

Part 1 – MIPS Arithmetic and Code Optimization. Relevant assembly files: part1_q1-3.s , part1_q4-6.s

- **Q1:** There are 22 instructions, 11 for each value of x
- **Q2:**

.data

x1: .word 3 # x = 3

x2: .word 2023 # x = 2023

result1: .word 0 # store result for x = 3

result2: .word 0 # store result for x = 2023

.text

.globl main

main:

 # evaluate f(x) for x = 3

 lw \$t0, x1 # load x

 li \$t1, 6 # load 6

 mul \$t2, \$t0, \$t0 # x^2

 mul \$t2, \$t2, \$t1 # 6x^2

 li \$t1, 5 # load 5

 mul \$t3, \$t0, \$t1 # 5x

 sub \$t2, \$t2, \$t3 # 6x^2 - 5x

 li \$t1, -21 # load -21

 add \$t2, \$t2, \$t1 # 6x^2 - 5x - 21

 sw \$t2, result1 # store result for x = 3 in result1

 move \$t5, \$t2 # store result for x = 3 in \$t5

 # evaluate f(x) for x = 2023

 lw \$t4, x2 # load x

 li \$t1, 6 # load 6

 mul \$t2, \$t4, \$t4 # x^2

 mul \$t2, \$t2, \$t1 # 6x^2

 li \$t1, 5 # load 5

 mul \$t3, \$t4, \$t1 # 5x

```
sub $t2, $t2, $t3 # 6x^2 - 5x
li $t1, -21      # load -21
add $t2, $t2, $t1 # 6x^2 - 5x - 21
sw $t2, result2  # store result for x = 2023 in result2
move $t6, $t2    # store result for x = 2023 in $t6
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```
# exit
li $v0, 10
syscall
```

