000000000000000000110	24	s8	0	00000000000000000000000000000000	25	s9	0	00000000000000000000000000000000	26	s10	0	00000000000000000000000000000000	27	s11	0	00000000000000000000000000000000	28	t3	0	00000000000000000000000000000000	29	t4	0	00000000000000000000000000000000	30	t5	0	00000000000000000000000000000000	31	t6	0	00000000000000000000000000000000
R.No.	Reg.Id.	Dec.Val	Binary Value (32 bit)																																																																																																																																						
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27	s11	0	00000000000000000000000000000000																																																																																																																																						
28	t3	0	00000000000000000000000000000000																																																																																																																																						
29	t4	0	00000000000000000000000000000000																																																																																																																																						
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2.b) Passagem em três estágios representativos do Pipeline (“SCHEMA LAYOUT”)

Estágio 1 - Busca de Instrução (IF): Nesse estágio, a instrução é buscada da memória de instruções com base no contador de programa (PC) atual.

Ciclo 1: IF: addi s2, zero, 4
Ciclo 2: IF: add s3, zero, s2
Ciclo 3: IF: addi s4, zero, 7
Ciclo 4: IF: addi s5, zero, 5
Ciclo 5: IF: addi s6, zero, 6
Ciclo 6: IF: add s7, s6, s1

Estágio 2 - Decodificação e Busca de Operandos (ID): Nesse estágio, a instrução é decodificada, os registradores necessários são lidos da memória de registradores (registraror de origem) e os operandos são buscados.

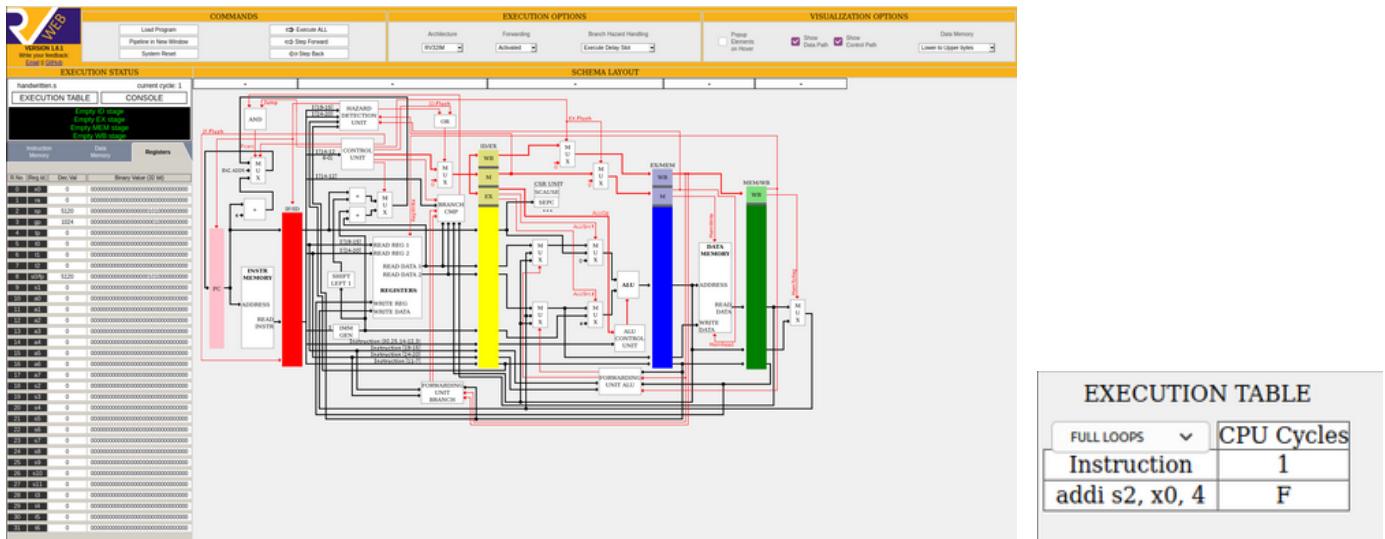
Ciclo 2: ID: addi s2, zero, 4
Ciclo 3: ID: add s3, zero, s2
Ciclo 4: ID: addi s4, zero, 7
Ciclo 5: ID: addi s5, zero, 5
Ciclo 6: ID: addi s6, zero, 6
Ciclo 7: ID: add s7, s6, s1

Estágio 3 - Execução e Cálculo de Endereço (EX): Nesse estágio, a instrução é executada e o resultado é calculado.

