

XIII Seminario de Invierno CAPAP-H, Almería, 1, 2 y 3 de febrero de 2023

## CREATOR como herramienta docente para la enseñanza de la programación en ensamblador con RISC V

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# Material

<https://github.com/fgcarbal/Creator/>



# Motivación de Creator didaCtic and geneRic assEmbly progrAmming simulaTOR

- ▶ Simulador didáctico para la enseñanza de la programación en ensamblador
  - ▶ Centrado en los estudiantes y profesores
- ▶ Multiplataforma
  - ▶ Ejecución en web sin servidor (sobremesa, tablets y móviles)
- ▶ Entorno integrado (edición, compilación y simulación de programas)
- ▶ Posibilidad de definir y trabajar con diferentes arquitecturas y lenguajes ensamblador
  - ▶ Características básicas (nº de bits, registros, ...)
  - ▶ Instrucciones
  - ▶ Pseudoinstrucciones
  - ▶ Directivas



# Creator desde el punto de vista docente

- ▶ Facilidades para entender:
  - ▶ La representación de datos e instrucciones
  - ▶ La diferencia entre instrucciones y pseudoinstrucciones
  - ▶ La carga de un programa en memoria
  - ▶ El flujo de ejecución de un programa en ensamblador conociendo en todo momento la instrucción en curso y la siguiente (útil en bucles)
  - ▶ El convenio de paso de parámetros y uso de pila con alertas cuando no se respeta
  - ▶ El concepto de biblioteca de funciones y su uso

# CREATOR

**didaCtic and geneRic assEmbly progrAmming simulaTOR**

Access to CREATOR

The screenshot shows the CREATOR interface for a RISC-V-like processor. The main window displays a table of loaded instructions with columns for Break, Address, Label, User Instruction, and Loaded Instructions. The loaded instructions include addi, jal, li, and ecall. The current instruction at address 0x34 is add a0 t1 zero. To the right, there is a register file view showing PC, SR, and various general-purpose registers (ra, sp, gp, etc.) with their current values. Below the table, a large button says "Execute assembly programs".

Break	Address	Label	User Instruction	Loaded Instructions
	0xc			addi a1 a1 0xfs3
	0x10	li a2 45		addi a2 x0 45
	0x14	jal x1 sum		jal x1 0x2c
	0x18	jal x1 sub		jal x1 0x40
	0x1c	li a7 1		addi a7 x0 1
	0x20	ecall		ecall
	0x24	li a7 10		addi a7 x0 10
	0x28	ecall		ecall
	0x2c	add t1 a0 a1		add t1 a0 a1
	0x30	add t2 a2 a2		add t2 a2 a2
	0x34	add a0 t1 zero		add a0 t1 zero
	0x38	add a1 t2 zero		add a1 t2 zero
	0x3c	jr ra		jalr x0 0 (ra)
	0x40	sub a0 a0 a1		sub a0 a0 a1

Register value representation:

Signed	Unsigned	IEEE 754	Hexadecimal
<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Register name representation:

Name	Alias	All
<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

PC, SR

zero 0	ra 24	sp 208405482	gp 0
tp 4	10 0	11 -34	12 99
sd 8	s1 0	a0 23	a1 -77
s2 48	a3 0	s2 0	s3 0
s6 0	a7 0	s6 0	s7 0
s4 8	s5 0	s10 0	s11 0
s8 0	s9 0		
t3 0	t4 208405482	t5 0	t6 0

Execute assembly programs

Clear    Edit

<https://creatorsim.github.io/>



# Características

- ▶ Permite describir las características de una arquitectura y su juego de instrucciones
  - ▶ Actualmente: MIPS-32, [RISC-V \(RV32IMFD\)](#)
- ▶ Editar y compilar programas en ensamblador del juego de instrucciones elegido
- ▶ Ejecutar/depurar programas en ensamblador en un mismo entorno
- ▶ Obtener estadísticas sobre los programas ejecutados
- ▶ Ejecución en navegador

Supported Browsers



# Contenido: empleo de CREATOR con RISC-V

- ▶ Juego de instrucciones soportado
- ▶ Visión del estudiante:
  - ▶ Características del entorno
  - ▶ Edición y compilación de programas
  - ▶ Ejecución y depuración de programas
  - ▶ Bibliotecas de funciones
  - ▶ Facilidades para entender el empleo de funciones y uso de pila
- ▶ Visión del profesor:
  - ▶ Soporte a la corrección de prácticas
  - ▶ Soporte a la creación de material didáctico
  - ▶ Capacidades para extender el juego de instrucciones y crear nuevas arquitecturas

# Disponibilidad

The screenshot shows the CREATOR simulator interface. At the top, there's a navigation bar with links for Introduction, Help, Supported Browsers, Publications, Evolution, and Authors. The main title is "didaCtic and geneRic assEmbly progrAmming simulaTOR". Below the title is a blue button labeled "Access to CREATOR". The central area contains a terminal-like window displaying assembly code. The code includes instructions like `addi \$a0, \$a0, 1` and `addi \$a1, \$a1, 1`. A status bar at the bottom indicates "Execute assembly programs".

<https://creatorsim.github.io>

The screenshot shows the RISC-V Exchange website. At the top, there's a navigation bar with links for About RISC-V, Membership, RISC-V Exchange, Technical, News & Events, Community, and a search bar. The main title is "RISC-V Exchange". Below the title, it says "The RISC-V Exchange hosts the hardware, software, services, and learning offerings in the RISC-V community. Browse the list or search for an offering below." There are two buttons: "SUBMIT AN ITEM" and "CONTACT US". Below this is a search bar with the placeholder "Search Exchange..." and a filter section with checkboxes for Hardware, Cores, Software, Services, and Learning. On the right, there are two cards: one for "CREATOR Simulator" and another for "emmtrix Parallel Studio".

<https://riscv.org/exchange>



# Juego de instrucciones soportado (RV32IMFD)

## 98 instrucciones y pseudoinstrucciones

[Guía de referencia](#)

- ▶ Transferencia de datos: `li`, `mv`, `lui`
- ▶ Aritméticas y lógicas sobre registros de enteros: `addi`, `add`, `and`, ...
- ▶ Aritméticas sobre números en coma flotante (float y double): `fadd.s`, `fmul.d`, ...
- ▶ Instrucciones de salto (registros enteros): `beq`, `bne`, ...
- ▶ Instrucciones de comparación (enteros y coma flotante): `slt`, `feq.s`, ...
- ▶ Instrucciones de transferencia entre registros enteros y coma flotante: `fmv.w.x`,
- ▶ Llamadas a funciones y llamadas al sistema: `jal`, `jr`, `ecall`
- ▶ Acceso a memoria (enteros y coma flotante): `lb`, `lw`, `flw`, `fsd`, ...
- ▶ Operaciones de conversión (enteros y coma flotante): `fcvt.w.s`, ...
- ▶ Otras:
  - ▶ Clasificación de coma flotante: `fclass.s`, `fclass.d`
  - ▶ Contador de ciclos: `rdcycle`



# Registros

Integer Registers	
Register Name	Usage
zero	Constant 0
ra	Return address (routines/functions)
sp	Stack pointer
gp	Global pointer
tp	Thread pointer
t0..t6	Temporary (NOT preserved across calls)
s0..s11	Saved temporary (preserved across calls)
a0, a1	Arguments for functions / return value
a2..a7	Arguments for functions
Floating-point registers	
ft0..ft11	Temporary (NOT preserved across calls)
fs0..fs11	Saved temporary (preserved across calls)
fa0, fa1	Arguments for functions / return value
fa2..fa7	Arguments for functions

# Llamadas al sistema

System Calls (ecall)			
Service	Call Code (a7)	Arguments	Result
Print_int	1	a0 = integer	
Print_float	2	fa0 = float	
Print_double	3	fa0 = double	
Print_string	4	a0 = string addr	
Read_int	5		Integer in a0
Read_float	6		Float in fa0
Read_double	7		Double in fa0
Read_string	8	a0 = string addr a1 = length	
Sbrk	9	a0 = length	Address in a0
Exit	10		
Print_char	11	a0 = ASCII code	
Read_char	12		Char in a0

# Directivas soportadas

Directivas	Uso
<b>.data</b>	Siguientes elementos van al segmento de dato
<b>.text</b>	Siguientes elementos van al segmento de código
<b>.ascii "tira de caracteres"</b>	Almacena cadena caracteres NO terminada en carácter nulo
<b>.string "tira de caracteres"</b>	Almacena cadena caracteres terminada en carácter nulo
<b>.byte 1, 2, 3</b>	Almacena bytes en memoria consecutivamente
<b>.half 300, 301, 302</b>	Almacena medias palabras en memoria consecutivamente
<b>.word 800000, 800001</b>	Almacena palabras en memoria consecutivamente
<b>.float 1.23, 2.13</b>	Almacena float en memoria consecutivamente
<b>.double 3.0e21</b>	Almacena double en memoria consecutivamente
<b>.zero 10</b>	Reserva un espacio de 10 bytes en el segmento actual
<b>.align n</b>	Alinea el siguiente dato en un límite de $2^n$

# CREATOR (RISC-V)

**CREATOR 3.2**  
didaCtic and geneRic assEmbly progrAmming simulaTOR

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Computer Science and Engineering Department

Configuration Info

**RISC-V (RV32IMFD)**

RISC-V is an instruction set architecture (ISA) whose design is based on the RISC type and its hardware is free. This architecture was created in 2010 at the University of California, Berkeley.

**MIPS-32**

The MIPS processor was developed by Dr.John Hennessey and his graduate students at Stanford University in the early 1980s. It is currently one of the major processors in the embedded processor market.

**Load Architecture**

Allows to load the definition of an already created architecture.

**New Architecture**

Allows you to define an architecture from scratch.

# Pantalla inicial

**CREATOR 3.2 RISC-V (RV32IMFD)**  
didactic and generic assembly programming simulator

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Computer Science and Engineering Department

Architecture # Assembly Reset Inst. Run Stop Examples Calculator Configuration Info

Break Address Label User Instruction Loaded Instructions

INT Registers FP Registers Memory Stats Energy (CLK Cycles)

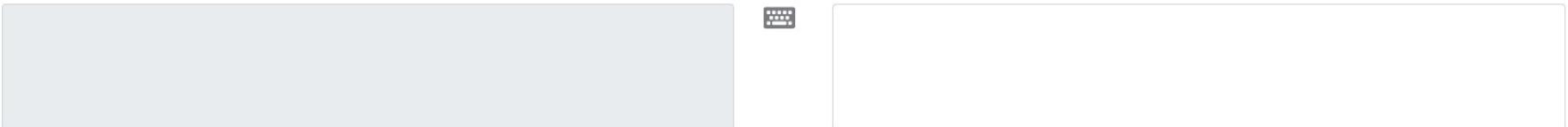
Register value representation Register name representation

Signed Unsig. IEEE 754 Hex.

Name Alias All

zero   x0 00000000	ra   x1 FFFFFFFF	sp   x2 0FFFFFFC	gp   x3 00000000
tp   x4 00000000	t0   x5 00000000	t1   x6 00000000	t2   x7 00000000
fp   s0   x8 00000000	s1   x9 00000000	a0   x10 00000000	a1   x11 00000000
a2   x12 00000000	a3   x13 00000000	a4   x14 00000000	a5   x15 00000000
a6   x16 00000000	a7   x17 00000000	s2   x18 00000000	s3   x19 00000000
s4   x20 00000000	s5   x21 00000000	s6   x22 00000000	s7   x23 00000000
s8   x24 00000000	s9   x25 00000000	s10   x26 00000000	s11   x27 00000000
t3   x28 00000000	t4   x29 00000000	t5   x30 00000000	t6   x31 00000000

Clear Enter



# Elección de la arquitectura

**CREATOR 3.2 RISC-V (RV32IMFD)**  
didaCtic and generic assembly programming simulator

ARCOS uc3m Universidad Carlos III de Madrid  
Computer Science and Engineering Department

Architecture # Assembly Reset Inst. Run Stop Examples Calculator Configuration Info

RISC-V (RV32IMFD)  
MIPS-32  
New Architecture

Label User Instruction Loaded Instructions

INT Registers FP Registers Memory Stats Energy (CLK Cycles)

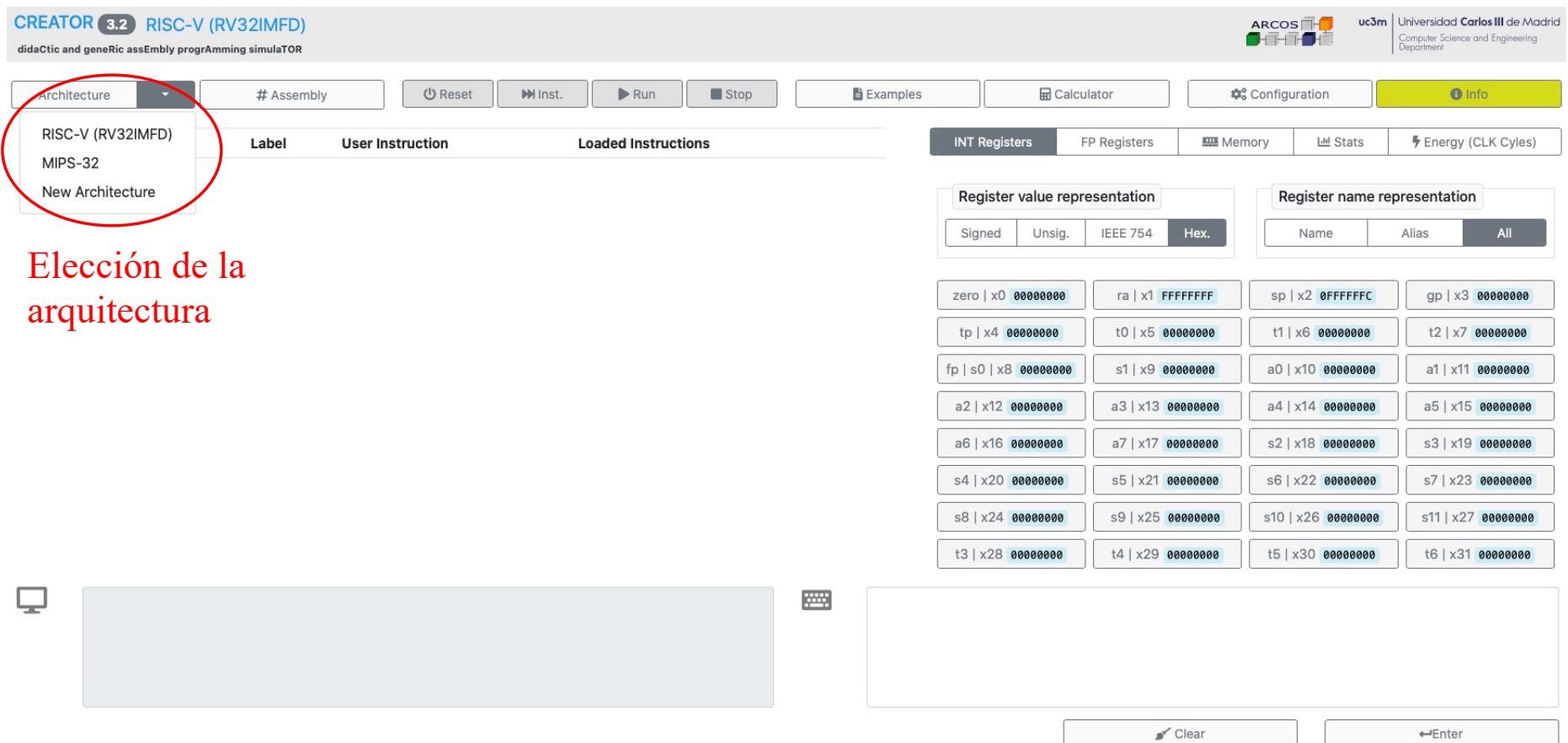
Register value representation Register name representation

Signed Unsig. IEEE 754 Hex.

Name Alias All

zero   x0 00000000	ra   x1 FFFFFFFF	sp   x2 0FFFFFFF	gp   x3 00000000
tp   x4 00000000	t0   x5 00000000	t1   x6 00000000	t2   x7 00000000
fp   s0   x8 00000000	s1   x9 00000000	a0   x10 00000000	a1   x11 00000000
a2   x12 00000000	a3   x13 00000000	a4   x14 00000000	a5   x15 00000000
a6   x16 00000000	a7   x17 00000000	s2   x18 00000000	s3   x19 00000000
s4   x20 00000000	s5   x21 00000000	s6   x22 00000000	s7   x23 00000000
s8   x24 00000000	s9   x25 00000000	s10   x26 00000000	s11   x27 00000000
t3   x28 00000000	t4   x29 00000000	t5   x30 00000000	t6   x31 00000000

Clear Enter



A screenshot of the ARCOS Creator 3.2 software interface. The top navigation bar includes tabs for Architecture, # Assembly, Reset, Inst., Run, Stop, Examples, Calculator, Configuration, and Info. The Configuration tab is highlighted. Below the tabs, there's a dropdown menu labeled "Architecture" with three options: "RISC-V (RV32IMFD)", "MIPS-32", and "New Architecture". The "New Architecture" option is circled in red. The main workspace shows tables for "User Instruction" and "Loaded Instructions". On the right, there are sections for "Register value representation" and "Register name representation", each with tabs for Signed, Unsig., IEEE 754, and Hex. The register value representation section displays 32 registers (x0 to x31) with their binary values. At the bottom, there are "Clear" and "Enter" buttons. The bottom left corner features the ARCOS logo.

# Edición de programas

The screenshot shows the 'CREATOR 3.2 RISC-V (RV32IMFD)' interface. A red circle highlights the '# Assembly' input field in the top navigation bar. The interface includes tabs for Architecture, # Assembly, Reset, Run, Stop, Examples, Calculator, Configuration, and Info. Below the tabs, there are columns for Break, Address, Label, User instruction, and Loaded Instructions. On the right, there are sections for INT Registers, FP Registers, Memory, Stats, and Energy (CLK Cycles). A large central area displays a grid of register values. At the bottom, there are icons for monitor, keyboard, and mouse, along with 'Clear' and 'Enter' buttons.