- **Q3:**
 - **a:** the value of $f(3)$ is stored in R13 [t5] = 18

FP Regs	Int Regs [10]	Data	Text
Int Regs [10]		Text	
PC	= 4194456	User Text Segment [00400000]..[00440000]	
EPC	= 0	[00400000] 8fa40000	lw \$4, 0(\$29) ; 183: lw \$a0 0(\$sp) # argc
Cause	= 0	[00400004] 27a50004	addiu \$5, \$29, 4 ; 184: addiu \$a1 \$sp 4 # argv
BadVAddr	= 0	[00400008] 24a60004	addiu \$6, \$5, 4 ; 185: addiu \$a2 \$a1 4 # envp
Status	= 805371664	[0040000c] 00041080	sll \$2, \$4, 2 ; 186: sll \$v0 \$a0 2
HI	= 0	[00400010] 00c23021	addu \$6, \$6, \$2 ; 187: addu \$a2 \$a2 \$v0
LO	= 10115	[00400014] 0c100009	jal 0x00400024 [main] ; 188: jal main
R0 [r0]	= 0	[00400018] 00000000	nop ; 189: nop
R1 [at]	= 268500992	[0040001c] 3402000a	ori \$2, \$0, 10 ; 191: li \$v0 10
R2 [v0]	= 10	[00400020] 0000000c	syscall ; 192: syscall # syscall 10 (exit)
R3 [v1]	= 0	[00400024] 3c011001	lui \$1, 4097 ; 11: lw \$t0, x1 # load x
R4 [a0]	= 1	[00400028] 8c280000	lw \$8, 0(\$1)
R5 [a1]	= 2147481444	[0040002c] 34090006	ori \$9, \$0, 6 ; 12: li \$t1, 6 # load 6
R6 [a2]	= 2147481452	[00400030] 71085002	mul \$10, \$8, \$8 ; 13: mul \$t2, \$t0, \$t0 # x^2
R7 [a3]	= 0	[00400034] 71495002	mul \$10, \$10, \$9 ; 14: mul \$t2, \$t2, \$t1 # 6x^2
R8 [t0]	= 3	[00400038] 34090005	ori \$9, \$0, 5 ; 15: li \$t1, 5 # load 5
R9 [t1]	= -21	[0040003c] 71095802	mul \$11, \$8, \$9 ; 16: mul \$t3, \$t0, \$t1 # 5x
R10 [t2]	= 24545038	[00400040] 014b5022	sub \$10, \$10, \$11 ; 17: sub \$t2, \$t2, \$t3 # 6x^2 - 5x
R11 [t3]	= 10115	[00400044] 3c01ffff	lui \$1, -1 ; 18: li \$t1, -21 # load -21
R12 [t4]	= 2023	[00400048] 3429ffeb	ori \$9, \$1, -21
R13 [t5]	= 18	[0040004c] 01495020	add \$10, \$10, \$9 ; 19: add \$t2, \$t2, \$t1 # 6x^2 - 5x - 21
R14 [t6]	= 24545038	[00400050] 3c011001	lui \$1, 4097 ; 20: sw \$t2, result1 # store result for x = 3 in result1
R15 [t7]	= 0	[00400054] ac2a0008	sw \$10, 8(\$1)
R16 [s0]	= 0	[00400058] 000a6821	addu \$13, \$0, \$10 ; 21: move \$t5, \$t2 # store result for x = 3 in \$t5
R17 [s1]	= 0	[0040005c] 3c011001	lui \$1, 4097 ; 24: lw \$t4, x2 # load x
R18 [s2]	= 0	[00400060] 8c2c0004	lw \$12, 4(\$1)
R19 [s3]	= 0	[00400064] 34090006	ori \$9, \$0, 6 ; 25: li \$t1, 6 # load 6
R20 [s4]	= 0	[00400068] 718c5002	mul \$10, \$12, \$12 ; 26: mul \$t2, \$t4, \$t4 # x^2
R21 [s5]	= 0	[0040006c] 71495002	mul \$10, \$10, \$9 ; 27: mul \$t2, \$t2, \$t1 # 6x^2
R22 [s6]	= 0	[00400070] 34090005	ori \$9, \$0, 5 ; 28: li \$t1, 5 # load 5
R23 [s7]	= 0	[00400074] 71895802	mul \$11, \$12, \$9 ; 29: mul \$t3, \$t4, \$t1 # 5x
R24 [t8]	= 0	[00400078] 014b5022	sub \$10, \$10, \$11 ; 30: sub \$t2, \$t2, \$t3 # 6x^2 - 5x
R25 [t9]	= 0	[0040007c] 3c01ffff	lui \$1, -1 ; 31: li \$t1, -21 # load -21
R26 [k0]	= 0	[00400080] 3429ffeb	ori \$9, \$1, -21
R27 [k1]	= 0	[00400084] 01495020	add \$10, \$10, \$9 ; 32: add \$t2, \$t2, \$t1 # 6x^2 - 5x - 21