Ciclo 3: EX: addi s2, zero, 4
Ciclo 4: EX: add s3, zero, s2
Ciclo 5: EX: addi s4, zero, 7
Ciclo 6: EX: addi s5, zero, 5
Ciclo 7: EX: addi s6, zero, 6
Ciclo 8: EX: add s7, s6, s1

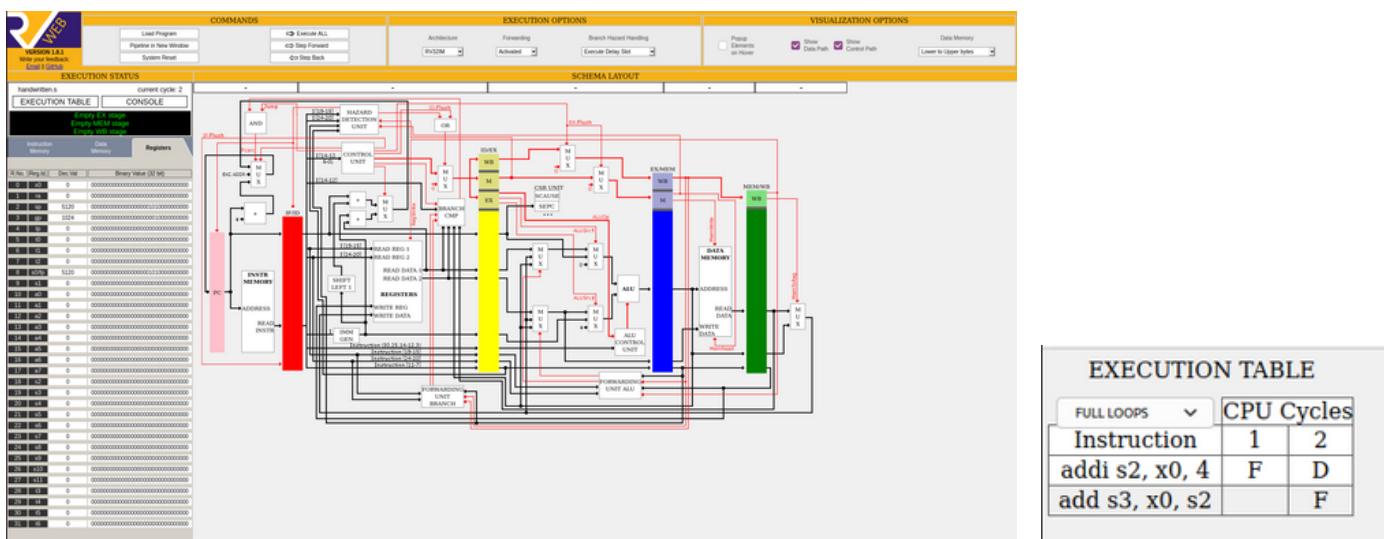
Ciclo 1:

- IF: addi s2, zero, 4



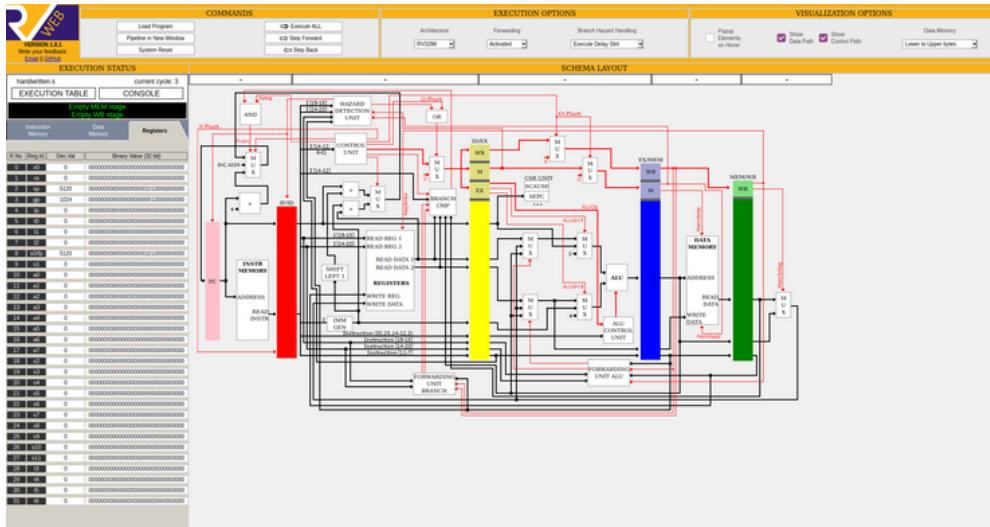
Ciclo 2:

- IF: add s3, zero, s2
- ID: addi s2, zero, 4



Ciclo 3:

- IF: addi s4, zero, 7
- ID: add s3, zero, s2
- EX: addi s2, zero, 4

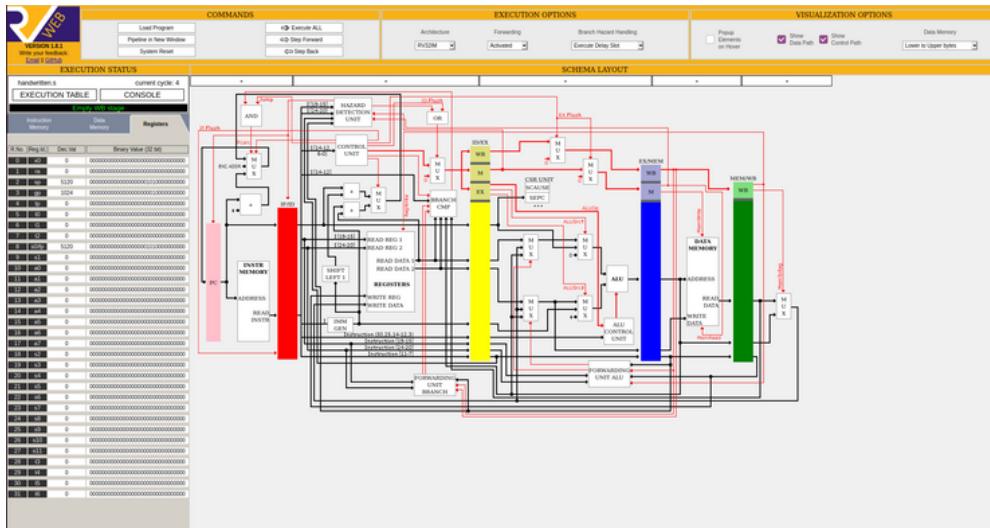


EXECUTION TABLE

FULL LOOPS	CPU Cycles
Instruction	1 2 3
addi s2, x0, 4	F D X
add s3, x0, s2	F D
addi s4, x0, 7	F

Ciclo 4:

- IF: addi s5, zero, 5
- ID: addi s4, zero, 7
- EX: add s3, zero, s2

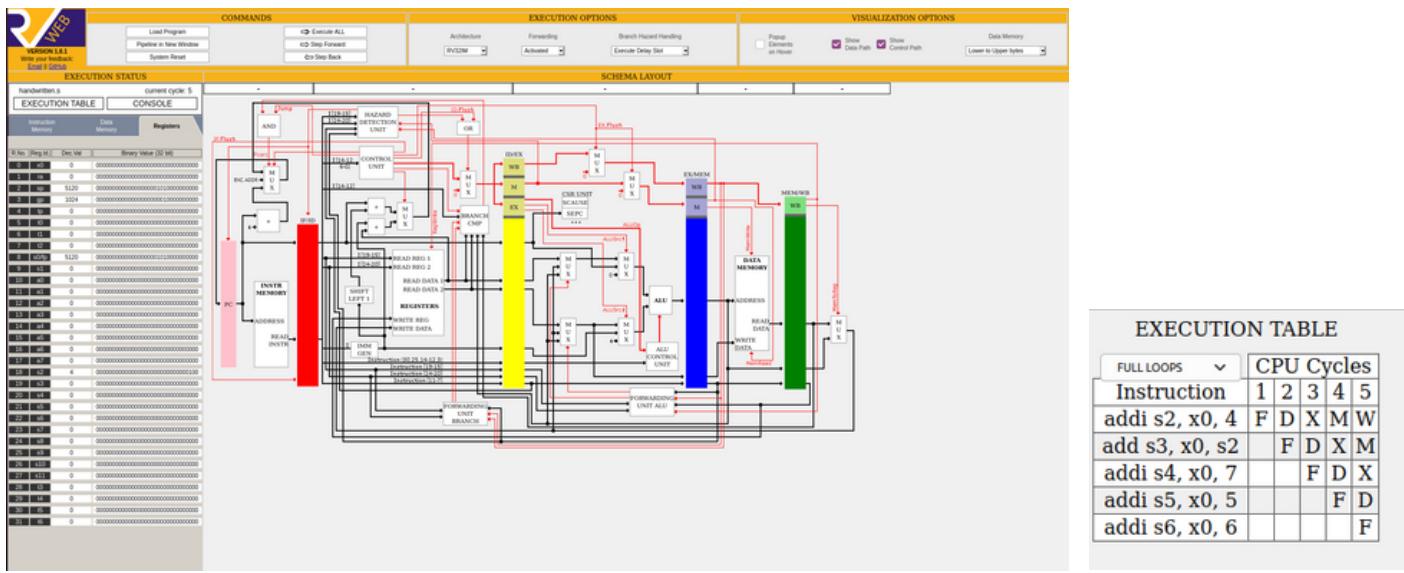


EXECUTION TABLE

FULL LOOPS	CPU Cycles
Instruction	1 2 3 4
addi s2, x0, 4	F D X M
add s3, x0, s2	F D X
addi s4, x0, 7	F D
addi s5, x0, 5	F

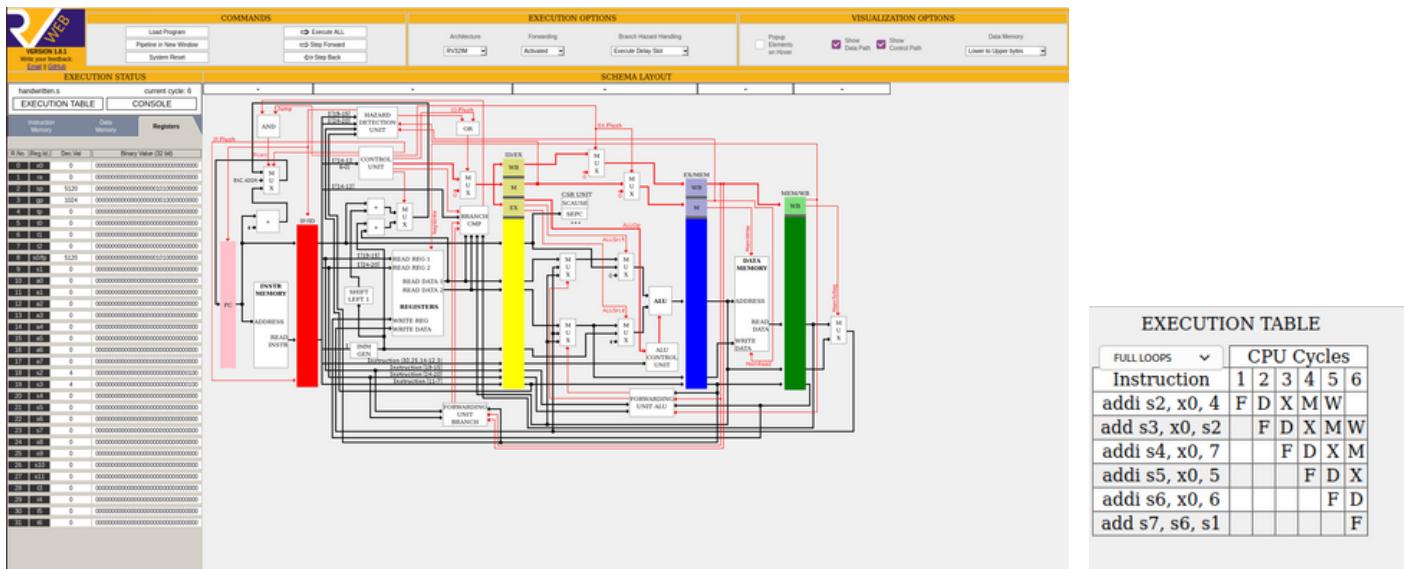
Ciclo 5:

- IF: addi s6, zero, 6
- ID: addi s5, zero, 5
- EX: addi s4, zero, 7



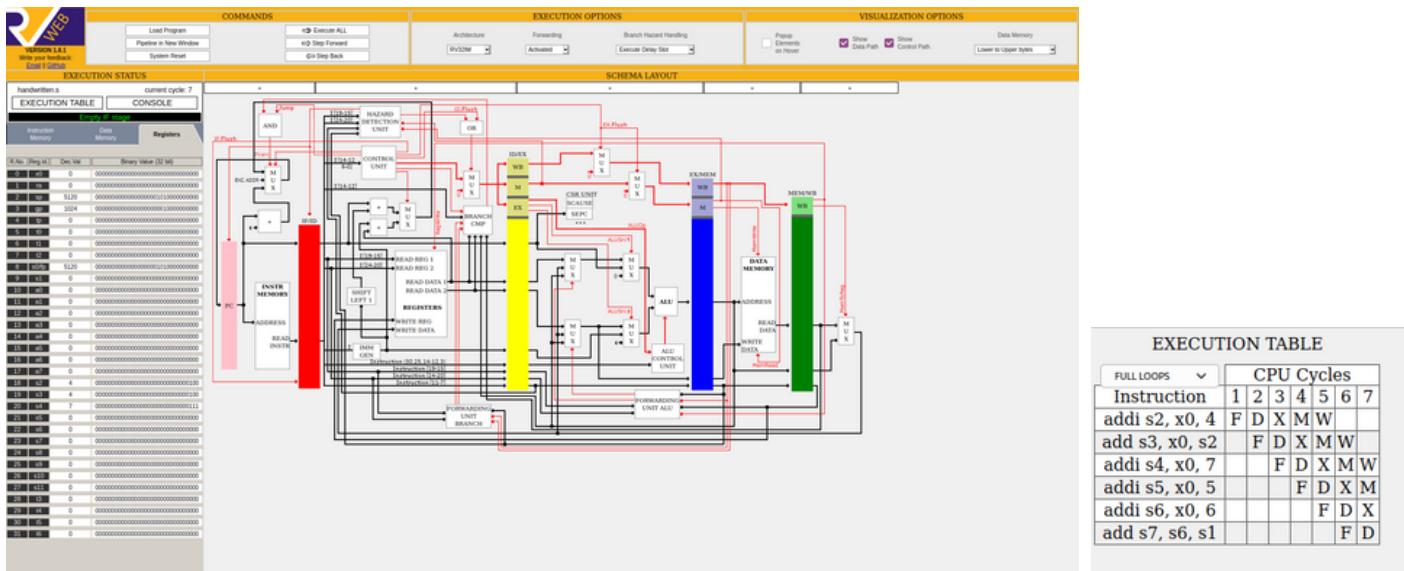
Ciclo 6:

- IF: add s7, s6, s1
- ID: addi s6, zero, 6
- EX: addi s5, zero, 5



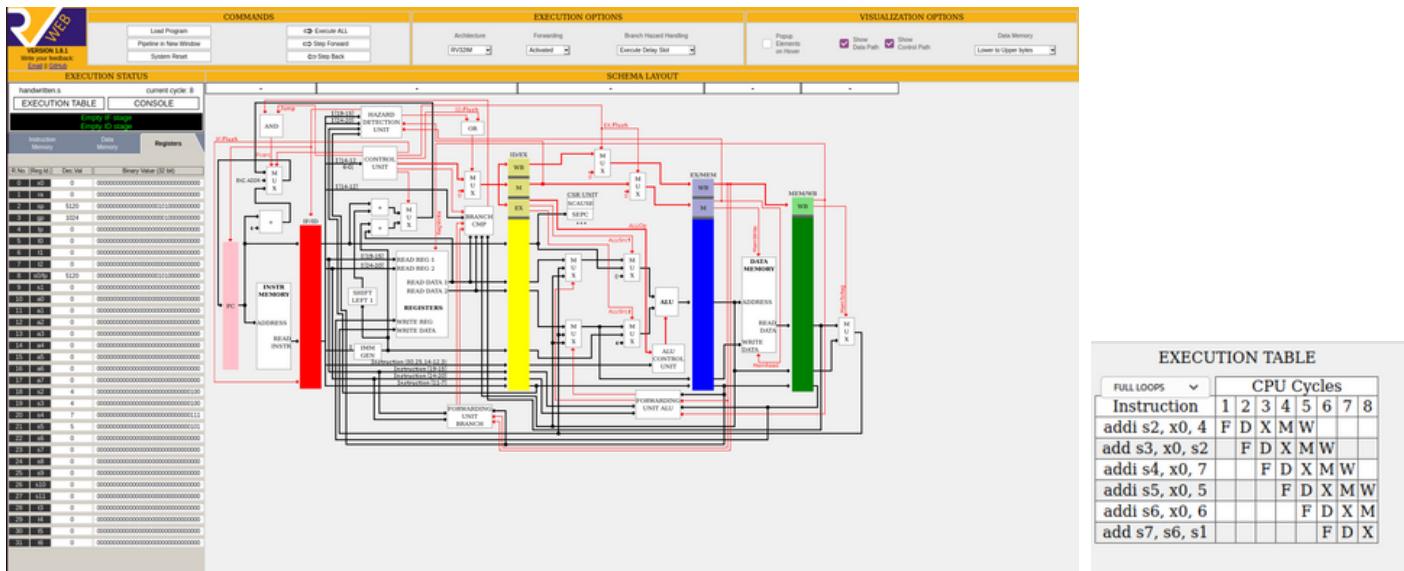
Ciclo 7:

- ID: add s7, s6, s1
- EX: addi s6, zero, 6



Ciclo 8:

- EX: add s7, s6, s1



2.c) Resultado final da execução em Pipeline, por meio da Tabela da Execução do Programa (“EXECUTION TABLE”).

EXECUTION TABLE		CPU Cycles									
FULL LOOPS	Instruction	1	2	3	4	5	6	7	8	9	10
	addi s2, x0, 4	F	D	X	M	W					
	add s3, x0, s2		F	D	X	M	W				
	addi s4, x0, 7			F	D	X	M	W			
	addi s5, x0, 5				F	D	X	M	W		
	addi s6, x0, 6					F	D	X	M	W	
	add s7, s6, s1						F	D	X	M	W

2.d) Ciclos de CPU necessários para executar esse programa.

Total de ciclos da CPU = 10