Edición de programas

Register value representation	Register name representation		
Signed Unsigned IEEE 754 Hex	Name Alias All		
zero   x0 00000000	ra   x1 FFFFFFFF	sp   x2 0FFFFFFC	gp   x3 00000000
tp   x4 00000000	t0   x5 00000000	t1   x6 00000000	t2   x7 00000000
fp   s0   x8 00000000	s1   x9 00000000	a0   x10 00000000	a1   x11 00000000
a2   x12 00000000	a3   x13 00000000	a4   x14 00000000	a5   x15 00000000
a6   x16 00000000	a7   x17 00000000	s2   x18 00000000	s3   x19 00000000
s4   x20 00000000	s5   x21 00000000	s6   x22 00000000	s7   x23 00000000
s8   x24 00000000	s9   x25 00000000	s10   x26 00000000	s11   x27 00000000
t3   x28 00000000	t4   x29 00000000	t5   x30 00000000	t6   x31 00000000

Clear Enter



# Control de la ejecución

The screenshot shows the 'CREATOR 3.2 RISC-V (RV32IMFD)' simulation interface. A red circle highlights the control buttons at the top: 'Reset' (with a power icon), 'Inst.' (with a play icon), 'Run' (with a right-pointing arrow icon), and 'Stop' (with a square icon). Below these buttons is a toolbar with links to 'Examples', 'Calculator', 'Configuration', and 'Info'. The main workspace has tabs for 'Break', 'Address', 'Label', 'User Instruction', and 'Loaded Instructions'. On the right side, there are two sections: 'Register value representation' and 'Register name representation'. The 'Register value representation' section contains 32 registers (x0 to x31) each with a value of '00000000'. The 'Register name representation' section lists the same 32 registers with their names. At the bottom, there are icons for monitor, keyboard, and mouse, along with 'Clear' and 'Enter' buttons.

Control de la ejecución

Registers (Value Representation):

zero   x0 00000000	ra   x1 FFFFFFFF	sp   x2 0FFFFFFC	gp   x3 00000000
tp   x4 00000000	t0   x5 00000000	t1   x6 00000000	t2   x7 00000000
fp   s0   x8 00000000	s1   x9 00000000	a0   x10 00000000	a1   x11 00000000
a2   x12 00000000	a3   x13 00000000	a4   x14 00000000	a5   x15 00000000
a6   x16 00000000	a7   x17 00000000	s2   x18 00000000	s3   x19 00000000
s4   x20 00000000	s5   x21 00000000	s6   x22 00000000	s7   x23 00000000
s8   x24 00000000	s9   x25 00000000	s10   x26 00000000	s11   x27 00000000
t3   x28 00000000	t4   x29 00000000	t5   x30 00000000	t6   x31 00000000

Registers (Name Representation):

Name	Alias	All
zero		
ra		
sp		
gp		
tp		
t0		
t1		
t2		
fp		
s1		
a0		
a1		
a2		
a3		
a4		
a5		
a6		
a7		
s2		
s3		
s4		
s5		
s6		
s7		
s8		
s9		
s10		
s11		
t3		
t4		
t5		
t6		

Bottom Buttons: Clear, Enter



# Ejemplos de programas en ensamblador

Examples

CREATOR 3.2 RISC-V  
didactic and generic assembly programs

Examples set available:

Architecture Break Address

default uc3m-ec-ag

Example 1: Data Storage

Example 2: ALU operations

Example 3: Store/Load Data in Memory

Example 4: FPU operations

Example 5: Loop

Example 6: Branch

Example 7: Loop + Memory

Example 8: Copy of matrices

Example 9: I/O Syscalls

Example 10: I/O Syscalls + Strings

Example 11: Subroutines

Example 12: Factorial

ejemplos

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INT Registers FP Registers Memory Stats Energy (CLK Cycles)

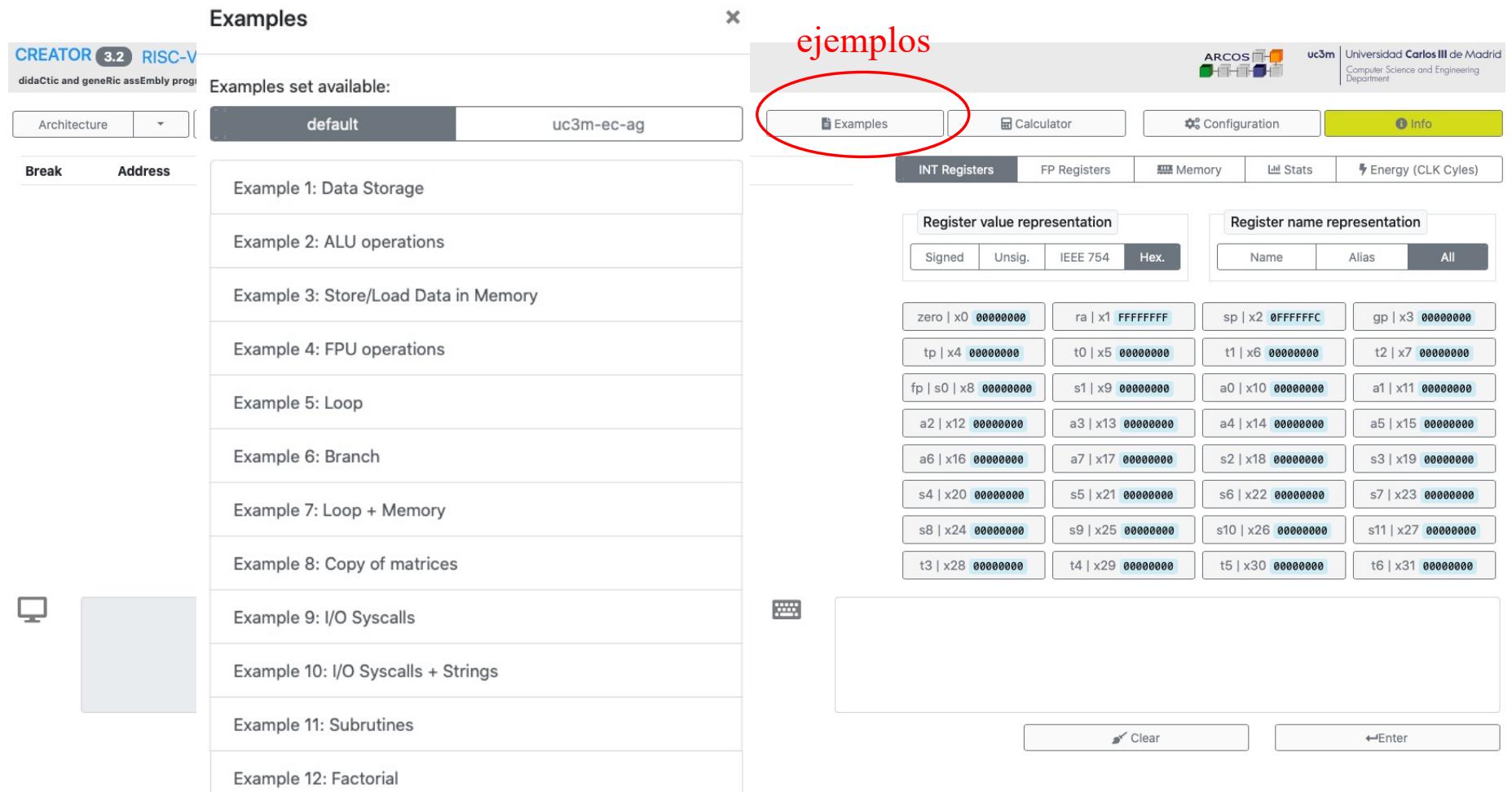
Register value representation Register name representation

Signed Unsigned IEEE 754 Hex.

Name Alias All

zero   x0 0000000	ra   x1 FFFFFFFF	sp   x2 0FFFFFC	gp   x3 0000000
tp   x4 0000000	t0   x5 0000000	t1   x6 0000000	t2   x7 0000000
fp   s0   x8 0000000	s1   x9 0000000	a0   x10 0000000	a1   x11 0000000
a2   x12 0000000	a3   x13 0000000	a4   x14 0000000	a5   x15 0000000
a6   x16 0000000	a7   x17 0000000	s2   x18 0000000	s3   x19 0000000
s4   x20 0000000	s5   x21 0000000	s6   x22 0000000	s7   x23 0000000
s8   x24 0000000	s9   x25 0000000	s10   x26 0000000	s11   x27 0000000
t3   x28 0000000	t4   x29 0000000	t5   x30 0000000	t6   x31 0000000

Clear Enter



# Calculadora de números en coma flotante

**CREATOR 3.2 RISC-V (RV32IMFD)**  
didaCtic and geneRic assEmby progrAmming simulaTOR

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Computer Science and Engineering Department

**Floating Point Calculator**

32 Bits      64 Bits

41840000

0      10000011      00001000000000000000000000000000

↓      ↓      ↓

-1<sup>0</sup> \*      2<sup>131-127</sup> \*      0.03125 = 16.5

Convert

**Calculator** (highlighted with a red circle)

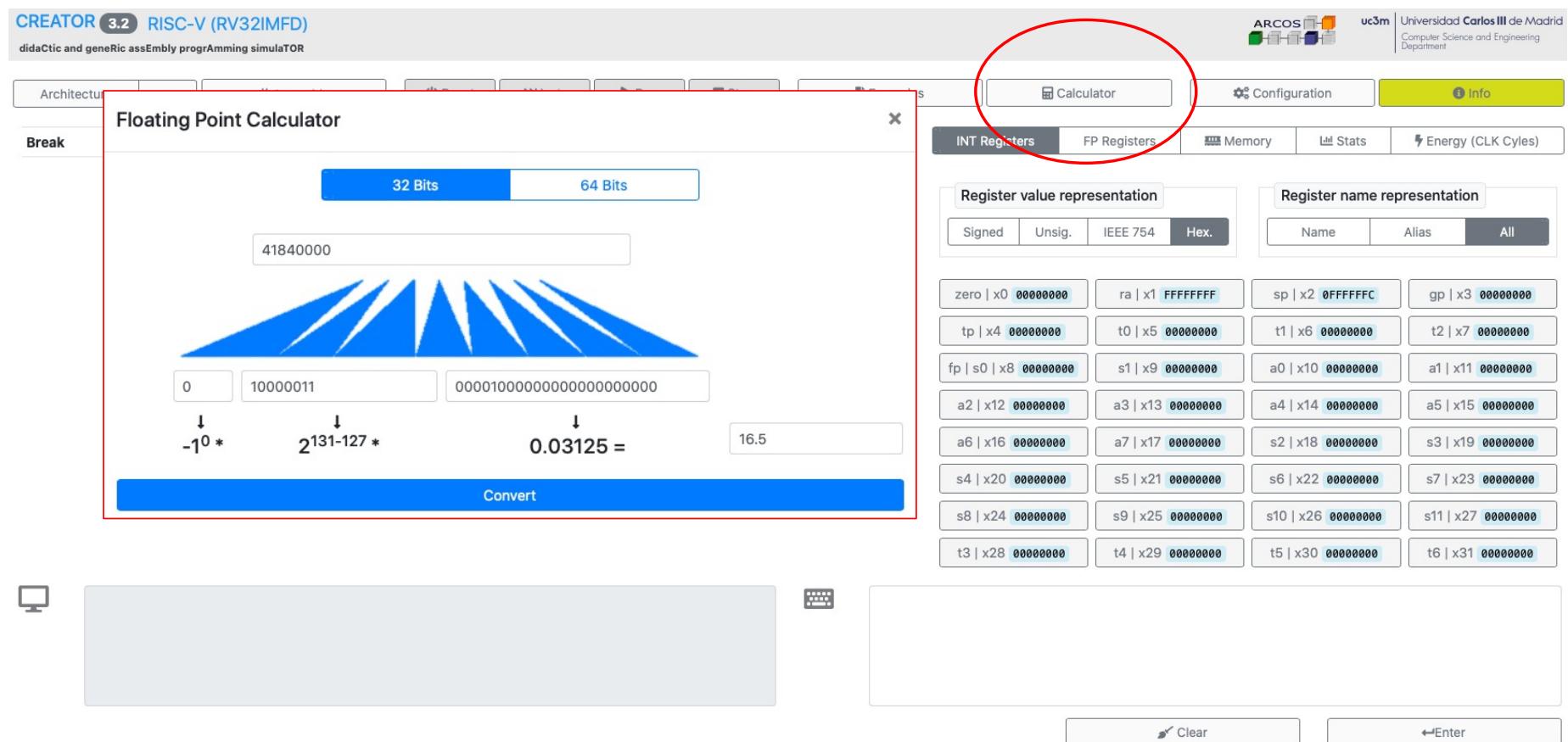
INT Registers      FP Registers      Memory      Stats      Energy (CLK Cycles)

Register value representation      Register name representation

Signed      Unsigned      IEEE 754      Hex.

Name	Alias	All	
zero   x0 00000000	ra   x1 FFFFFFFF	sp   x2 0FFFFFFC	gp   x3 00000000
tp   x4 00000000	t0   x5 00000000	t1   x6 00000000	t2   x7 00000000
fp   s0   x8 00000000	s1   x9 00000000	a0   x10 00000000	a1   x11 00000000
a2   x12 00000000	a3   x13 00000000	a4   x14 00000000	a5   x15 00000000
a6   x16 00000000	a7   x17 00000000	s2   x18 00000000	s3   x19 00000000
s4   x20 00000000	s5   x21 00000000	s6   x22 00000000	s7   x23 00000000
s8   x24 00000000	s9   x25 00000000	s10   x26 00000000	s11   x27 00000000
t3   x28 00000000	t4   x29 00000000	t5   x30 00000000	t6   x31 00000000

Clear      Enter



# Configuración

The screenshot shows the configuration interface for the RISC-V (RV32IMFD) simulator. The top navigation bar includes tabs for 'Calculator', 'Configuration' (which is highlighted with a red circle), and 'Info'. The main area is titled 'Configuration' and contains several sliders and toggle switches:

- Execution Speed: A slider from - to +, currently at 0.
- Maximum stack values listed: A slider from - to +, currently at 0.
- Execution Autoscroll: A toggle switch (blue circle).
- Notification Time: A slider from - to +, currently at 0.
- Instruction Help Size: A slider from - to +, currently at 0.
- Dark Mode: A toggle switch (grey circle).
- Debug: A toggle switch (grey circle).

On the right side, there is a table showing register representations:

sig.	IEEE 754	Hex.	Name	Alias	All
00	ra   x1 FFFFFFFF	sp   x2 0FFFFFFC	gp   x3 00000000		
01	t0   x5 00000000	t1   x6 00000000	t2   x7 00000000		
000	s1   x9 00000000	a0   x10 00000000	a1   x11 00000000		
00	a3   x13 00000000	a4   x14 00000000	a5   x15 00000000		
00	a7   x17 00000000	s2   x18 00000000	s3   x19 00000000		
00	s5   x21 00000000	s6   x22 00000000	s7   x23 00000000		
00	s9   x25 00000000	s10   x26 00000000	s11   x27 00000000		
00	t4   x29 00000000	t5   x30 00000000	t6   x31 00000000		

At the bottom are buttons for 'Clear' and 'Enter'.



# Configuración

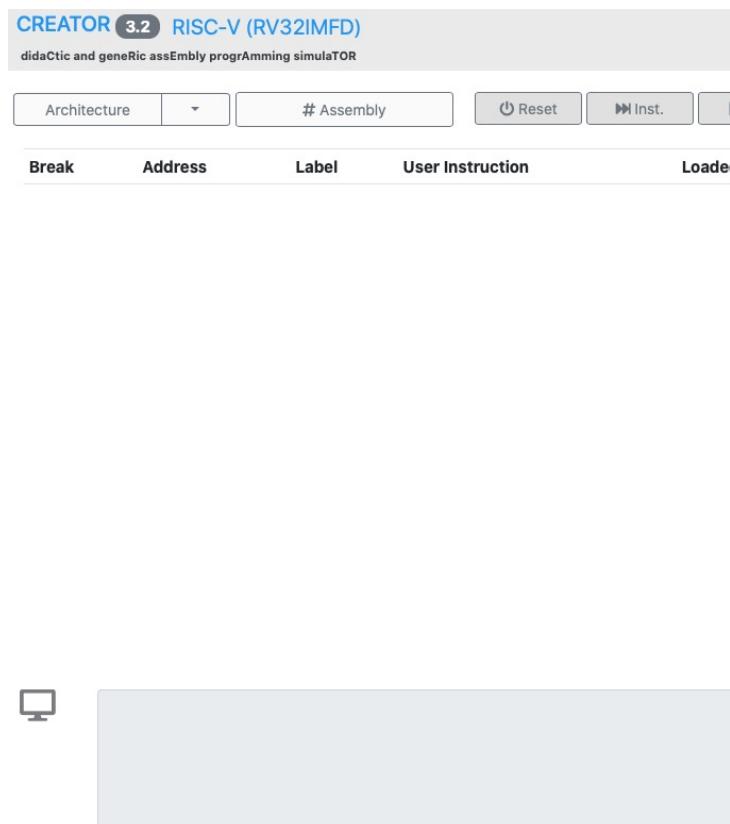
The screenshot shows the 'Info' tab of the RISC-V (RV32IMFD) configuration interface. The interface includes tabs for Architecture, Assembly, Reset, Run, Stop, Examples, Calculator, Configuration, and Info. The Configuration tab is highlighted with a red oval. Below the tabs, there are sections for Break, Address, Label, User Instruction, and Loaded Instructions. A large table displays register values in various formats (Signed, Unsigned, IEEE 754, Hex). The table has four columns: Register name representation (Name, Alias, All) and Register value representation (zero, ra, sp, gp, tp, t0, t1, t2, fp, s0, s1, a0, a1, a2, a3, a4, a5, a6, a7, s2, s3, s4, s5, s6, s7, s8, s9, s10, t3, t4, t5, t6). The first column shows the register name followed by its bit range and hex value. The second column shows the register name followed by its bit range and hex value. The third column shows the register name followed by its bit range and hex value. The fourth column shows the register name followed by its bit range and hex value.