- o b: the value of f(3) is stored in R13 [t5] = 18

FP Regs	Int Regs [10]	Data	Text
Int Regs [10]		Data	
PC	= 4194456	User data segment [10000000]..[10040000]	
EPC	= 0	[10000000]..[1000ffff]	00000000
Cause	= 0	[10010000]	00000003 000007e7 00000012 0176870e v .
BadVAddr	= 0	[10010010]..[1003ffff]	00000000
Status	= 805371664		
HI	= 0	User Stack [7ffff760]..[80000000]	
LO	= 10115	[7ffff760]	00000001 7ffff825 00000000 7fffffeb %
R0 [r0]	= 0	[7ffff770]	7fffffdb 7fffffbc 7fffff95 7fffff69 i . . .
R1 [at]	= 268500992	[7ffff780]	7fffff3d 7fffff0c 7ffffed0 7ffffe9f =
R2 [v0]	= 10	[7ffff790]	7ffffe88 7ffffe64 7ffffe32 7ffffe27 d . . . 2 . . . ' . . .
R3 [v1]	= 0	[7ffff7a0]	7ffffela 7ffffe04 7ffffdda 7ffffdc2
R4 [a0]	= 1	[7ffff7b0]	7ffffdaa 7ffffd73 7ffffd32 7ffffd24 s . . . 2 . . . \$. . .
R5 [a1]	= 2147481444	[7ffff7c0]	7ffffb7e 7ffffb37 7ffffbla 7ffffad3 ~ . . . 7
R6 [a2]	= 2147481452	[7ffff7d0]	7ffffac0 7ffffaa8 7ffffa8d 7ffffa6f o . . .
R7 [a3]	= 0	[7ffff7e0]	7ffffa46 7ffffa28 7ffff9bd 7ffff9a6 F . . . (.
R8 [t0]	= 3	[7ffff7f0]	7ffff995 7ffff981 7ffff972 7ffff95c r . . . \ . . .
R9 [t1]	= -21	[7ffff800]	7ffff935 7ffff90f 7ffff8fa 7ffff8d6 5
R10 [t2]	= 24545038	[7ffff810]	7ffff8c7 7ffff8ac 7ffff872 7ffff860 r . . . \ . . .
R11 [t3]	= 10115	[7ffff820]	00000000 2f3a4300 72657355 6e612f73 C : / U s e r s / a n
R12 [t4]	= 2023	[7ffff830]	2f696861 75636f44 746e656d 65522f73 a h i / D o c u m e n t s / R e
R13 [t5]	= 18	[7ffff840]	342f6f70 412f3034 67697373 6e656d6e p o / 4 4 0 / A s s i g n m e n t
R14 [t6]	= 24545038	[7ffff850]	702f3174 31747261 2d31715f 00732e33 t l / p a r t l _ q l - 3 . s .
R15 [t7]	= 0	[7ffff860]	646e6977 433d7269 49575c3a 574f444e w i n d i r = C : \ W I N D O W
R16 [s0]	= 0	[7ffff870]	42560053 4d5f584f 495f4953 4154534e S . V B O X _ M S I _ I N S T A
R17 [s1]	= 0	[7ffff880]	505f4c4c 3d485441 505c3a43 72676f72 L L _ P A T H = C : \ P r o g r
R18 [s2]	= 0	[7ffff890]	46206d61 73656c69 61724f5c 5c656c63 a m _ F i l e s \ O r a c l e \
R19 [s3]	= 0	[7ffff8a0]	74726956 426c6175 005c786f 52455355 V i r t u a l B o x \ . U S E R
R20 [s4]	= 0	[7ffff8b0]	464f5250 3d454c49 555c3a43 73726573 P R O F I L E = C : \ U s e r s
R21 [s5]	= 0	[7ffff8c0]	616e615c 55006968 4e524553 3d454d41 \ a n a h i . U S E R N A M E =
R22 [s6]	= 0	[7ffff8d0]	68616e61 53550069 4f445245 4e49414d a n a h i . U S E R D O M A I N
R23 [s7]	= 0	[7ffff8e0]	414f525f 474e494d 464f5250 3d454c49 _ R O A M I N G P R O F I L E =
R24 [t8]	= 0	[7ffff8f0]	48414e41 502d4449 53550043 4f445245 A N A H I D - P C . U S E R D O
R25 [t9]	= 0	[7ffff900]	4e49414d 414e413d 2d444948 54004350 M A I N = A N A H I D - P C . T
R26 [k0]	= 0	[7ffff910]	433d504d 73555c3a 5c737265 68616e61 M P = C : \ U s e r s \ a n a h
R27 [k1]	= 0	[7ffff920]	70415c69 74614470 6f4c5c61 5c6c6163 i \ A p p D a t a \ L o c a l \
		[7ffff930]	706d6554 4d455400 3a433d50 6573555c T e m p . T E M P = C : \ U s e