Register name representation	Register value representation
Name	zero   x0 0000000
Alias	ra   x1 FFFFFFFF
All	sp   x2 0FFFFFC
Name	gp   x3 0000000
Alias	tp   x4 0000000
All	t0   x5 0000000
Name	t1   x6 0000000
Alias	t2   x7 0000000
All	fp   s0   x8 0000000
Name	s1   x9 0000000
Alias	a0   x10 0000000
All	a1   x11 0000000
Name	a2   x12 0000000
Alias	a3   x13 0000000
All	a4   x14 0000000
Name	a5   x15 0000000
Alias	a6   x16 0000000
All	a7   x17 0000000
Name	s2   x18 0000000
Alias	s3   x19 0000000
All	s4   x20 0000000
Name	s5   x21 0000000
Alias	s6   x22 0000000
All	s7   x23 0000000
Name	s8   x24 0000000
Alias	s9   x25 0000000
All	s10   x26 0000000
Name	t3   x28 0000000
Alias	t4   x29 0000000
All	t5   x30 0000000
Name	t6   x31 0000000

Below the table are icons for monitor, keyboard, and clear/enter buttons.



# Configuración



The 'Instruction Help' window is open, showing a search bar at the top with the placeholder 'Search instruction' and a link to the 'RISC-V (RV32IMFD) Guide'. Below the search bar is a list of RISC-V instructions:

- lui**  
lui rd imm
- auipc**  
auipc rd imm
- jal**  
jal rd imm
- jalr**  
jalr rd imm (rs1)
- beq**  
beq rs1 rs2 imm
- bne**  
bne rs1 rs2 imm
- blt**  
blt rs1 rs2 imm
- bge**  
bge rs1 rs2 imm
- bltu**  
bltu rs1 rs2 imm
- bgeu**  
bgeu rs1 rs2 imm

The ARCOS simulation interface is shown with a red box highlighting the 'Info' button in the top right corner. The interface includes tabs for 'Memory', 'Stats', and 'Energy (CLK Cycles)'. Below these are sections for 'Register name representation' (hex, name, alias, all) and a table of register values:

x1 FFFFFFFF	sp   x2 0FFFFFFC	gp   x3 00000000
x5 00000000	t1   x6 00000000	t2   x7 00000000
x9 00000000	a0   x10 00000000	a1   x11 00000000
x13 00000000	a4   x14 00000000	a5   x15 00000000
x17 00000000	s2   x18 00000000	s3   x19 00000000
x21 00000000	s6   x22 00000000	s7   x23 00000000
x25 00000000	s10   x26 00000000	s11   x27 00000000
x29 00000000	t5   x30 00000000	t6   x31 00000000

At the bottom are 'Clear' and 'Enter' buttons.



# Configuración

X	Instruction Help
	<input type="text"/> Search instruction
▶	<a href="#">RISC-V (RV32IMFD) Guide</a>
	<b>lui</b>
	<i>lui rd inm</i>
	<b>auipc</b>
	<i>auipc rd inm</i>
	<b>jal</b>
	<i>jal rd inm</i>
	<b>jalr</b>
	<i>jalr rd inm (rs1)</i>
	<b>beq</b>
	<i>beq rs1 rs2 inm</i>
	<b>bne</b>
	<i>bne rs1 rs2 inm</i>
	<b>blt</b>
	<i>blt rs1 rs2 inm</i>
	<b>bge</b>
	<i>bge rs1 rs2 inm</i>
	<b>bltu</b>
	<i>bltu rs1 rs2 inm</i>
	<b>bgeu</b>

The screenshot shows the ARCOS software interface. At the top, there is a logo for ARCOS, the text "uc3m Universidad Carlos III de Madrid", and "Computer Science and Engineering Department". Below the logo, there are two tabs: "Configuration" and "Info", with "Info" being highlighted by a red circle. The main area displays a table titled "Register name representation" with columns for Name, Alias, and All. The table contains 10 rows of register pairs:

	Name	Alias	All
x1	FFFFFFFFFF	sp   x2	0FFFFFFC
x5	00000000	t1   x6	00000000
x9	00000000	a0   x10	00000000
x13	00000000	a4   x14	00000000
x17	00000000	s2   x18	00000000
x21	00000000	s6   x22	00000000
x25	00000000	s10   x26	00000000
x29	00000000	t5   x30	00000000
		t6   x31	00000000

At the bottom left is a "Clear" button, and at the bottom right is an "Enter" button.



# Registros enteros

The screenshot shows the 'INT Registers' tab of the RISC-V (RV32IMFD) simulation interface. A red circle highlights the 'INT Registers' button in the top navigation bar. Below it, two sections are visible: 'Register value representation' and 'Register name representation'. The 'Register value representation' section contains 32 registers, each with a name and a hex value. The 'Register name representation' section lists the same 32 registers by name. At the bottom, there are 'Clear' and 'Enter' buttons.

Register	Value (Hex)
zero   x0	00000000
ra   x1	FFFFFFFFFF
sp   x2	0FFFFFFC
gp   x3	00000000
tp   x4	00000000
t0   x5	00000010
t1   x6	00000000
t2   x7	00000000
fp   s0   x8	00000000
s1   x9	00000000
a0   x10	00000000
a1   x11	00000000
a2   x12	00000000
a3   x13	00000000
a4   x14	00000000
a5   x15	00000000
a6   x16	00000000
a7   x17	00000000
s2   x18	00000000
s3   x19	00000000
s4   x20	00000000
s5   x21	00000000
s6   x22	00000000
s7   x23	00000000
s8   x24	00000000
s9   x25	00000000
s10   x26	00000000
s11   x27	00000000
t3   x28	00000000
t4   x29	00000000
t5   x30	00000000
t6   x31	00000000



# Registros enteros

The screenshot shows the 'CREATOR 3.2 RISC-V (RV32IMFD)' simulation interface. At the top, there are tabs for Architecture, # Assembly, Reset, Run, Stop, Examples, Calculator, Configuration, and Info. The Configuration tab is highlighted.

In the center, there's a table for 'Loaded Instructions' with columns for Break, Address, Label, User Instruction, and Loaded Instructions. Below this is a navigation bar with tabs for INT Registers, FP Registers, Memory, Stats, and Energy (CLK Cycles). The INT Registers tab is selected.

A red circle highlights the 'Register value representation' section, which includes buttons for Signed, Unsigned, IEEE 754, and Hex. The Hex button is selected. To the right is the 'Register name representation' section with tabs for Name, Alias, and All. The All tab is selected.

The main area displays a grid of 32-bit register values in hex format:

zero   x0 00000000	ra   x1 FFFFFFFF	sp   x2 0FFFFFFC	gp   x3 00000000
tp   x4 00000000	t0   x5 00000010	t1   x6 00000000	t2   x7 00000000
fp   s0   x8 00000000	s1   x9 00000000	a0   x10 00000000	a1   x11 00000000
a2   x12 00000000	a3   x13 00000000	a4   x14 00000000	a5   x15 00000000
a6   x16 00000000	a7   x17 00000000	s2   x18 00000000	s3   x19 00000000
s4   x20 00000000	s5   x21 00000000	s6   x22 00000000	s7   x23 00000000
s8   x24 00000000	s9   x25 00000000	s10   x26 00000000	s11   x27 00000000
t3   x28 00000000	t4   x29 00000000	t5   x30 00000000	t6   x31 00000000

At the bottom, there are icons for monitor, keyboard, and mouse, along with 'Clear' and 'Enter' buttons.



# Registros enteros

The screenshot shows the CREATOR 3.2 RISC-V (RV32IMFD) simulator interface. A red box highlights the register value representation for register t0 | x5, which has a hex value of 00000010. An arrow points from this highlighted area to the main register table below.

Register	Value
zero   x0	00000000
ra   x1	FFFFFFF
sp   x2	0FFFFFFC
gp   x3	00000000
tp   x4	00000000
t0   x5	00000010
t1   x6	00000000
t2   x7	00000000
fp   s0   x8	00000000
s1   x9	00000000
a0   x10	00000000
a1   x11	00000000
a2   x12	00000000
a3   x13	00000000
a4   x14	00000000
a5   x15	00000000
a6   x16	00000000
a7   x17	00000000
s2   x18	00000000
s3   x19	00000000
s4   x20	00000000
s5   x21	00000000
s6   x22	00000000
s7   x23	00000000
s8   x24	00000000
s9   x25	00000000
s10   x26	00000000
s11   x27	00000000
t3   x28	00000000
t4   x29	00000000
t5   x30	00000000
t6   x31	00000000

Below the table are two input fields: "Enter new value" and "Update". At the bottom right are "Clear" and "Enter" buttons.

# Registros en coma flotante

The screenshot shows the CREATOR 3.2 RISC-V (RV32IMFD) simulation interface. At the top, there are tabs for Architecture, # Assembly, Reset, Inst., Run, Stop, Examples, Calculator, Configuration, and Info. The Info tab is highlighted with a yellow background. Below these are tabs for Break, Address, Label, User Instruction, and Loaded Instructions. The Loaded Instructions tab is also highlighted with a yellow background. To the right of these tabs is a navigation bar with INT Registers, FP Registers (which is circled in red), Memory, Stats, and Energy (CLK Cycles). Under the FP Registers tab, there are two sections: Register value representation (with Signed, Unsigned, IEEE 754, and Hex options, where Hex is selected) and Register name representation (with Name, Alias, and All options, where All is selected). Below these sections is a grid of 32 floating-point registers (ft0 to ft31) each with its name and a hex value.

Register	Value (Hex)
ft0   f0	0000000000000000
ft1   f1	0000000000000000
ft2   f2	0000000000000000
ft3   f3	0000000000000000
ft4   f4	0000000000000000
ft5   f5	0000000000000000
ft6   f6	0000000000000000
ft7   f7	0000000000000000
fs0   f8	0000000000000000
fs1   f9	0000000000000000
fa0   f10	0000000000000000
fa1   f11	0000000000000000
fa2   f12	0000000000000000
fa3   f13	0000000000000000
fa4   f14	0000000000000000
fa5   f15	0000000000000000
fa6   f16	0000000000000000
fa7   f17	0000000000000000
fs2   f18	0000000000000000
fs3   f19	0000000000000000
fs4   f20	0000000000000000
fs5   f21	0000000000000000
fs6   f22	0000000000000000
fs7   f23	0000000000000000
fs8   f24	0000000000000000
fs9   f25	0000000000000000
fs10   f26	0000000000000000
fs11   f27	0000000000000000
ft8   f28	0000000000000000
ft9   f29	0000000000000000
ft10   f30	0000000000000000
ft11   f31	0000000000000000



# Registros en coma flotante

CREATOR 3.2 RISC-V (RV32IMFD)  
didaCtic and geneRic assEmby progrAMming simulaTOR

ARCOS | uc3m | Universidad Carlos III de Madrid  
Computer Science and Engineering Department

Architecture # Assembly Reset Inst. Run Stop Examples Calculator Configuration Info

Break Address Label User Instruction Loaded Instructions INT Registers FP Registers Memory Stats Energy (CLK Cyles)

ft5 | f5

Hex.	00000000C1840000
Binary	00000000000000000000000000000000100000110000100000000000000000
IEEE 754 (32 bits)	-16.5
IEEE 754 (64 bits)	1.6040599287e-314

Enter new value Simple Precision Update

ft5 | f5 00000000C1840000

fs5 | f21

Hex.	C030800000000000
Binary	1100000000110000100
IEEE 754 (32 bits)	0
IEEE 754 (64 bits)	-16.5

Enter new value Double Precision Update

Register value representation Register name representation

Signed Unsigned IEEE 754 Hex. Name Alias All

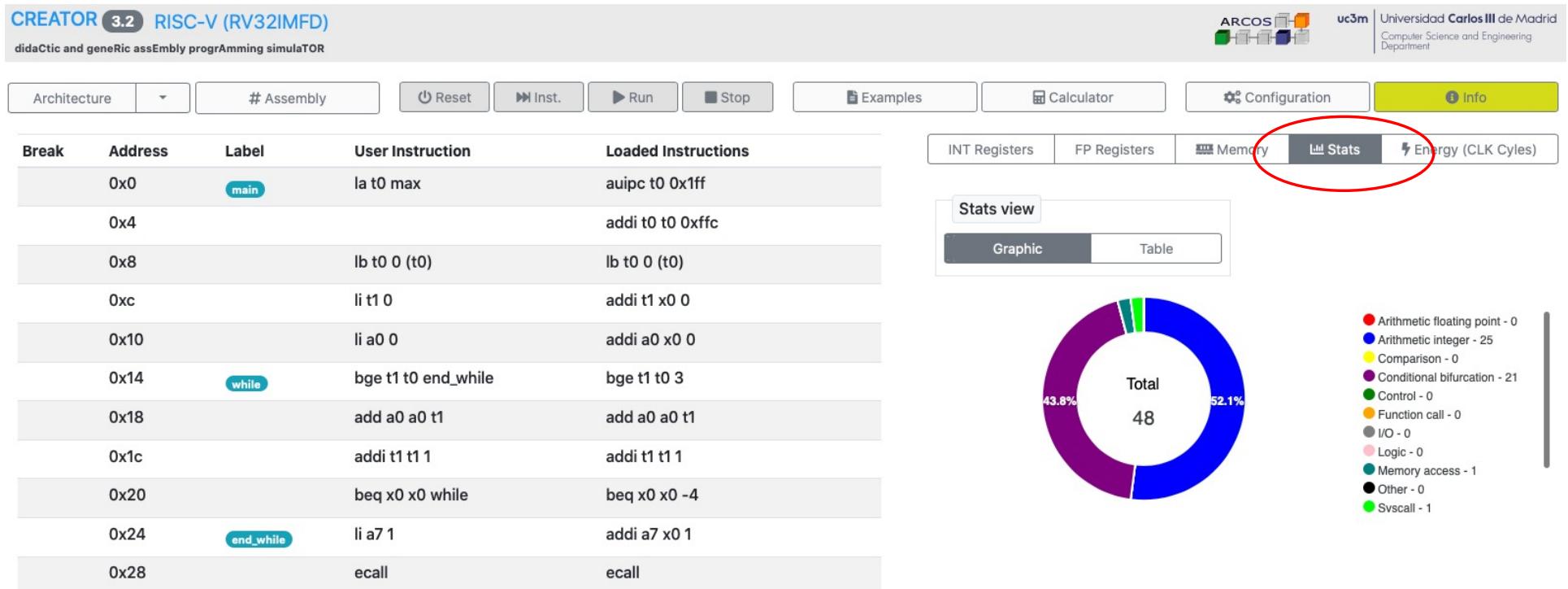
ft0   f0 0000000000000000	ft1   f1 0000000000000000	ft2   f2 0000000000000000	ft3   f3 0000000000000000
ft4   f4 0000000000000000	ft5   f5 00000000C1840000	ft6   f6 0000000000000000	ft7   f7 0000000000000000
fs0   f8 0000000000000000	fs1   f9 0000000000000000	fa0   f10 0000000000000000	fa1   f11 0000000000000000
fa2   f12 0000000000000000	fa3   f13 0000000000000000	fa4   f14 0000000000000000	fa5   f15 0000000000000000
fa6   f16 0000000000000000	fa7   f17 0000000000000000	fs2   f18 0000000000000000	fs3   f19 0000000000000000
fs4   f20 0000000000000000	fs5   f21 C030800000000000	fs6   f22 0000000000000000	fs7   f23 0000000000000000
fs8   f24 0000000000000000	fs9   f25 0000000000000000	fs10   f26 0000000000000000	fs11   f27 0000000000000000
ft8   f28 0000000000000000	ft9   f29 0000000000000000	ft10   f30 0000000000000000	ft11   f31 0000000000000000

# Contenido de la memoria

The screenshot shows the 'MEMORY' tab of the RISC-V (RV32IMFD) simulation interface. The top navigation bar includes tabs for Architecture, # Assembly, Reset, Run, Stop, Examples, Calculator, Configuration, and Info. Below the tabs, there are columns for Break, Address, Label, User Instruction, and Loaded Instructions. A red circle highlights the 'MEMORY' tab in the navigation bar. The main area displays the 'Main memory segment' with tabs for Data, Text, and Stack. Below this, there is a table with columns for Address, Binary, and Value, which is currently empty. At the bottom, there are icons for monitor, keyboard, and mouse, along with 'Clear' and 'Enter' buttons.



# Estadísticas de ejecución



# Ciclos ejecutados

**CREATOR 3.2 RISC-V (RV32IMFD)**  
didaCtic and geneRic assEmbyl progrAmming simulaTOR

ARCOS uc3m Universidad Carlos III de Madrid  
Computer Science and Engineering Department

Architecture	# Assembly	Reset	Inst.	Run	Stop	Examples	Calculator	Configuration	Info
Break	Address	Label	User Instruction	Loaded Instructions					
0x0		main	la t0 max	auipc t0 0x1ff					
0x4				addi t0 t0 0xfffc					
0x8			lb t0 0 (t0)	lb t0 0 (t0)					
0xc			li t1 0	addi t1 x0 0					
0x10			li a0 0	addi a0 x0 0					
0x14		while	bge t1 t0 end_while	bge t1 t0 3					
0x18			add a0 a0 t1	add a0 a0 t1					
0x1c			addi t1 t1 1	addi t1 t1 1					
0x20			beq x0 x0 while	beq x0 x0 -4					
0x24		end_while	li a7 1	addi a7 x0 1					
0x28			ecall	ecall					

INT Registers FP Registers Memory Stats Energy (CLK Cycles)

CLK Cycles view Graphic Table Total CLK Cycles: 48

Instruction Type	CLK Cycles
Arithmetic floating point	~25
Arithmetic integer	~25
Comparison	~21
Conditional bifurcation	~21
Control	~1
Function call	~1
I/O	~1
Logic	~1
Memory access	~1
Other	~1
Syscall	~1
Transfer between registers	~1
Unconditional bifurcation	~1

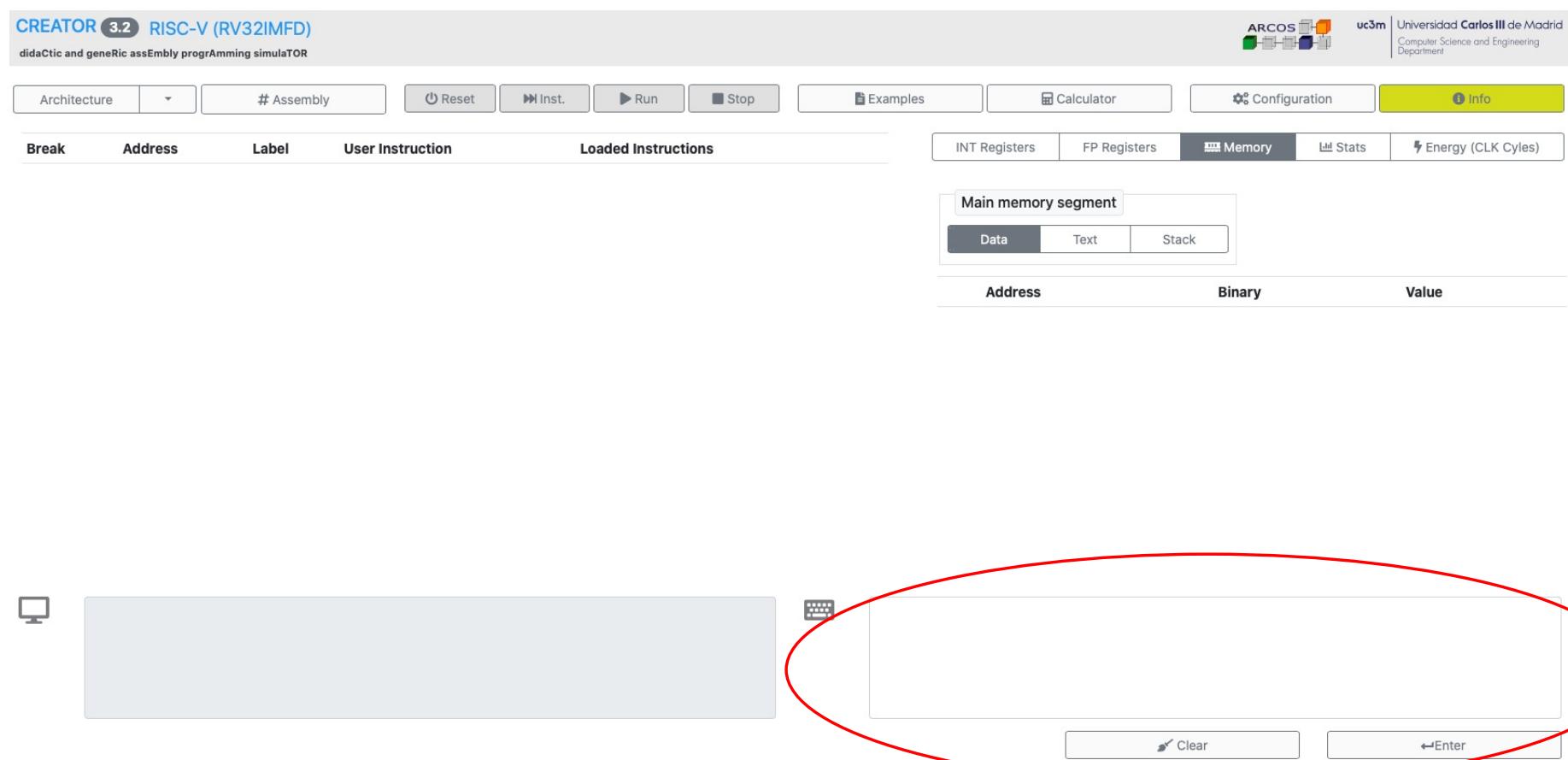


# Pantalla

The screenshot shows the 'CREATOR 3.2 RISC-V (RV32IMFD)' interface. At the top, there's a navigation bar with tabs for Architecture, # Assembly, Reset, Run, Stop, Examples, Calculator, Configuration, and Info. The Info tab is highlighted in yellow. Below the navigation bar, there are columns for Break, Address, Label, User Instruction, and Loaded Instructions. To the right, there are tabs for INT Registers, FP Registers, Memory (which is selected), Stats, and Energy (CLK Cycles). A large central area is labeled 'Main memory segment' and contains tabs for Data, Text, and Stack. Below this is a table with columns for Address, Binary, and Value. At the bottom, there are buttons for Clear and Enter.



# Teclado



# Edición de programas en ensamblador

CREATOR 3.2 RISC-V (RV32IMFD)

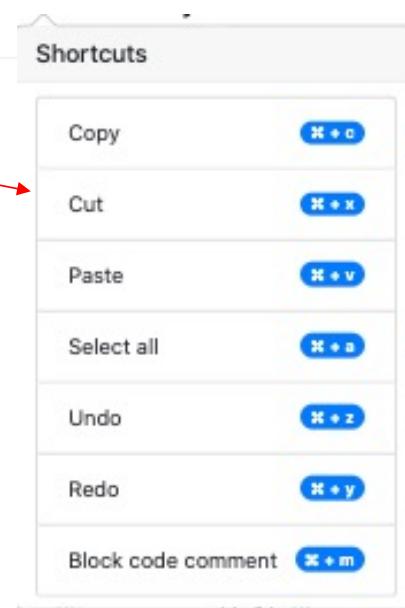
didaCtic and geneRic assEmbly progrAMming simulaTOR

Architecture ▾ Simulator ➔ Compile/Linked

Assembly:

```
1 #
2 #
3 # Creator (https://creatorsim.github.io/creator/)
4 #
5 .text
6 main:
7
8     li t0 10
9     li t2 -20
10
11    add    t3,t0, t2
12    mul    t4 t0, t2
13    div    t5, t0, t2
14
15
```

ejemplo



# Compilación

The screenshot shows the CREATOR 3.2 RISC-V (RV32IMFD) interface. The title bar reads "CREATOR 3.2 RISC-V (RV32IMFD)" and "didaCtic and geneRic assEmbly progrAMming simulaTOR". The menu bar includes "Architecture", "Simulator", "Compile/Linked", and "File". A green notification box in the top right corner says "Compilation completed successfully". The main area displays assembly code:

```
1
2 #
3 # Creator (https://creatorsim.github.io/creator/)
4 #
5
6 .text
7 main:
8
9     li t0 10
10    li t2 -20
11
12   add    t3,t0, t2
13   mul    t4 t0, t2
14   div    t5, t0, t2
15
```

# Error de compilación

CREATOR 3.2 RISC-V (RV32IMFD)  
didactic and generic assembly programming simulator

Architecture Simulator

Assembly:

```
1
2 #
3 # Creator (https://creatorsim.github.io/creator/)
4 #
5
6 .text
7 main:
8
9   li t0 10
10  li t2 -20
11
12  add   t3,t0, t2
13  mul   t4 t0, t2
14  div   ti, t0, t2
15
```

Assembly Code Error

Code fragment:

```
...
13      mul t4 t0, t2
*     14      div ti, t0, t2
15
...
```

Error description:

Register 'ti' not found



# Paso al simulador

CREATOR 3.2 RISC-V (RV32IMFD)  
didactic and generic assembly programming simulator

Architecture ▾ Simulator ▾ Compile/Linked File ▾

❶ Assembly:

```
1
2 #
3 # Creator (https://creatorsim.github.io/creator/)
4 #
5
6 .text
7 main:
8
9     li t0 10
10    li t2 -20
11
12    add    t3,t0, t2
13    mul    t4 t0, t2
14    div    t5, t0, t2
15
```



# Simulador

ejemplo

CREATOR 3.2 RISC-V (RV32IMFD)  
didaCtic and generic assembly programming simulator

ARCOS uc3m Universidad Carlos III de Madrid  
Computer Science and Engineering Department

Architecture # Assembly Reset Inst. Run Stop Examples Calculator Configuration Info

Break	Address	Label	User Instruction
0x0		main	li t0 10
0x4			li t2 -20
0x8			
0xc			
0x10			add t3 t0 t2
0x14			mul t4 t0 t2
0x18			div t5 t0 t2

Loaded Instructions

addi t0 x0 10  
lui t2 0  
lui t2 0xFFFFF  
addi t2 t0 0xfc  
add t3 t0 t2  
mul t4 t0 t2  
div t5 t0 t2

Next

INT Registers FP Registers Memory Stats Energy (CLK Cycles)

Register value representation Register name representation

Signed Unsigned IEEE 754 Hex.

Name Alias All

zero   x0 00000000	ra   x1 FFFFFFFF	sp   x2 0FFFFFFC	gp   x3 00000000
tp   x4 00000000	t0   x5 00000000	t1   x6 00000000	t2   x7 00000000
fp   s0   x8 00000000	s1   x9 00000000	a0   x10 00000000	a1   x11 00000000
a2   x12 00000000	a3   x13 00000000	a4   x14 00000000	a5   x15 00000000
a6   x16 00000000	a7   x17 00000000	s2   x18 00000000	s3   x19 00000000
s4   x20 00000000	s5   x21 00000000	s6   x22 00000000	s7   x23 00000000
s8   x24 00000000	s9   x25 00000000	s10   x26 00000000	s11   x27 00000000
t3   x28 00000000	t4   x29 00000000	t5   x30 00000000	t6   x31 00000000

Programa escrito (inst. y pseudoinst.)

Programa en memoria (instrucciones máquina)

Clear Enter

The screenshot shows the 'User Instruction' section with assembly code and the 'Loaded Instructions' section with machine code. Red arrows point from the labels 'Programa escrito (inst. y pseudoinst.)' and 'Programa en memoria (instrucciones máquina)' to their respective sections. The 'Registers' panel shows various integer and floating-point registers with their hex values. At the bottom, there are 'Clear' and 'Enter' buttons.



# Flujo de ejecución

CREATOR 3.2 RISC-V (RV32IMFD)  
didactic and generic assembly programming simulator

Architecture	# Assembly	Reset	Inst.	Run	Stop	Examples
Break	Address	Label	User Instruction	Loaded Instructions		
0x0		main	li t0 10	addi t0 x0 10		
0x4			li t2 -20	lui t2 0		
0x8				lui t2 0xFFFFF	Current	
0xc				addi t2 t2 0xfc	Next	
0x10			add t3 t0 t2	add t3 t0 t2		
0x14			mul t4 t0 t2	mul t4 t0 t2		
0x18			div t5 t0 t2	div t5 t0 t2		



# Puntos de ruptura

CREATOR 3.2 RISC-V (RV32IMFD)  
didactic and generic assembly programming simulator

Architecture	# Assembly	Reset	Inst.	Run	Stop	Examples
Break	Address	Label	User Instruction	Loaded Instructions		
	0x0	main	li t0 10	addi t0 x0 10		
	0x4		li t2 -20	lui t2 0		
	0x8			lui t2 0xFFFFF		
	0xc			addi t2 t2 0xfc		
	0x10		add t3 t0 t2	add t3 t0 t2	Current	
STOP	0x14		mul t4 t0 t2	mul t4 t0 t2		Next
	0x18		div t5 t0 t2	div t5 t0 t2		

# Segmento de datos

ejemplo



## Assembly:

```
1 .data
2
3     cadena: .string "Hola mundo"
4     A:      .byte 1
5     .align 2
6     N:      .word 64
7     C:      .byte 'a'
8     .align 2
9     F:      .float -12.5
10    D:      .double -12.5
11
12    # int v1[5]={1,2,3,4,5}
13    v1:      .word 1, 2, 3, 4, 5
14
15    #int v2[10]
16    v2:      .zero 40
```



# Visualización de datos en memoria

ejemplo

## 1 Assembly:

```
1 .data
2
3     cadena: .string "Hola mundo"
4     A:     .byte 1
5     .align 2
6     N:     .word 64
7     C:     .byte 'a'
8     .align 2
9     F:     .float -12.5
10    D:     .double -12.5
11
12    # int v1[5]={1,2,3,4,5}
13    v1:     .word 1, 2, 3, 4, 5
14
15    #int v2[10]
16    v2:     .zero 40
```

Main memory segment			
Data	Text	Stack	
Address	Binary	Value	
0x00200000 - 0x00200003	48 6F 6C 61	H, o, l, a	①
0x00200004 - 0x00200007	20 6D 75 6E	, m, u, n	②
0x00200008 - 0x0020000B	64 6F 00 01	d, o, 0, 1	③
0x0020000C - 0x0020000F	00 00 00 40	64	④
0x00200010 - 0x00200013	61 00 00 00	97	⑤
0x00200014 - 0x00200017	C1 48 00 00	-12.5	⑥
0x00200018 - 0x0020001B	C0 28 00 00	-12.5	⑦
0x0020001C - 0x0020001F	00 00 00 00		
0x00200020 - 0x00200023	00 00 00 01	1	⑧
0x00200024 - 0x00200027	00 00 00 02	2	
0x00200028 - 0x0020002B	00 00 00 03	3	
0x0020002C - 0x0020002F	00 00 00 04	4	



# Visualización de datos en memoria

## 1 Assembly:

```
1 .data  
2  
3     cadena: .string "Hola mundo"  
4     A:     .byte 1  
5     .align 2  
6     N:     .word 64  
7     C:     .byte 'a'  
8     .align 2  
9     F:     .float -12.5  
10    D:    .double -12.5  
11  
12    # int v1[5]={1,2,3,4,5}  
13    v1:    .word 1, 2, 3, 4, 5  
14  
15    #int v2[10]  
16    v2:    .zero 40
```

Main memory segment			
Data	Text	Stack	
Address	Binary	Value	
0x0020001C - 0x0020001F	00 00 00 00		
0x00200020 - 0x00200023	00 00 00 01	v1 1	
0x00200024 - 0x00200027	00 00 00 02	2	
0x00200028 - 0x0020002B	00 00 00 03	3	
0x0020002C - 0x0020002F	00 00 00 04	4	
0x00200030 - 0x00200033	00 00 00 05	5	
0x00200034 - 0x00200037	00 00 00 00	v2 0	
0x00200038 - 0x0020003B	00 00 00 00		
0x0020003C - 0x0020003F	00 00 00 00		
0x00200040 - 0x00200043	00 00 00 00		
0x00200044 - 0x00200047	00 00 00 00		
0x00200048 - 0x0020004B	00 00 00 00		

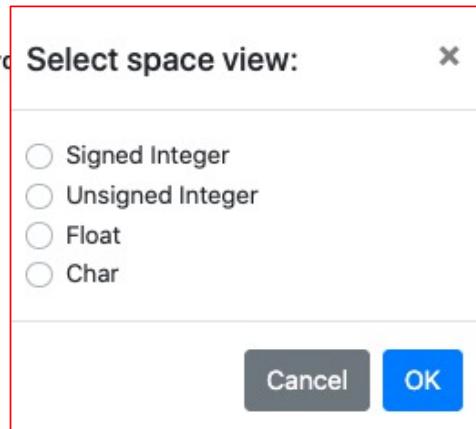


# Visualización de datos en memoria

## 1 Assembly:

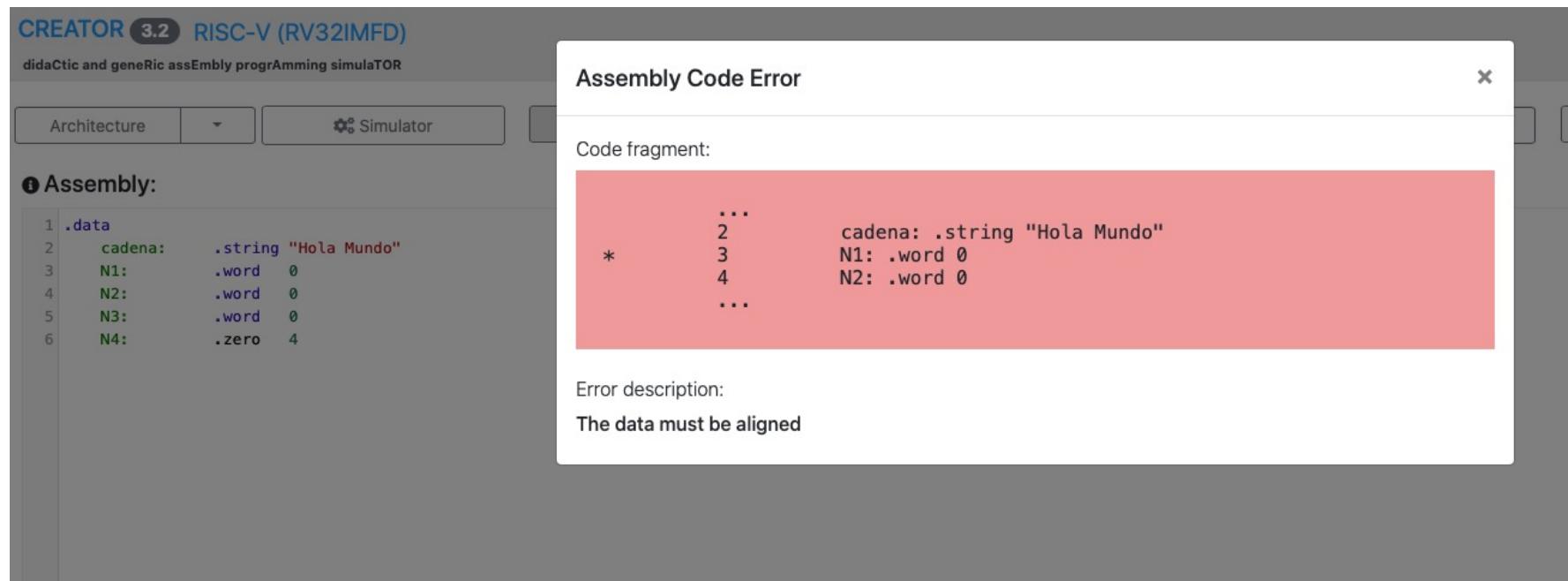
```
1 .data
2
3     cadena: .string "Hola mundo"
4     A:     .byte 1
5     .align 2
6     N:     .word 64
7     C:     .byte 'a'
8     .align 2
9     F:     .float -12.5
10    D:     .double -12.5
11
12    # int v1[5]={1,2,3,4,5}
13    v1:     .word 1, 2, 3, 4, 5
14
15    #int v2[10]
16    v2:     .zero
```

Main memory segment			
Data	Text	Stack	
Address	Binary	Value	
0x0020001C - 0x0020001F	00 00 00 00		v1
0x00200020 - 0x00200023	00 00 00 01	1	⊕
0x00200024 - 0x00200027	00 00 00 02	2	
0x00200028 - 0x0020002B	00 00 00 03	3	
0x0020002C - 0x0020002F	00 00 00 04	4	
0x00200030 - 0x00200033	00 00 00 05	5	⊕
0x00200034 - 0x00200037	00 00 00 00		⊕
0x00200038 - 0x0020003B	00 00 00 00		
0x0020003C - 0x0020003F	00 00 00 00		
0x00200040 - 0x00200043	00 00 00 00		
0x00200044 - 0x00200047	00 00 00 00		
0x00200048 - 0x0020004B	00 00 00 00		



# Detección de datos no alineados

ejemplo



# Segmento de datos corregido

ejemplo

The screenshot shows the CREATOR 3.2 RISC-V (RV32IMFD) interface. The title bar reads "CREATOR 3.2 RISC-V (RV32IMFD)" and "didaCtic and geneRic assEmbyl progrAmming simulaTOR". The menu bar includes "Architecture", "Simulator", "Compile/Linked" (which is highlighted), "File", and "Library". A green notification box in the top right corner says "Compilation completed successfully". The assembly code editor contains the following code:

```
1 .data
2     cadena:    .string "Hola Mundo"
3     .align 2 ←
4     N1:        .word  0
5     N2:        .word  0
6     N3:        .word  0
7     N4:        .zero   4
```

A red arrow points to the ".align 2" instruction at line 3.