- o c: the value of f(2023) is stored in R14 [t6] = 24545038

FP Regs	Int Regs [10]	Data	Text
Int Regs [10]			
PC	= 4194456	[00400050] 3c011001 lui \$1, 4097	; 20: sw \$t2, result1 # store result for x = 3 in result1
EPC	= 0	[00400054] ac2a0008 sw \$10, 8(\$1)	
Cause	= 0	[00400058] 000a6821 addu \$13, \$0, \$10	; 21: move \$t5, \$t2 # store result for x = 3 in \$t5
BadVAddr	= 0	[0040005c] 3c011001 lui \$1, 4097	; 24: lw \$t4, x2 # load x
Status	= 805371664	[00400060] 8c2c0004 lw \$12, 4(\$1)	
HI	= 0	[00400064] 34090006 ori \$9, \$0, 6	; 25: li \$t1, 6 # load 6
LO	= 10115	[00400068] 718c5002 mul \$10, \$12, \$12	; 26: mul \$t2, \$t4, \$t4 # x^2
R0 [r0]	= 0	[0040006c] 71495002 mul \$10, \$10, \$9	; 27: mul \$t2, \$t2, \$t1 # 6x^2
R1 [at]	= 268500992	[00400070] 34090005 ori \$9, \$0, 5	; 28: li \$t1, 5 # load 5
R2 [v0]	= 10	[00400074] 71895802 mul \$11, \$12, \$9	; 29: mul \$t3, \$t4, \$t1 # 5x
R3 [v1]	= 0	[00400078] 014b5022 sub \$10, \$10, \$11	; 30: sub \$t2, \$t2, \$t3 # 6x^2 - 5x
R4 [a0]	= 1	[0040007c] 3c01ffff lui \$1, -1	; 31: li \$t1, -21 # load -21
R5 [a1]	= 2147481444	[00400080] 3429ffeb ori \$9, \$1, -21	
R6 [a2]	= 2147481452	[00400084] 01495020 add \$10, \$10, \$9	; 32: add \$t2, \$t2, \$t1 # 6x^2 - 5x - 21
R7 [a3]	= 0	[00400088] 3c011001 lui \$1, 4097	; 33: sw \$t2, result2 # store result for x = 2023 in result2
R8 [t0]	= 3	[0040008c] ac2a000c sw \$10, 12(\$1)	
R9 [t1]	= -21	[00400090] 000a7021 addu \$14, \$0, \$10	; 34: move \$t6, \$t2 # store result for x = 2023 in \$t6
R10 [t2]	= 24545038	[00400094] 3402000a ori \$2, \$0, 10	; 37: li \$v0, 10
R11 [t3]	= 10115	[00400098] 0000000c syscall	; 38: syscall
R12 [t4]	= 2023	Kernel Text Segment [80000000]..[80010000]	
R13 [t5]	= 18	[80000180] 0001d821 addu \$27, \$0, \$1	; 90: move \$k1 \$at # Save \$at
R14 [t6]	= 24545038	[80000184] 3c019000 lui \$1, -28672	; 92: sw \$v0 \$1 # Not re-entrant and we can't trust \$sp
R15 [t7]	= 0	[80000188] ac220200 sw \$2, 512(\$1)	
R16 [s0]	= 0	[8000018c] 3c019000 lui \$1, -28672	
R17 [s1]	= 0	[80000190] ac240204 sw \$4, 516(\$1)	; 93: sw \$a0 \$2 # But we need to use these registers
R18 [s2]	= 0	[80000194] 401a6800 mfc0 \$26, \$13	; 95: mfc0 \$k0 \$13 # Cause register
R19 [s3]	= 0	[80000198] 001a2082 srl \$4, \$26, 2	; 96: srl \$a0 \$k0 2 # Extract ExcCode Field
R20 [s4]	= 0	[8000019c] 3084001f andi \$4, \$4, 31	; 97: andi \$a0 \$a0 0x1f
R21 [s5]	= 0	[800001a0] 34020004 ori \$2, \$0, 4	; 101: li \$v0 4 # syscall 4 (print_str)
R22 [s6]	= 0	[800001a4] 3c049000 lui \$4, -28672 [__m1_]	; 102: la \$a0 __m1_
R23 [s7]	= 0	[800001a8] 0000000c syscall	; 103: syscall
R24 [t8]	= 0	[800001ac] 34020001 ori \$2, \$0, 1	; 105: li \$v0 1 # syscall 1 (print_int)
R25 [t9]	= 0	[800001b0] 001a2082 srl \$4, \$26, 2	; 106: srl \$a0 \$k0 2 # Extract ExcCode Field
R26 [k0]	= 0	[800001b4] 3084001f andi \$4, \$4, 31	; 107: andi \$a0 \$a0 0x1f
R27 [k1]	= 0	[800001b8] 0000000c syscall	; 108: syscall