# Ejemplo. Ejecutar el siguiente programa

ejemplo

## ● Assembly:

```
1 .data
2     N1: .word  0
3     N2: .word  0
4     N3: .word  0
5     N4: .zero  4
6
7 .text
8     main:
9         li t0, 1
10        la t1, N1
11        sw t0, @t1)
12
13        li t0, 2
14        la t1, N2
15        sw t0, @t1)
16
17        li t0, -3
18        la t1, N3
19        sw t0, @t1)
20
21        li t0, 4
22        la t1, N4
23        sw t0, @t1)
```



# Ejemplo: antes de la ejecución

Architecture ▾ # Assembly ⏪ Reset ⏴ Inst. ▶ Run ⏹ Stop Examples Calculator Configuration Info

Break	Address	Label	User Instruction	Loaded Instructions
0x0		main	li t0 1	addi t0 x0 1
0x4			la t1 N1	auipc t1 0x1ff
0x8				addi t1 t1 0xff8
0xc			sw t0 0 (t1)	sw t0 0 (t1)
0x10			li t0 2	addi t0 x0 2
0x14			la t1 N2	auipc t1 0x1ff
0x18				addi t1 t1 0xfc
0x1c			sw t0 0 (t1)	sw t0 0 (t1)
0x20			li t0 -3	lui t0 0
0x24				lui t0 0xffff
0x28				addi t0 t0 0ffd
0x2c			la t1 N3	auipc t1 0x1ff
0x30				addi t1 t1 0xfd8

INT Registers FP Registers Memory Stats Energy (CLK Cycles)

Main memory segment

Address	Binary	Value
0x00200000 - 0x00200003	N1 00 00 00 00	0
0x00200004 - 0x00200007	N2 00 00 00 00	0
0x00200008 - 0x0020000B	N3 00 00 00 00	0
0x0020000C - 0x0020000F	N4 00 00 00 00	0

# Ejemplo: después de la ejecución

Architecture ▾ # Assembly ⏪ Reset ► Inst. ▶ Run ■ Stop Examples Calculator Configuration Info

Break	Address	Label	User Instruction	Loaded Instructions
0x0		main	li t0 1	addi t0 x0 1
0x4			la t1 N1	auipc t1 0x1ff
0x8				addi t1 t1 0xff8
0xc			sw t0 0 (t1)	sw t0 0 (t1)
0x10			li t0 2	addi t0 x0 2
0x14			la t1 N2	auipc t1 0x1ff
0x18				addi t1 t1 0xfc
0x1c			sw t0 0 (t1)	sw t0 0 (t1)
0x20			li t0 -3	lui t0 0
0x24				lui t0 0xffff
0x28				addi t0 t0 0ffd
0x2c			la t1 N3	auipc t1 0x1ff
0x30				addi t1 t1 0xfd8

INT Registers FP Registers Memory Stats Energy (CLK Cycles)

Main memory segment

Address	Binary	Value
0x00200000 - 0x00200003	N1 00 00 00 01	1
0x00200004 - 0x00200007	N2 00 00 00 02	2
0x00200008 - 0x0020000B	N3 FF FF FF FD	4294967293
0x0020000C - 0x0020000F	N4 00 00 00 04	

# Ejemplo: después de la ejecución

Architecture ▾ # Assembly ⏪ Reset ► Inst. ▶ Run ■ Stop Examples Calculator Configuration Info

Break	Address	Label	User Instruction	Loaded Instructions
0x0		main	li t0 1	addi t0 x0 1
0x4			la t1 N1	auipc t1 0x1ff
0x8				addi t1 t1 0xff8
0xc			sw t0 0 (t1)	sw t0 0 (t1)
0x10			li t0 2	addi t0 x0 2
0x14			la t1 N2	auipc t1 0x1ff
0x18				addi t1 t1 0xfc
0x1c			sw t0 0 (t1)	sw t0 0 (t1)
0x20			li t0 -3	lui t0 0
0x24				lui t0 0xffff
0x28				addi t0 t0 0ffd
0x2c			la t1 N3	auipc t1 0x1ff
0x30				addi t1 t1 0xfd8

INT Registers FP Registers Memory Stats Energy (CLK Cycles)

Main memory segment

Address	Binary	Value
0x00200000 - 0x00200003	N1 00 00 00 01	1
0x00200004 - 0x00200007	N2 00 00 00 02	2
0x00200008 - 0x0020000B	N3 FF FF FF FD	4294967293
0x0020000C - 0x0020000F	N4 00 00 00 04	

# Ejemplo: después de la ejecución

Screenshot of a debugger interface showing assembly code, registers, memory, and a floating-point status window.

**Assembly View:**

Break	Address	Label	User Instruction	Loaded Instructions
0x0		main	li t0 1	addi t0 x0 1
0x4			la t1 N1	auipc t1 0x1ff
0x8				addi t1 t1 0xff8
0xc			sw t0 0 (t1)	sw t0 0 (t1)
0x10			li t0 2	addi t0 x0 2
0x14			la t1 N2	auipc t1 0x1ff
0x18				addi t1 t1 0xfc
0x1c			sw t0 0 (t1)	sw t0 0 (t1)
0x20			li t0 -3	lui t0 0
0x24				lui t0 0xFFFF
0x28				addi t0 t0 0ffd
0x2c			la t1 N3	auipc t1 0x1ff
0x30				addi t1 t1 0xfd8
0x34			sw t0 0 (t1)	sw t0 0 (t1)

**Registers View:**

- INT Registers
- FP Registers
- Memory** (selected)
- Stats
- Energy (CLK Cycles)

**Main memory segment:**

Address	Binary	Value
0x00200000 - 0x00200003	N1 00 00 00 01	1
0x00200004 - 0x00200007	N2 00 00 00 02	2
0x00200008 - 0x0020000B	N3 FF FF FF FD	-3
0x0020000C - 0x0020000F	N4 00 00 00 04	4

**Floating-point Status:**

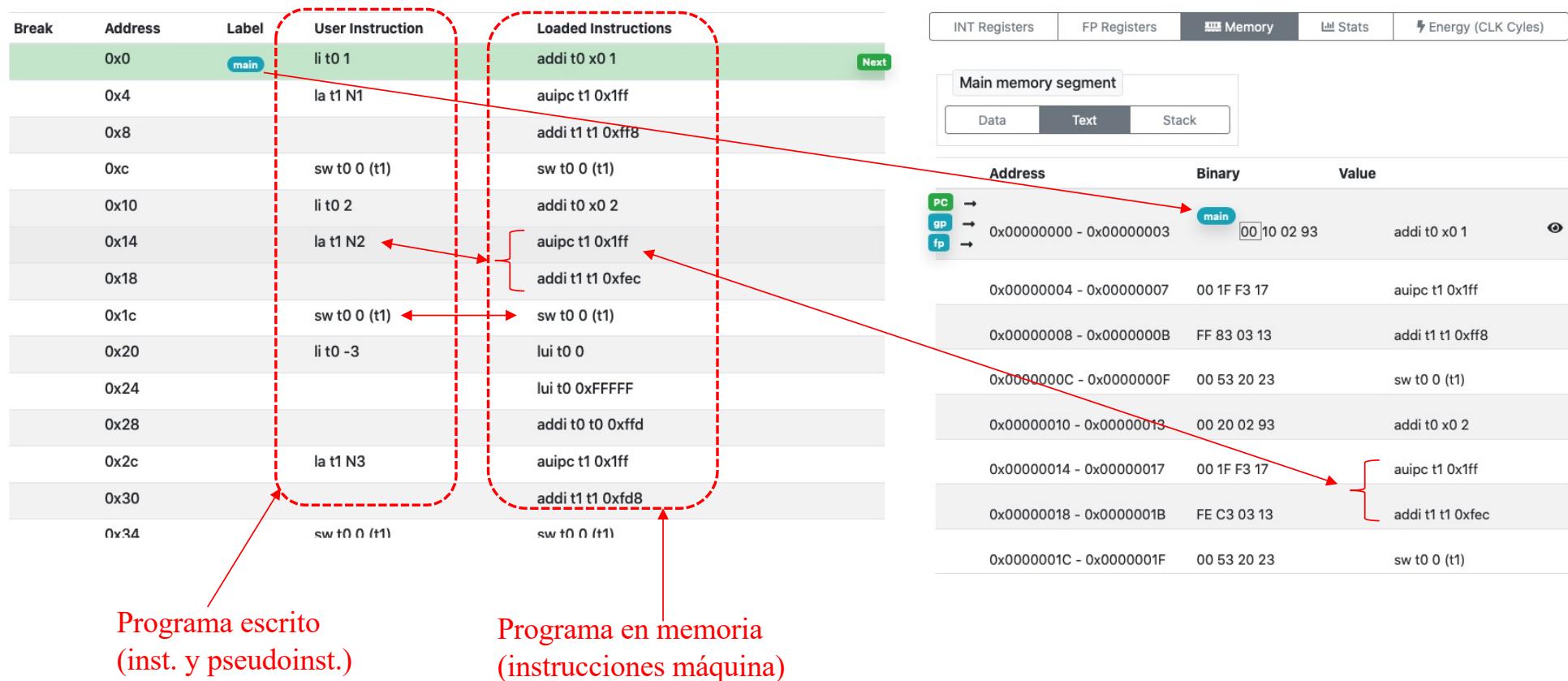
Select space view:  Signed Integer  Unsigned Integer  Float  Char

Cancel OK



# Visualización del segmento de texto Instrucciones y pseudoinstrucciones

**ejemplo**



# Visualización del segmento de texto

## Flujo de ejecución

ejemplo

Break	Address	Label	User Instruction	Loaded Instructions
0x0		main	li t0 1	addi t0 x0 1
0x4			la t1 N1	auipc t1 0x1ff
0x8				addi t1 t1 0xff8
0xc			sw t0 0 (t1)	sw t0 0 (t1)
0x10			li t0 2	addi t0 x0 2
0x14			la t1 N2	auipc t1 0x1ff
0x18				addi t1 t1 0xfc
0x1c			sw t0 0 (t1)	sw t0 0 (t1)
0x20			li t0 -3	lui t0 0
0x24				lui t0 0xFFFF
0x28				addi t0 t0 0xfd
0x2c			la t1 N3	auipc t1 0x1ff
0x30				addi t1 t1 0xfd8
0x34			sw t0 0 (t1)	sw t0 0 (t1)

INT Registers	FP Registers	Memory	Stats	Energy (CLK Cycles)
Main memory segment				
Data	Text	Stack		
Address                      Binary                      Value				
0x00000008 - 0x0000000B	FF 83 03 13	addi t1 t1 0xff8		
0x0000000C - 0x0000000F	00 53 20 23	sw t0 0 (t1)		
0x00000010 - 0x00000013	00 20 02 93	addi t0 x0 2		
0x00000014 - 0x00000017	00 1F F3 17	auipc t1 0x1ff		
PC → 0x00000018 - 0x0000001B	FE C3 03 13	addi t1 t1 0xfc		
0x0000001C - 0x0000001F	00 53 20 23	sw t0 0 (t1)		
0x00000020 - 0x00000023	00 00 02 B7	lui t0 0		
0x00000024 - 0x00000027	FF FF F2 B7	lui t0 0xFFFF		
0x00000028 - 0x0000002B	FF D2 82 93	addi t0 t0 0xfd		



# Visualización del segmento de texto

## Varias funciones

ejemplo

CREATOR 3.2 RISC-V (RV32IMFD)  
didactic and generic assembly programming simulator

Architecture ▾ Simulator ➔ Compile/Linked [ ]

➊ Assembly:

```
1 .text
2     f1:           li  a0, 1
3                 jr  ra
4
5     f2:           li  a0, 2
6                 jr  ra
7
8     f3:           li  a0, 3
9                 jr  ra
10
11
12    main:
13        jal   ra, f1
14        jal   ra, f2
15        jal   ra, f3
```



# Visualización del segmento de texto

## Varias funciones

Architecture # Assembly ⏪ Reset ► Inst. ▶ Run ■ Stop Examples Calculator Configuration Info

Break	Address	Label	User Instruction	Loaded Instructions	Next
0x0		f1	li a0 1	addi a0 x0 1	
0x4			jr ra	jalr x0 0 (ra)	
0x8		f2	li a0 2	addi a0 x0 2	
0xc			jr ra	jalr x0 0 (ra)	
0x10		f3	li a0 3	addi a0 x0 3	
0x14			jr ra	jalr x0 0 (ra)	
0x18		main	jal ra f1	jal ra 0x0	Current
0x1c			jal ra f2	jal ra 0x8	
0x20			jal ra f3	jal ra 0x10	

INT Registers	FP Registers	Memory	Stats	Energy (CLK Cycles)
Main memory segment				
Data	Text	Stack		
Address	Binary	Value		
PC → 0x00000000 - 0x00000003	00 10 05 13	f1 addi a0 x0 1		
0x00000004 - 0x00000007	00 00 80 67	jalr x0 0 (ra)		
0x00000008 - 0x0000000B	00 20 05 13	f2 addi a0 x0 2		
0x0000000C - 0x0000000F	00 00 80 67	jalr x0 0 (ra)		
0x00000010 - 0x00000013	00 30 05 13	f3 addi a0 x0 3		
0x00000014 - 0x00000017	00 00 80 67	jalr x0 0 (ra)		
0x00000018 - 0x0000001B	00 00 00 EF	main jal ra 0x0		
0x0000001C - 0x0000001F	00 00 80 EF	jal ra 0x8		



# Llamadas al sistema

ejemplo

CREATOR 3.2 RISC-V (RV32IMFD)

didaCtic and geneRic assEmbly programing simulaTOR

Architecture ▾ Simulator ➔ Compile/Linked File ▾

Assembly:

```
4
5 .data
6     str_text: .string "Insert a number: "
7     str_result: .string "Result = "
8
9
10
11 .text
12 main:
13     # print "Insert a number: "
14     la a0 str_text
15     li a7 4
16     ecall
17
18     # read int
19     li a7 5
20     ecall
21
22     mv t0, a0
23
24     # print "Insert a number: "
25     la a0 str_text
26     li a7 4
27     ecall
28
29     # read int
30     li a7 5
31     ecall
32     mv t1, a0
33
34     # print "Result = "
35     la a0 str_result
36     li a7 4
37     ecall
```



# Llamadas al sistema

Architecture # Assembly Reset Inst. Run Stop Examples Calculator Configuration Info

Break	Address	Label	User Instruction	Loaded Instructions
0x0		main	la a0 str_text	auipc a0 0x1ff
0x4				addi a0 a0 0xffc
0x8			li a7 4	addi a7 x0 4
0xc			ecall	ecall
0x10			li a7 5	addi a7 x0 5
0x14			ecall	ecall
0x18			mv t0 a0	addi t0 a0 0
0x1c			la a0 str_text	auipc a0 0x1ff
0x20				addi a0 a0 0xfe0
0x24			li a7 4	addi a7 x0 4
0x28			ecall	ecall
0x2c			li a7 5	addi a7 x0 5
0x30			ecall	ecall
0x34			mv t1 a0	addi t1 a0 0

INT Registers FP Registers Memory Stats Energy (CLK Cycles)

Register value representation Register name representation

Signed	Unsig.	IEEE 754	Hex.
Name Alias All			
zero   x0 0000000	ra   x1 FFFFFFFF	sp   x2 0FFFFFFC	gp   x3 00000000
tp   x4 0000000	t0   x5 0000000	t1   x6 0000000	t2   x7 0000000
fp   s0   x8 0000000	s1   x9 0000000	a0   x10 00200000	a1   x11 00000000
a2   x12 0000000	a3   x13 0000000	a4   x14 0000000	a5   x15 0000000
a6   x16 0000000	a7   x17 00000005	s2   x18 0000000	s3   x19 0000000
s4   x20 0000000	s5   x21 0000000	s6   x22 0000000	s7   x23 0000000
s8   x24 0000000	s9   x25 0000000	s10   x26 0000000	s11   x27 0000000
t3   x28 0000000	t4   x29 0000000	t5   x30 0000000	t6   x31 0000000

Insert a number:  Clear Enter



# Ejemplo: ejecutar el siguiente programa

ejemplo

## Assembly:

```
1 #
2 # Creator (https://creatorsim.github.io/creator/)
3 #
4
5 .data
6
7     string1:    .string "Hola Mundo"
8     string2:    .zero 32
9
10 .text
11     main:
12         la t0, string1
13         la t1, string2
14
15     loop:    lbu   t2, 0(t0)
16             beq   t2, zero, end
17             sb    t2, 0(t1)
18             addi  t0, t0, 1
19             addi  t1, t1, 1
20             j     loop
21     end:
22         li a7, 10
23         ecall
24
```

Main memory segment		
Data	Text	Stack
0x00200000 - 0x00200003	48 6F 6C 61	H, o, l, a
0x00200004 - 0x00200007	20 4D 75 6E	, M, u, n
0x00200008 - 0x0020000B	64 6F 00 00	d, o, 0
0x0020000C - 0x0020000F	00 00 00 00	
0x00200010 - 0x00200013	00 00 00 00	
0x00200014 - 0x00200017	00 00 00 00	
0x00200018 - 0x0020001B	00 00 00 00	
0x0020001C - 0x0020001F	00 00 00 00	

# Ejecución del programa

Architecture	# Assembly	Reset	Inst.	Run	Stop	Examples	Calculator	Configuration	Info
<b>Break</b>	<b>Address</b>	<b>Label</b>	<b>User Instruction</b>	<b>Loaded Instructions</b>					
0x0		main	la t0 string1	auipc t0 0x1ff					
0x4				addi t0 t0 0xfffc					
0x8			la t1 string2	auipc t1 0x1ff					
0xc				addi t1 t1 0xffff					
0x10		loop	lbu t2 0 (t0)	lbu t2 0 (t0)	Current				
0x14			beq t2 zero end	beq t2 zero 4	Next				
0x18			sb t2 0 (t1)	sb t2 0 (t1)					
0x1c			addi t0 t0 1	addi t0 t0 1					
0x20			addi t1 t1 1	addi t1 t1 1					
0x24			j loop	jal x0 0x10					
0x28		end	li a7 10	addi a7 x0 10					
0x2c			ecall	ecall					