- o d: the value of f(2023) is stored in R14 [t6] = 24545038

FP Regs		Int Regs [10]	Data	Text
Int Regs [10]			Data	
PC	=	4194456	User data segment [10000000]..[10040000]	
EPC	=	0	[10000000]..[1000ffff]	00000000
Cause	=	0	[10010000]	00000003 000007e7 00000012 0176870e v .
BadVAddr	=	0	[10010010]..[1003ffff]	00000000
Status	=	805371664		
HI	=	0	User Stack [7ffff760]..[80000000]	
LO	=	10115	[7ffff760]	00000001 7ffff825 00000000 7fffffeb %
R0 [r0]	=	0	[7ffff770]	7fffffdb 7ffffbfc 7fffff95 7fffff69 i . . .
R1 [at]	=	268500992	[7ffff780]	7fffff3d 7fffff0c 7ffffed0 7ffffe9f =
R2 [v0]	=	10	[7ffff790]	7ffffe88 7ffffe64 7ffffe32 7ffffe27 d . . . 2 . . . ' . . .
R3 [v1]	=	0	[7ffff7a0]	7ffffela 7ffffe04 7ffffdda 7ffffdc2
R4 [a0]	=	1	[7ffff7b0]	7ffffdaa 7ffffd73 7ffffd32 7ffffd24 s . . . 2 . . . \$. . .
R5 [a1]	=	2147481444	[7ffff7c0]	7ffffb7e 7ffffb37 7ffffbla 7ffffad3 ~ 7
R6 [a2]	=	2147481452	[7ffff7d0]	7ffffac0 7ffffaa8 7ffffa8d 7ffffa6f o . . .
R7 [a3]	=	0	[7ffff7e0]	7ffffa46 7ffffa28 7ffff9bd 7ffff9a6 F . . . (.
R8 [t0]	=	3	[7ffff7f0]	7ffff995 7ffff981 7ffff972 7ffff95c r . . . \ . . .
R9 [t1]	=	-21	[7ffff800]	7ffff935 7ffff90f 7ffff8fa 7ffff8d6 5
R10 [t2]	=	24545038	[7ffff810]	7ffff8c7 7ffff8ac 7ffff872 7ffff860 r . . . ` . . .
R11 [t3]	=	10115	[7ffff820]	00000000 2f3a4300 72657355 6e612f73 C : / U s e r s / a n
R12 [t4]	=	2023	[7ffff830]	2f696861 75636f44 746e656d 65522f73 a h i / D o c u m e n t s / R e
R13 [t5]	=	18	[7ffff840]	342f6f70 412f3034 67697373 6e656d6e p o / 4 4 0 / A s s i g n m e n t
R14 [t6]	=	24545038	[7ffff850]	702f3174 31747261 2d31715f 00732e33 t l / p a r t l _ q l - 3 . s .
R15 [t7]	=	0	[7ffff860]	646e6977 433d7269 49575c3a 574f444e w i n d i r = C : \ W I N D O W
R16 [s0]	=	0	[7ffff870]	42560053 4d5f584f 495f4953 4154534e S . V B O X _ M S I _ I N S T A
R17 [s1]	=	0	[7ffff880]	505f4c4c 3d485441 505c3a43 72676f72 L L _ P A T H = C : \ P r o g r
R18 [s2]	=	0	[7ffff890]	46206d61 73656c69 61724f5c 5c656c63 a m _ F i l e s \ O r a c l e \
R19 [s3]	=	0	[7ffff8a0]	74726956 426c6175 005c786f 52455355 V i r t u a l B o x \ . U S E R
R20 [s4]	=	0	[7ffff8b0]	464f5250 3d454c49 555c3a43 73726573 P R O F I L E = C : \ U s e r s
R21 [s5]	=	0	[7ffff8c0]	616e615c 55006968 4e524553 3d454d41 \ a n a h i . U S E R N A M E =
R22 [s6]	=	0	[7ffff8d0]	68616e61 53550069 4f445245 4e49414d a n a h i . U S E R D O M A I N
R23 [s7]	=	0	[7ffff8e0]	414f525f 474e494d 464f5250 3d454c49 _ R O A M I N G P R O F I L E =
R24 [t8]	=	0	[7ffff8f0]	48414e41 502d4449 53550043 4f445245 A N A H I D - P C . U S E R D O
R25 [t9]	=	0	[7ffff900]	4e49414d 414e413d 2d444948 54004350 M A I N = A N A H I D - P C . T
R26 [k0]	=	0	[7ffff910]	433d504d 73555c3a 5c737265 68616e61 M P = C : \ U s e r s \ a n a h
R27 [k1]	=	0	[7ffff920]	70415c69 74614470 6f4c5c61 5c6c6163 i \ A p p D a t a \ L o c a l \
			[7ffff930]	706d6554 4d455400 3a433d50 6573555c T e m p . T E M P = C : \ U s e