INT Registers	FP Registers	Memory	Stats	Energy (CLK Cycles)
<b>Main memory segment</b>				
Data	Text	Stack		
Address	Binary	Value		
0x00000004 - 0x00000007	FF C2 02 93	auipc t0 0x1ff		
0x00000008 - 0x0000000B	00 1F F3 17	auipc t1 0x1ff		
0x0000000C - 0x0000000F	FF F3 03 13	addi t1 t1 0xffff		
0x00000010 - 0x00000013	loop 00 02 C3 83	lbu t2 0 (t0)	①	
PC → 0x00000014 - 0x00000017	00 03 82 63	beq t2 zero 4		
0x00000018 - 0x0000001B	00 73 00 23	sb t2 0 (t1)		
0x0000001C - 0x0000001F	00 12 82 93	addi t0 t0 1		
0x00000020 - 0x00000023	00 13 03 13	addi t1 t1 1		
0x00000024 - 0x00000027	00 01 00 6F	jal x0 0x10		
	end			



# Ejecución del programa. Bucles

Architecture ▾ # Assembly ⏹ Reset ⏷ Inst. ▶ Run ⏻ Stop Examples Calculator Configuration Info

Break	Address	Label	User Instruction	Loaded Instructions
0x0		main	la t0 string1	auipc t0 0x1ff
0x4				addi t0 t0 0xffff
0x8		la t1 string2		auipc t1 0x1ff
0xc				addi t1 t1 0xffff
0x10		loop	lbu t2 0 (t0)	lbu t2 0 (t0) <span style="float: right;">Next</span>
0x14			beq t2 zero end	beq t2 zero 4
0x18			sb t2 0 (t1)	sb t2 0 (t1)
0x1c			addi t0 t0 1	addi t0 t0 1
0x20			addi t1 t1 1	addi t1 t1 1
0x24			j loop	jal x0 0x10 <span style="float: right;">Current</span>
0x28		end	li a7 10	addi a7 x0 10
0x2c			ecall	ecall

INT Registers FP Registers Memory Stats Energy (CLK Cycles)

Main memory segment

Data	Text	Stack
0x00000004 - 0x00000007 FF C2 82 83		
0x00000008 - 0x0000000B 00 1F F3 17		auipc t1 0x1ff
0x0000000C - 0x0000000F FF F3 03 13		addi t1 t1 0xffff
0x00000010 - 0x00000013 00 02 C3 83	loop	lbu t2 0 (t0) <span style="float: right;">②</span>
0x00000014 - 0x00000017 00 03 82 63		beq t2 zero 4
0x00000018 - 0x0000001B 00 73 00 23		sb t2 0 (t1)
0x0000001C - 0x0000001F 00 12 82 93		addi t0 t0 1
0x00000020 - 0x00000023 00 13 03 13		addi t1 t1 1
0x00000024 - 0x00000027 00 01 00 6F		jal x0 0x10
	end	



# Ejemplo de llamadas a funciones anidadas

ejemplo

- ▶ Comprobar el crecimiento de la pila

Main memory segment			
Data	Text	Stack	
0x0FFFFFF0 - 0x0FFFFFF3	00 00 00 00	undefined	
sp → 0x0FFFFFF4 - 0x0FFFFFF7	00 00 00 00	undefined	
0x0FFFFFF8 - 0x0FFFFFFB	FF FF FF FF	4294967295	
0x0FFFFFFC - 0x0FFFFFFF	00 00 00 00	00	



# Ejemplo de llamadas a funciones anidadas

ejemplo

- ▶ Comprobar el crecimiento de la pila

Main memory segment		INT Registers	FP Registers	Memory	Stats	Energy (CLK Cyles)
		Data	Text	Stack		
Address	Binary	Value				
sp → 0xFFFFFFF0 - 0xFFFFFFF3	00 00 00 28	40				
0xFFFFFFF0	0x000...	f3	F7	00 00 00 94	148	
0xFFFFFFF1		f2	FB	FF FF FF FF	4294967295	
0xFFFFFFF2		f1	FF	00 00 00 00	00	
		main				
0xFFFF...						

Stack memory areas: ⓘ

Free stack

Callee: f3 Caller: f2 ... 2 System stack

# Llamadas a funciones

- ▶ Convenio simplificado
  - ▶ La pila no necesita estar alineada a 8 bytes
- ▶ Alerta si se incumple el convenio de paso de parámetros y uso de pila

Integer Registers	
Register Name	Usage
zero	Constant 0
ra	Return address (routines/functions)
sp	Stack pointer
gp	Global pointer
tp	Thread pointer
t0..t6	Temporary (NOT preserved across calls)
s0..s11	Saved temporary (preserved across calls)
a0, a1	Arguments for functions / return value
a2..a7	Arguments for functions

Floating-point registers	
Register Name	Usage
ft0..ft11	Temporary (NOT preserved across calls)
fs0..fs11	Saved temporary (preserved across calls)
fa0, fa1	Arguments for functions / return value
fa2..fa7	Arguments for functions

# Detección de errores en el convenio de paso de parámetros

- ▶ Corregir los fallos que aparecen en el ejemplo por un uso incorrecto del convenio de paso de parámetros y uso de pila
- ▶ Modelo simplificado que se utiliza actualmente
  - ▶ La pila no tiene porque estar alineada a 8

Integer Registers	
Register Name	Usage
zero	Constant 0
ra	Return address (routines/functions)
sp	Stack pointer
gp	Global pointer
tp	Thread pointer
t0..t6	Temporary (NOT preserved across calls)
s0..s11	Saved temporary (preserved across calls)
a0, a1	Arguments for functions / return value
a2..a7	Arguments for functions
Floating-point registers	
ft0..ft11	Temporary (NOT preserved across calls)
fs0..fs11	Saved temporary (preserved across calls)
fa0, fa1	Arguments for functions / return value
fa2..fa7	Arguments for functions

**ejemplo**

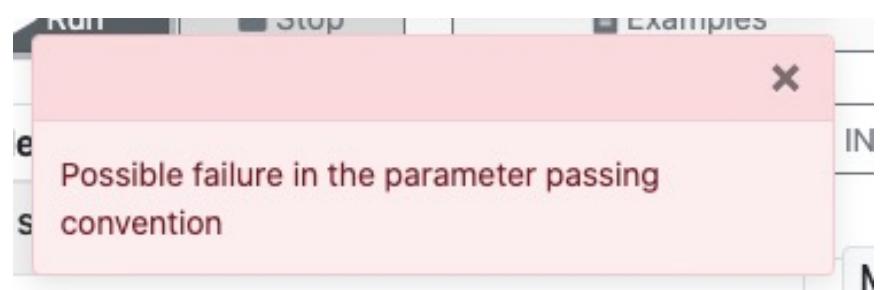
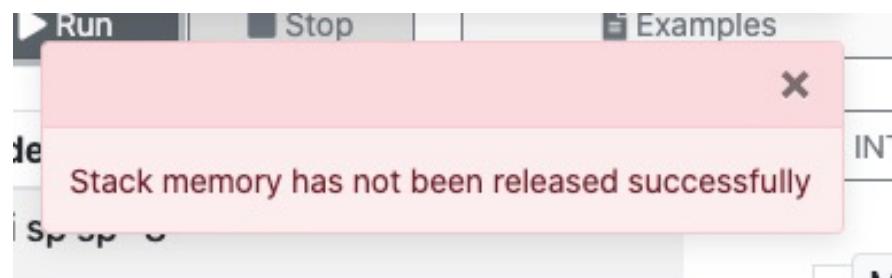
```
.data
.text
max:    addi    sp, sp -8
        sw      s0, 0(sp)
        mv      s0, a0
        mv      s1, a1
        bge   s0, s1, bigger
        mv      a0, s1
        jr      ra
bigger: mv      a0, s0
        jr      ra

main:   li      a0, 8
        li      a1, 7
        jal     ra, max
        li      a7, 1
        ecall
        li a7, 10
        ecall
```



# Detección de errores en el convenio de paso de parámetros

## ▶ Fallos detectados:



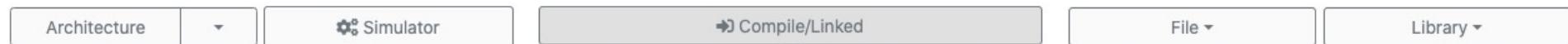
ejemplo

```
.data
.max:      addi    sp, sp -8
           sw     s0, 0(sp)
           mv     s0, a0
           mv     s1, a1
           bge   s0, s1, bigger
           mv     a0, s1
           jr     ra
.bigger:   mv     a0, s0
           jr     ra

.text
main:      li      a0, 8
           li      a1, 7
           jal    ra, max
           li      a7, 1
           ecall
           li      a7, 10
           ecall
```

# Creación de librerías

ejemplo



## ➊ Assembly:

```
1 .globl max, min
2
3 .text
4
5
6
7 max:      bge a0, a1, bigger
8         mv  a0, a1
9     bigger: jr  ra
10
11
12 min:      ble a0, a1, minor
13         mv  a0, a1|
14     minor: jr  ra
15
```

# Creación de librerías

The screenshot shows the ARCOS software interface. At the top, there are several tabs: 'Architecture' (with a dropdown arrow), 'Simulator' (with a CPU icon), 'Compile/Linked' (highlighted in grey), 'File' (with a dropdown arrow), and 'Library' (highlighted in dark grey). Below these tabs, the main area is titled 'Assembly' with a gear icon. A red dashed box highlights the assembly code area. The code itself is as follows:

```
1 .globl max, min
2
3 .text
4
5
6
7 max:      bge a0, al, bigger
8         mv  a0, al
9         bigger: jr  ra
10
11
12 min:      ble a0, al, minor
13         mv  a0, al
14         minor: jr  ra
15
```

To the right of the assembly code, another red dashed box highlights the 'Library' menu. The 'Library' menu contains three items: '+ Create' (with a plus sign icon), 'Load Library' (with a downward arrow icon), and 'Remove' (with a trash bin icon).



# Uso de librerías

ejemplo

The screenshot shows the ARCOS simulator interface. At the top, there are tabs for 'Architecture' (selected), 'Simulator', 'Compile/Linked' (disabled), 'File', and 'Library'. A red dashed box highlights the 'Library' dropdown menu, which includes options: '+ Create', 'Load Library' (with an upward arrow icon), and 'Remove' (with a trash bin icon).

**Assembly:**

```
1 #  
2 # Creator (https://creatorsim.github.io/creator/)  
3 #  
4  
5 .text  
6  
7     main:    li  a0, 5  
8         li  a1, 10  
9         jal ra, max  
10        li  a7, 1  
11        ecall  
12  
13        li  a0, '\n'  
14        li  a7, 11  
15        ecall  
16  
17        li  a0, 5  
18        li  a1, 10  
19        jal ra, min  
20        li  a7, 1  
21        ecall  
22  
23        li  a0, '\n'  
24        li  a7, 11  
25        ecall
```

Two red arrows point from the text 'Llamadas' (Calls) to the 'jal ra, max' and 'jal ra, min' assembly instructions.

Llamadas



# Librería cargada

The screenshot shows the ARCOS tool interface with the following components:

- Top navigation bar: Architecture (dropdown), Simulator, Compile/Linked, File (dropdown), Library (dropdown), Configuration, Info.
- Assembly view: A text area titled "Assembly" containing assembly code. The code defines a "main" function that performs two operations: calculating the maximum of two values (using a "max" library function) and calculating the minimum of two values (using a "min" library function). Both operations involve loading immediate values into registers a0 and a1, calling the respective library functions, and then printing the result to the console.

```
1 #
2 # Creator (https://creatorsim.github.io/creator/)
3 #
4 .
5 .text
6
7     main:    li    a0, 5
8             li    a1, 10
9             jal   ra, max
10            li    a7, 1
11            ecall
12
13            li    a0, '\n'
14            li    a7, 11
15            ecall
16
17            li    a0, 5
18            li    a1, 10
19            jal   ra, min
20            li    a7, 1
21            ecall
22
23            li    a0, '\n'
24            li    a7, 11
25            ecall
26
27
28
29
```
- Library tags: A panel on the right labeled "Library tags:" containing two entries: "max" and "min". This panel is highlighted with a red dotted rectangle.

# Uso de librerías

Architecture ▾ # Assembly ⏹ Reset ⏷ Inst. ⏸ Run ⏹ Stop Examples Calculator Configuration Info

Break	Address	Label	User Instruction	Loaded Instructions
0x0		max	<<Hidden>>	<<Hidden>>
0xc		min	<<Hidden>>	<<Hidden>>
0x18		main	li a0 5	addi a0 x0 5 <span style="float: right;">Next</span>
0x1c			li a1 10	addi a1 x0 10
0x20			jal ra max	jal ra 0x0
0x24			li a7 1	addi a7 x0 1
0x28			ecall	ecall
0x2c			li a0 10	addi a0 x0 10
0x30			li a7 11	addi a7 x0 11
0x34			ecall	ecall

INT Registers FP Registers Memory Stats Energy (CLK Cycles)

Main memory segment

Data Text Stack

Address	Binary	Value
gp → 0x00000000 - 0x00000003	max 01 00 B5 50	0
0x00000004 - 0x00000007	00 05 85 13	
0x00000008 - 0x0000000B	00 00 80 67	***** 0
0x0000000C - 0x0000000F	min 01 00 A5 D0	0

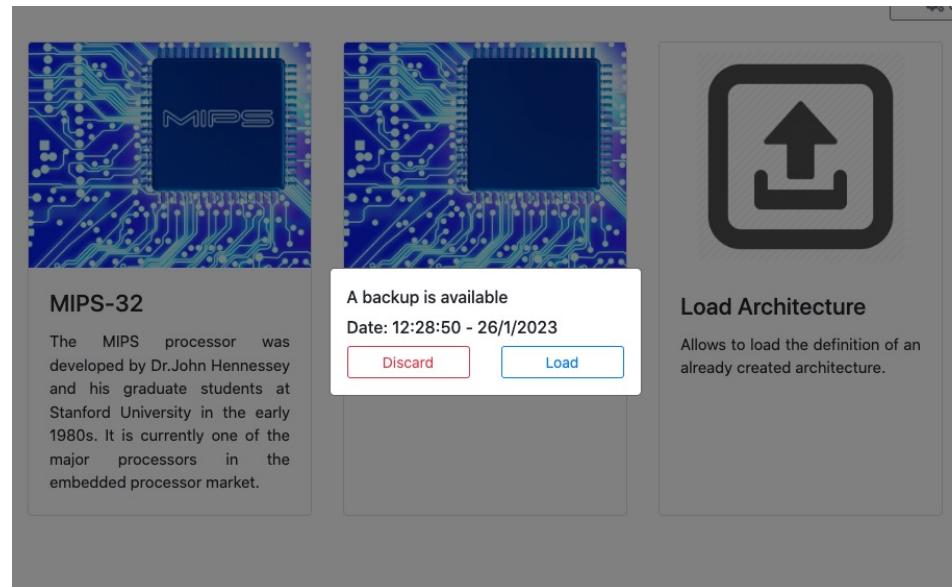


## Errores en tiempo de ejecución

- ▶ Programa sin función main
- ▶ Puntero de pila (sp) apunta al segmento de datos o de texto
- ▶ Escritura en el segmento de texto
- ▶ Acceso a una posición de memoria no alineada

# Caché del navegador para recuperación de errores

- ▶ El programa que se está editando se guarda en la caché del navegador cada vez que se compila
- ▶ Si el navegador falla se puede recuperar el programa al volverlo a cargar



# Contenido (RISC-V)

- ▶ Juego de instrucciones soportado
- ▶ Visión del estudiante:
  - ▶ Características del entorno
  - ▶ Edición y compilación de programas
  - ▶ Ejecución y depuración de programas
  - ▶ Bibliotecas de funciones
  - ▶ Facilidades para entender el empleo de funciones y uso de pila
- ▶ Visión del profesor:
  - ▶ Soporte a la corrección de prácticas
  - ▶ Soporte a la creación de material didáctico
  - ▶ Capacidades para extender el juego de instrucciones y crear nuevas arquitecturas

# Soporte a la corrección de prácticas

- ▶ Ejecución en línea de comandos
- ▶ Prerrequisitos:
  - ▶ Linux, node.js y npm
- ▶ Pasos:
  - ▶ Descargar el repositorio:
    - ▶ `git clone https://github.com/creatorsim/creator.git`
  - ▶ `cd creator`
  - ▶ Instalar los paquetes:
    - ▶ `npm install terser jshint colors yargs readline-sync`



# Compilación y ejecución de un programa

▶ `./creator.sh -h`

```
CREATOR
-----
version: 3.2
website: https://creatorsim.github.io/

Usage: creator.sh -a <file name> -s <file name>
Usage: creator.sh -h

Options:
  --version      Show version number          [boolean]
  -a, --architecture Architecture file        [string] [required] [default: ""]
  -s, --assembly   Assembly file              [string] [required] [default: ""]
  -d, --directory  Assemblies directory       [string] [default: ""]
  -l, --library    Assembly library file     [string] [default: ""]
  -r, --result     Result file to compare with [string] [default: ""]
  --describe      Help on element            [string] [default: ""]
  --maxins        Maximum number of instructions to be executed
                  [string] [default: "1000000"]
  -o, --output     Define output format       [string] [default: "normal"]
  --color          Colored output             [boolean] [default: false]
  -h, --help        Show help                 [boolean]

Examples:
  ./creator.sh To show examples.
```



# Ejecución de un programa

▶ `./creator.sh -a architecture/RISC_V_RV32IMFD.json -s ./factorial.s`

```
CREATOR
-----
version: 3.2
website: https://creatorsim.github.io/

[./factorial.s]
120
[Architecture] Architecture 'architecture/RISC_V_RV32IMFD.json' loaded successfully.
[Library] Without library
[Compile] Code './factorial.s' compiled successfully.
[Execute] Executed successfully.
[FinalState] cr[PC]:0x18; ir[ra,x1]:0x8; ir[t0,x5]:0x2; ir[t1,x6]:0x5; ir[a0,x10]:0x78; ir[a7,x17]:0xa; keyboard[0x0]:'';
display[0x0]:'120';
```

## Ejecución de un programa y comprobación de resultados

- ▶ Podemos comparar la salida con un resultado de referencia
- ▶ Ejemplo de resultado de referencia para comparar solo la salida:

referencia.txt

```
display[0x0]: '120';
```

- ▶ Ejecución y comparación con salida de referencia:

```
▶ ./creator.sh -a architecture/RISC_V_RV32IMFD.json -s ./factorial.s  
-r referencia.txt
```



## Ejemplo de salida correcta

- ▶ ./creator.sh -a architecture/ RISC\_V\_RV32IMFD.json -s factorial.s -r referencia.txt

```
CREATOR
-----
version: 3.2
website: https://creatorsim.github.io/

[./factorial.s]
120
[Architecture] Architecture 'architecture/RISC_V_RV32IMFD.json' loaded successfully.
[Library] Without library
[Compile] Code './factorial.s' compiled successfully.
[Execute] Executed successfully.
[State] Equals
```

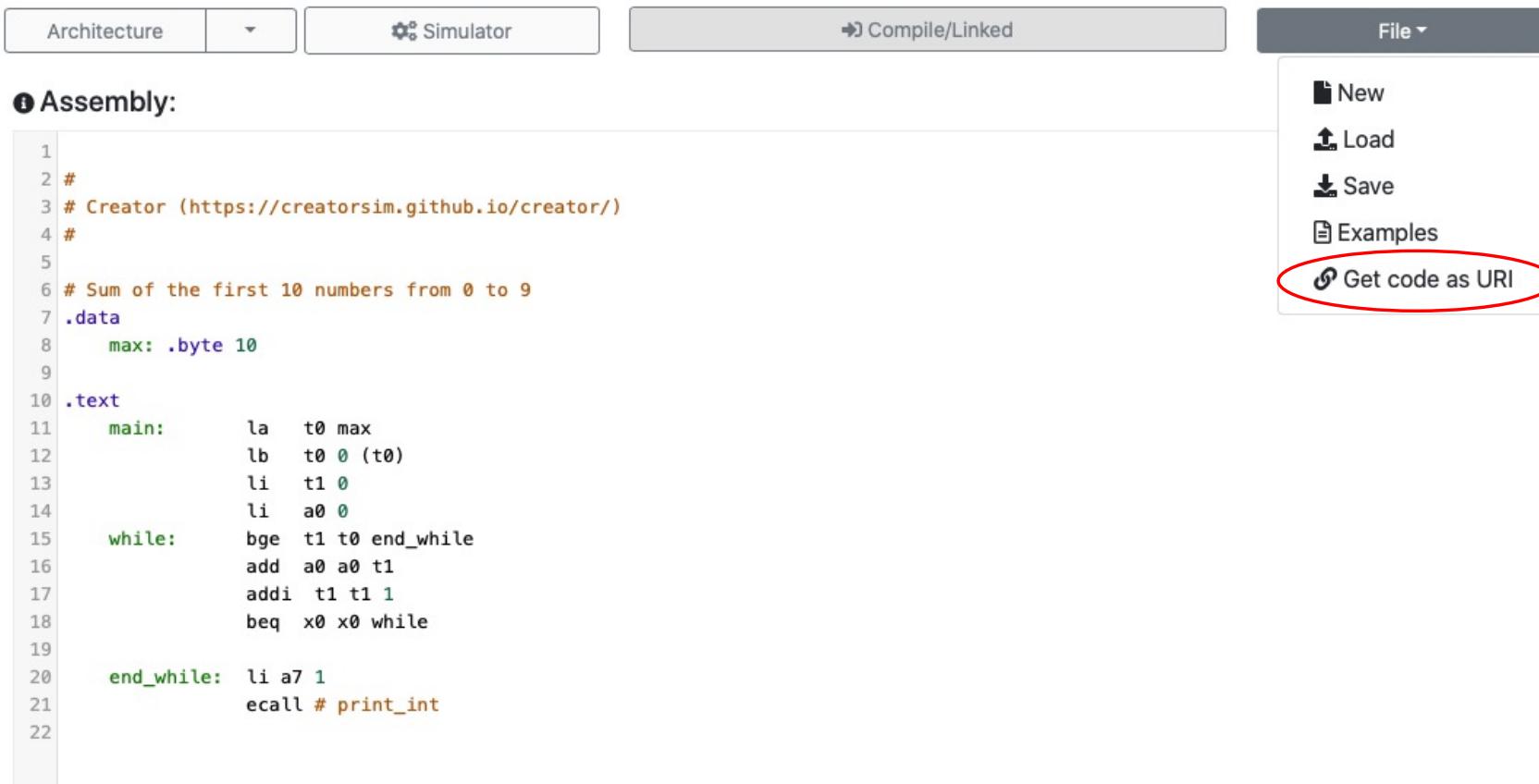
## Ejemplo de salida incorrecta

- ▶ ./creator.sh -a architecture/ RISC\_V\_RV32IMFD.json -s factorial.s -r referencia.txt

```
CREATOR
-----
version: 3.2
website: https://creatorsim.github.io/

[./factorial.s]
808
[Architecture] Architecture 'architecture/RISC_V_RV32IMFD.json' loaded successfully.
[Library] Without library
[Compile] Code './factorial.s' compiled successfully.
[Execute] Executed successfully.
[State] Different: display[0x0]='120' is ='808'.
```

# Ayuda a la creación de materiales docentes



The screenshot shows the ARCOS assembly editor interface. At the top, there are tabs for "Architecture" (selected), "Simulator", "Compile/Linked" (disabled), and "File". The "File" menu is open, showing options: New, Load, Save, Examples, and Get code as URI, with the last option circled in red.

**Assembly:**

```
1
2 #
3 # Creator (https://creatorsim.github.io/creator/)
4 #
5
6 # Sum of the first 10 numbers from 0 to 9
7 .data
8     max: .byte 10
9
10 .text
11     main:    la    t0 max
12         lb    t0 0 (t0)
13         li    t1 0
14         li    a0 0
15     while:   bge   t1 t0 end_while
16         add   a0 a0 t1
17         addi  t1 t1 1
18         beq   x0 x0 while
19
20     end_while: li a7 1
21         ecall # print_int
22
```

# Ayuda a la creación de materiales docentes

The screenshot shows the Creatorsim assembly editor interface. At the top, there are tabs for 'Architecture' (with a dropdown), 'Simulator', 'Compile/Linked' (highlighted in grey), and 'File'. A context menu is open under the 'File' tab, listing 'New', 'Load', 'Save', 'Examples', and 'Get code as URI'. A red arrow points from the 'enlace' button to the 'URI' field in a modal window. Another red arrow points from the 'URI' field back to the 'enlace' button. The assembly code in the editor is:

```
1 #
2 # Creator (https://creatorsim.github.io/creator/)
3 #
4 #
5 # Sum of the first 10 numbers from 0 to 9
6 .data
7     max: .byte 10
8
9 .text
10    main:    la    t0 max
11        lb    t0 0 (t0)
12        li    t1 0
13        li    a0 0
14    while:   bge  t1 t0 end_while
15        add  a0 a0 t1
16        addi t1 t1 1
17        beq  x0 x0 while
18
19    end_while: li a7 1
20        ecall # print_int
21
22
```

The 'URI' field contains the URL: [https://creatorsim.github.io/creator/?architecture=RISC-V%20\(RV32IMFD\)&asm=%0A%23%0A%23%20Creator%20https%3A%2F%2Fcreatorsim.github.io%2Fcreator%2F\)%0A%23%0A%0A%23%20Sum%20of%20the%20first%2010%20numbers%20from%200%20to%209%0A.data%0A%09max](https://creatorsim.github.io/creator/?architecture=RISC-V%20(RV32IMFD)&asm=%0A%23%0A%23%20Creator%20https%3A%2F%2Fcreatorsim.github.io%2Fcreator%2F)%0A%23%0A%0A%23%20Sum%20of%20the%20first%2010%20numbers%20from%200%20to%209%0A.data%0A%09max)

# Capacidades para extender el juego de instrucciones y crear nuevas arquitecturas

Architecture Info	Memory Layout	Register File	Instructions	Pseudoinstructions	Directives
Architecture general information:					
Field	Value	Actions			
Name	RISC-V (RV32IMFD)				
Bits	32	<button>Edit</button>	<button>Reset</button>		
Data Format	Big Endian	<button>Edit</button>	<button>Reset</button>		
Memory Alignment	Enabled	<button>Edit</button>	<button>Reset</button>		
Main Function	main	<button>Edit</button>	<button>Reset</button>		
Passing Convention	Enabled	<button>Edit</button>	<button>Reset</button>		
Sensitive Register Name	Enabled	<button>Edit</button>	<button>Reset</button>		



# Ejemplo de definición de una instrucción (addi)

CREATOR 3.2 RISC-V (RV32IMFD)  
didactic and generic assembly programming simulator

ARCOS uc3m Universidad Carlos III de Madrid  
Computer Science and Engineering Department

# Assembly Simulator Save Configuration Info

Architecture Info Memory Layout Register File Instructions Pseudoinstructions Directives

Instruction set:

+ New instruction ⚡ Reset Instructions

Name	Co	Extended CO	Nwords	Instruction syntax	Properties	Power Consumption	Fields	Definition	Actions
addi	0010011	000	1	addi rd rs1 imm addi,INT-Reg,INT-Reg,inm-signed		1	<button>View Fields</button>	rsz_name);  rd = rs1 + inm;	<button>Edit</button> <button>Delete</button>

# Ejemplo de definición de una instrucción (addi)

Edit addi

Name:  ✓

Type:  ✓ ▾

Number of Words:  ✓

CLK Cycles:  ✓

Number of fields: (Including co and cop)  ✓

Properties:

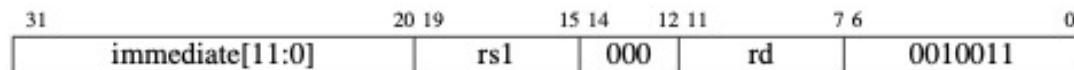
Enter Subroutine  Exit Subroutine

[Principal](#) [Fields](#) [Syntax](#) [Definition](#) [Help](#) > »

Cancel Save



# Ejemplo de definición de una instrucción (addi)



Edit addi ×

	Name:	Type	Break	Start Bit	End Bit	
Field 0	addi	co		6 ✓	0 ✓	
Field 1	inm ✓	inm-sign ✓	<input type="checkbox"/>	31 ✓	20 ✓	
Field 2	rs1 ✓	INT-Reg ✓		19 ✓	15 ✓	
Field 3	rd ✓	INT-Reg ✓		11 ✓	7 ✓	
Field 4	cop ✓	cop ✓		14 ✓	12 ✓	000 ✓

código de operación

[«](#) [<](#) [Principal](#) [Fields](#) [Syntax](#) [Definition](#) [Help](#) [»](#) [»](#)

[Cancel](#) [Save](#)

# Ejemplo de definición de una instrucción (addi)

Edit addi ×

Instruction Syntax Definition:

F0 F3 F2 F1

Detailed Syntax:

addi,INT-Reg,INT-Reg,inm-signed

Instruction Syntax:

addi rd rs1 inm

[\*\*<\*\*](#) [\*\*<\*\*](#) [Principal](#) [Fields](#) [Syntax](#) [Definition](#) [Help](#) [\*\*>\*\*](#) [\*\*>>\*\*](#)

[Cancel](#) [Save](#)

# Ejemplo de definición de una instrucción (addi)

Edit addi ×

---

Assembly Definition:

```
rd = rs1 + inm;
```

✓

---

[«](#) [‹](#) [Principal](#) [Fields](#) [Syntax](#) **Definition** [Help](#) [›](#) [»](#)

---

[Cancel](#) [Save](#)

# Ejemplo de definición de una instrucción (addi)

Edit addi

x

Assembly help:

Example: reg1=reg2+reg3

« < Principal Fields Syntax Definition Help

Cancel Save



# Creación de una nueva pseudoinstrucción

- ▶ Ejemplo:
  - ▶ bltz rs1, offset              if (rs1 < 0)    PC = PC + offset
  - ▶ Se expande a: blt rs1, zero, offset

The screenshot shows the ARCOS architecture configuration interface. On the left, there is a sidebar with a dropdown menu showing 'Architecture' and three options: 'RISC-V (RV32IMFD)', 'MIPS-32', and 'New Architecture'. A red arrow points from the 'RISC-V (RV32IMFD)' option to the main content area. The main content area has tabs at the top: '# Assembly', 'Simulator', 'Save', and 'Configuration'. Below these tabs, there are several other tabs: 'Architecture Info' (which is selected), 'Memory Layout', 'Register File', 'Instructions', 'Pseudoinstructions', and 'Directives'. The 'Architecture general information:' section contains a table with the following data:

Field	Value	Actions
Name	RISC-V (RV32IMFD)	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Bits	32	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Data Format	Big Endian	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Memory Alignment	Enabled	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Main Function	main	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Passing Convention	Enabled	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Sensitive Register Name	Enabled	<input type="button" value="Edit"/> <input type="button" value="Reset"/>



# Creación de una nueva pseudoinstrucción

New Pseudoinstruction X

---

Name:  ✓

Number of Words:  ✓

Number of fields:  ✓

---

Principal Fields Syntax Definition Help > »

---

Cancel Save

# Creación de una nueva pseudoinstrucción

New Pseudoinstruction ×

---

	Name:	Type
Field 0	rs1	✓ INT-Reg ✓ ▾
Field 1	offset	✓ inm-signed ✓ ▾

---

[«](#) [<](#) [Principal](#) Fields [Syntax](#) [Definition](#) [Help](#) [>](#) [»](#)

---

Cancel Save

# Creación de una nueva pseudoinstrucción

## New Pseudoinstruction



Pseudoinstruction Syntax Definition:

bltz F0 F1



Detailed Syntax:

bltz,INT-Reg,inm-signed

Pseudoinstruction Syntax:

bltz rs1 offset

« < Principal Fields Syntax Definition Help > »

Cancel

Save

# Creación de una nueva pseudoinstrucción

Edit blitz rs1 offset ×

---

Pseudoinstruction Definition:

```
blt rs1, zero, offset;
```

Pseudoinstruction Definition

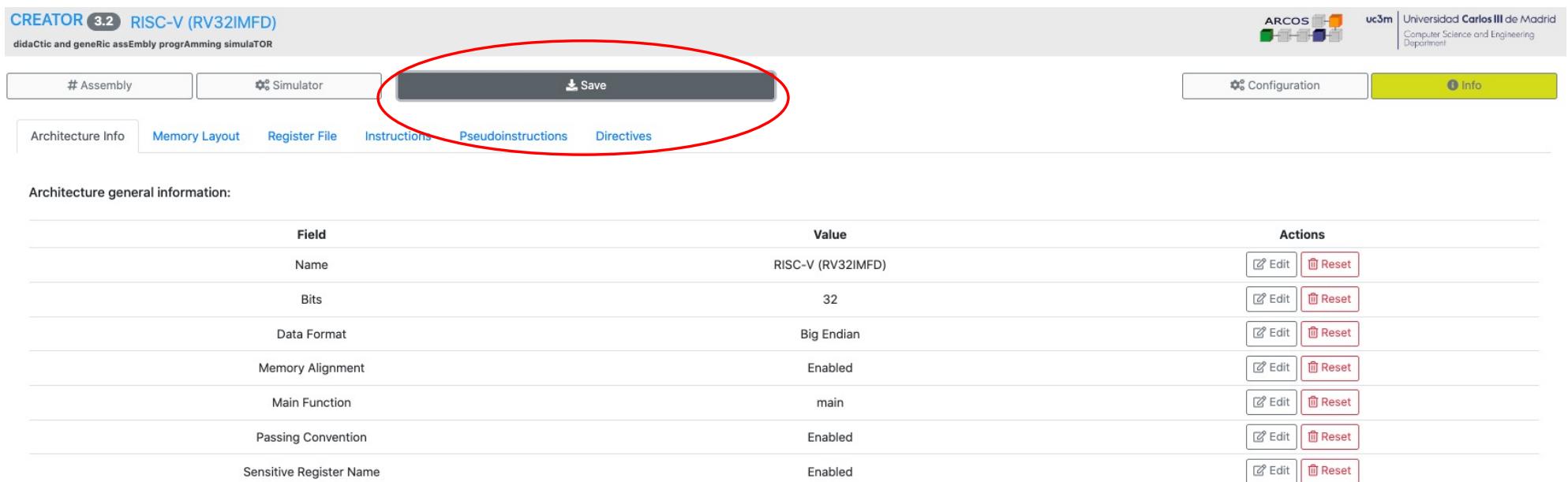
---

[«](#) [‹](#) [Principal](#) [Fields](#) [Syntax](#) [Definition](#) [Help](#) [›](#) [»](#)

---

[Cancel](#) [Save](#)

# Creación de una nueva pseudoinstrucción



The screenshot shows the CREATOR 3.2 RISC-V (RV32IMFD) interface. At the top, there is a header with the title "CREATOR 3.2 RISC-V (RV32IMFD)" and a subtitle "didaCtic and geneRic assEmbly progrAMming simulaTOR". On the right side of the header, there are logos for "ARCOS" and "uc3m Universidad Carlos III de Madrid Computer Science and Engineering Department". Below the header, there is a navigation bar with tabs: "# Assembly", "Simulator", "Save" (which is highlighted with a red oval), "Configuration", and "Info". Underneath the tabs, there is a sub-navigation bar with tabs: "Architecture Info", "Memory Layout", "Register File", "Instructions", "Pseudoinstructions" (which is also highlighted with a red oval), and "Directives". The main content area is titled "Architecture general information:" and contains a table with the following data:

Field	Value	Actions
Name	RISC-V (RV32IMFD)	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Bits	32	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Data Format	Big Endian	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Memory Alignment	Enabled	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Main Function	main	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Passing Convention	Enabled	<input type="button" value="Edit"/> <input type="button" value="Reset"/>
Sensitive Register Name	Enabled	<input type="button" value="Edit"/> <input type="button" value="Reset"/>



# Creación de una nueva instrucción

- ▶ Ejemplo: fmadd.s rd, rs1, rs2, rs3

**fmadd.s** rd, rs1, rs2, rs3

$$f[rd] = f[rs1] \times f[rs2] + f[rs3]$$

*Floating-point Fused Multiply-Add, Single-Precision.* Tipo R4, RV32F y RV64F.

Multiplica los números de punto flotante de precisión simple en f[rs1] y f[rs2], suma el producto sin redondear al número de punto flotante de precisión simple en f[rs3], y escribe el resultado redondeado de precisión simple en f[rd].

31	27 26	25 24	20 19	15 14	12 11	7 6	0
rs3	00	rs2	rs1	rm	rd	1000011	

# Creación de una nueva instrucción

**CREATOR 3.2 RISC-V (RV32IMFD)**  
didaCtic and geneRic assEmbly progrAmming simulaTOR

# Assembly    Simulator    Save    Configuration    Info

Architecture Info    Memory Layout    Register File    Instructions    Pseudoinstructions    Directives

**Instruction set:**

Name	Co	Extended CO	Nwords	Instruction syntax	Properties	Power Consumption	Fields	Definition	Actions
jalr	1100111	000	1	jalr rd imm (rs1) jalr,INT-Reg,imm-signed,(INT-Reg)	exit_subroutine	1	<a href="#">View Fields</a>	PC = (rs1+imm)&~1; capi_callconv_end(); capi_drawstack_end(PC);	<a href="#">Edit</a> <a href="#">Delete</a>
beq	1100011	000	1	beq rs1 rs2 imm beq,INT-Reg,INT-Reg,offset_words		1	<a href="#">View Fields</a>	if (rs1 === rs2) PC = PC + ((imm << 16) >> 14);	<a href="#">Edit</a> <a href="#">Delete</a>
bne	1100011	001	1	bne rs1 rs2 imm bne,INT-Reg,INT-Reg,offset_words		1	<a href="#">View Fields</a>	if (rs1 != rs2) PC = PC + ((imm << 16) >> 14);	<a href="#">Edit</a> <a href="#">Delete</a>
blt	1100011	100	1	blt rs1 rs2 imm blt,INT-Reg,INT-Reg,offset_words		1	<a href="#">View Fields</a>	if (capi_uint2int(rs1) < capi_uint2int(rs2)) PC = PC + ((imm << 16) >> 14);	<a href="#">Edit</a> <a href="#">Delete</a>
bge	1100011	101	1	bge rs1 rs2 imm bge,INT-Reg,INT-Reg,offset_words		1	<a href="#">View Fields</a>	if (capi_uint2int(rs1) >= capi_uint2int(rs2)) PC = PC + ((imm << 16) >> 14);	<a href="#">Edit</a> <a href="#">Delete</a>



# Nueva instrucción: fmadd.s

New Instruction X

Name:  ✓

Type:  ✓ ▼

Number of Words:  ✓

CLK Cycles:  ✓

Number of fields: (Including co and cop)  ✓

Properties:

Enter Subroutine  Exit Subroutine

---

[Principal](#) [Fields](#) [Syntax](#) [Definition](#) [Help](#) > »

Cancel Save

**fmadd.s** rd, rs1, rs2, rs3  $f[rd] = f[rs1] \times f[rs2] + f[rs3]$   
Floating-point Fused Multiply-Add, Single-Precision. Tipo R4, RV32F y RV64F.  
Multiplica los números de punto flotante de precisión simple en f[rs1] y f[rs2], suma el producto sin redondear al número de punto flotante de precisión simple en f[rs3], y escribe el resultado redondeado de precisión simple en f[rd].

31	27 26 25 24	20 19	15 14	12 11	7 6	0
rs3	00	rs2	rs1	rm	rd	1000011



## Nueva instrucción: fmadd.s

31	27 26	25 24	20 19	15 14	12 11	7 6	0
rs3	00	rs2	rs1	rm	rd	1000011	

enlace

Edit fmadd.s

Name:	Type	Break	Start Bit	End Bit
Field 0	fmadd.s	co	6	0 1000011 ✓
Field 1	rd	SFP-Reg ✓	11	7 ✓
Field 2	rs1	SFP-Reg ✓	19	15 ✓
Field 3	rs2	SFP-Reg ✓	24	20 ✓
Field 4	co	cop ✓	26	25 00 ✓
Field 5	rs3	SFP-Reg ✓	31	27 ✓

« < Principal Fields Syntax Definition Help > »

Cancel Save

# Nueva instrucción: fmadd.s

31	27 26	25 24	20 19	15 14	12 11	7 6	0
rs3	00	rs2	rs1	rm	rd	1000011	
F5	F4	F3	F2	F1	F0		

## Edit fmadd.s



Instruction Syntax Definition:

F0 F1 F2 F3 F5



Detailed Syntax:

fmadd.s,SFP-Reg,SFP-Reg,SFP-Reg,SFP-Reg

Instruction Syntax:

fmadd.s rd rs1 rs2 rs3

« < Principal Fields **Syntax** Definition Help > »

**Cancel** **Save**

# Nueva instrucción: fmadd.s

New Instruction ×

---

Assembly Definition:

```
rd=rs1*rs2+rs3;
```

✓

Instruction Definition

---

[«](#) [‹](#) [Principal](#) [Fields](#) [Syntax](#) **Definition** [Help](#) [›](#) [»](#)

---

[Cancel](#) [Save](#)

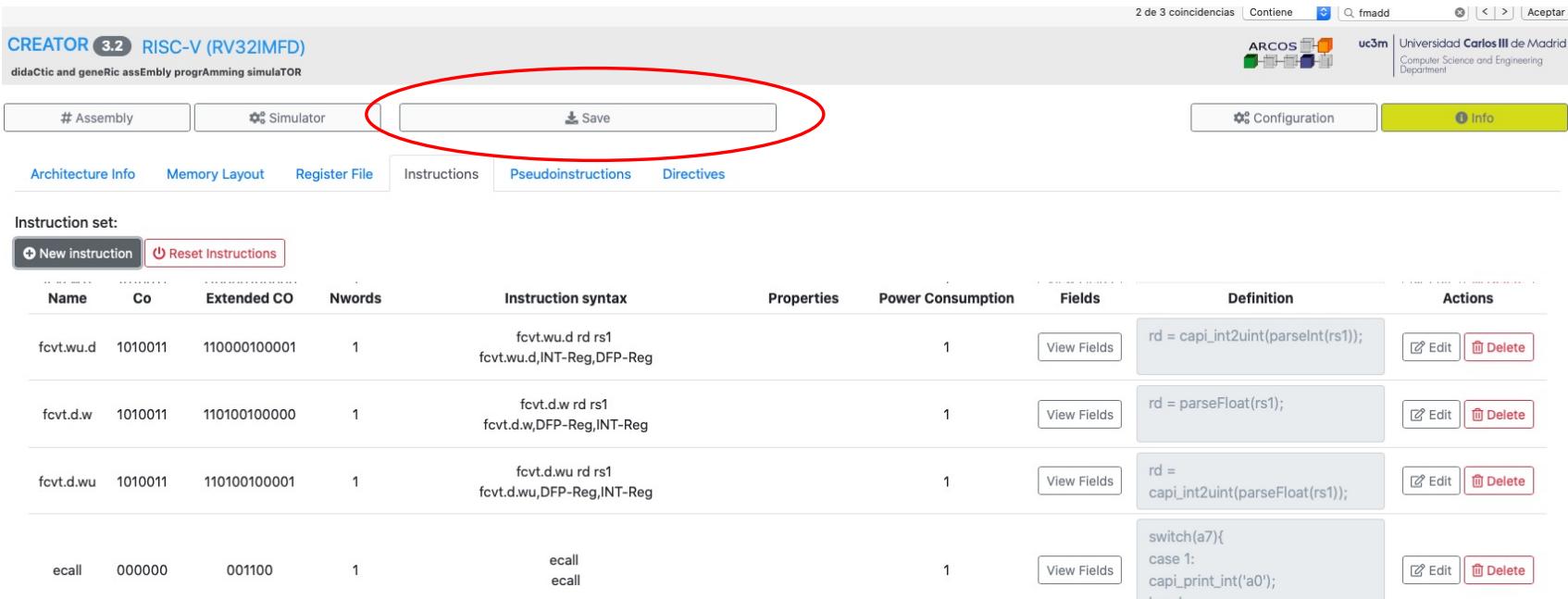
**fmadd.s** rd, rs1, rs2, rs3       $f[rd] = f[rs1] \times f[rs2] + f[rs3]$

*Floating-point Fused Multiply-Add, Single-Precision.* Tipo R4, RV32F y RV64F.

Multiplica los números de punto flotante de precisión simple en f[rs1] y f[rs2], suma el producto sin redondear al número de punto flotante de precisión simple en f[rs3], y escribe el resultado redondeado de precisión simple en f[rd].

31	27 26 25 24	20 19	15 14	12 11	7 6	0
rs3	00	rs2	rs1	rm	rd	1000011

# Creación de una nueva instrucción

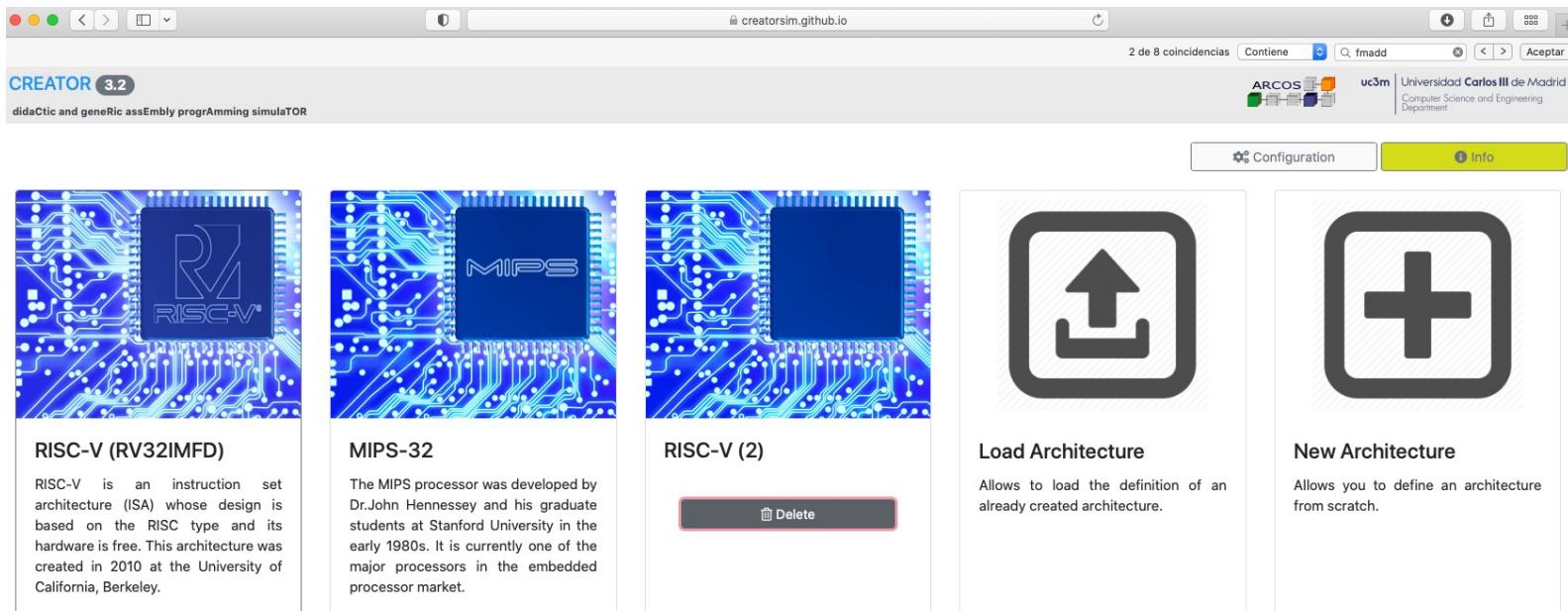


The screenshot shows the 'CREATOR 3.2 RISC-V (RV32IMFD)' interface. A red oval highlights the 'Save' button in the top navigation bar. Below the navigation bar, there are tabs for 'Architecture Info', 'Memory Layout', 'Register File', 'Instructions' (which is selected), 'Pseudoinstructions', and 'Directives'. The main area displays an instruction set table with columns for Name, Co, Extended CO, Nwords, Instruction syntax, Properties, Power Consumption, Fields, Definition, and Actions. The table contains four rows for instructions: fcvt.wu.d, fcvt.d.w, fcvt.d.wu, and ecall. Each row includes a 'View Fields' button and 'Edit' and 'Delete' links.

Name	Co	Extended CO	Nwords	Instruction syntax	Properties	Power Consumption	Fields	Definition	Actions
fcvt.wu.d	1010011	110000100001	1	fcvt.wu.d rd rs1 fcvt.wu.d,INT-Reg,DFP-Reg	1		<a href="#">View Fields</a>	rd = capi_int2uint(parseInt(rs1));	<a href="#">Edit</a> <a href="#">Delete</a>
fcvt.d.w	1010011	110100100000	1	fcvt.d.w rd rs1 fcvt.d.w,DFP-Reg,INT-Reg	1		<a href="#">View Fields</a>	rd = parseFloat(rs1);	<a href="#">Edit</a> <a href="#">Delete</a>
fcvt.d.wu	1010011	110100100001	1	fcvt.d.wu rd rs1 fcvt.d.wu,DFP-Reg,INT-Reg	1		<a href="#">View Fields</a>	rd = capi_int2uint(parseFloat(rs1));	<a href="#">Edit</a> <a href="#">Delete</a>
ecall	000000	001100	1	ecall ecall	1		<a href="#">View Fields</a>	switch(a7){ case 1: capi_print_int('a0'); break;	<a href="#">Edit</a> <a href="#">Delete</a>



# Nueva arquitectura



# Ejemplo

➊ Assembly:

ejemplo

```
1 .data
2
3     a: .float 4
4     b: .float 5.5
5     c: .float 2.3
6
7 .text
8
9 main:
10    li t0, a
11    flw ft1, 0(t0)
12
13    li t0, b
14    flw ft2, 0(t0)
15
16    li t0, c
17    flw ft3, 0(t0)
18
19    fmadd.s fa0, ft1, ft2, ft3
20
21    li a7, 2
22    ecall
```



# API para la definición de instrucciones

- ▶ [API de ayuda](#) para definición de instrucciones

- ▶ Instrucción: lw rd inm (rs1)

- ▶ Definición:

```
var addr = capi_int2uint(rs1)+inm;  
rd = capi_mem_read(addr, 'w', rd_name);
```

- ▶ Instrucción: sb rd inm (rs1)

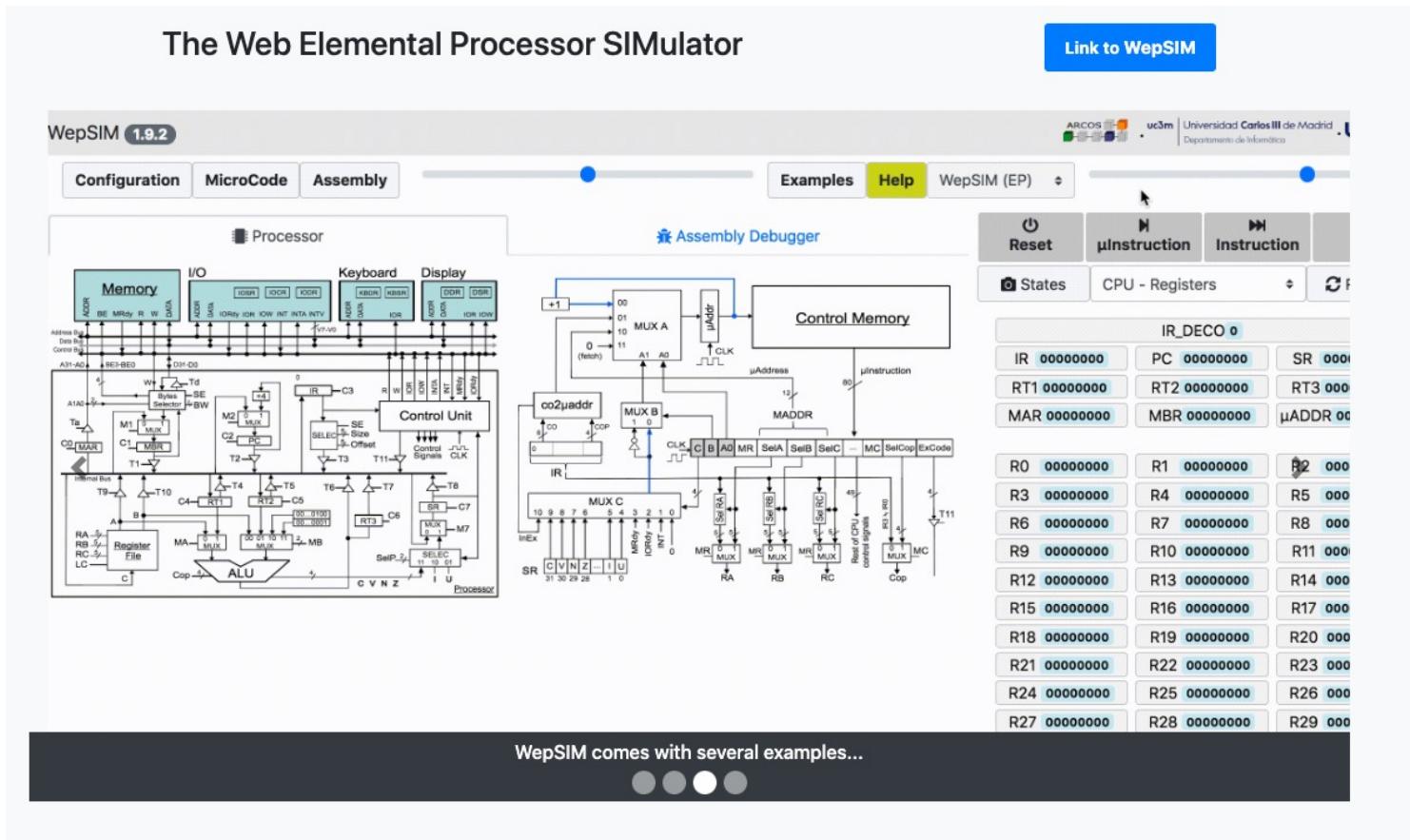
- ▶ Definición:

```
capi_mem_write(rs1+inm, rd, 'b', rs2_name);
```

## Extensiones futuras

- ▶ Simulador de caché
- ▶ Registros e instrucciones vectoriales
- ▶ Simulador de pipeline
- ▶ ....

# Otro simulador: WepSim



# WepSim