- **Q4:** There are 18 instructions, 9 for each value of x
- **Q5:**

.data

x1: .word 3 # x = 3

x2: .word 2023 # x = 2023

result1: .word 0 # store result for x = 3

result2: .word 0 # store result for x = 2023

.text

.globl main

main:

 # evaluate f(x) for x = 3

 lw \$t0, x1 # load x

 li \$t1, 6 # load 6

 mul \$t2, \$t0, \$t1 # 6x

 sub \$t2, \$t2, 5 # 6x-5

 mul \$t2, \$t2, \$t0 # (6x-5)x

 li \$t1, -21 # load -21

 add \$t2, \$t2, \$t1 # (6x-5)x - 21

 sw \$t2, result1 # store result for x = 3 in result1

 move \$t5, \$t2 # store result for x = 3 in \$t5

 # evaluate f(x) for x = 2023

 lw \$t4, x2 # load x

 li \$t1, 6 # load 6

 mul \$t2, \$t4, \$t1 # 6x

 sub \$t2, \$t2, 5 # 6x-5

 mul \$t2, \$t2, \$t4 # (6x-5)x

 li \$t1, -21 # load -21

 add \$t2, \$t2, \$t1 # (6x-5)x - 21

 sw \$t2, result2 # store result for x = 2023 in result2

 move \$t6, \$t2 # store result for x = 2023 in \$t6

```
# exit  
li $v0, 10  
syscall
```

- **Q6:**
 - **a:** the value of $f(3)$ is stored in R13 [t5] = 18

FP Regs	Int Regs [10]	Data	Text
Int Regs [10]		Text	
PC	= 4194440		
EPC	= 0		
Cause	= 0		
BadVAddr	= 0		
Status	= 805371664		
HI	= 0		
LO	= 24545059		
R0 [r0]	= 0		
R1 [at]	= 268500992		
R2 [v0]	= 10		
R3 [v1]	= 0		
R4 [a0]	= 1		
R5 [a1]	= 2147481444		
R6 [a2]	= 2147481452		
R7 [a3]	= 0		
R8 [t0]	= 3		
R9 [t1]	= -21		
R10 [t2]	= 24545038		
R11 [t3]	= 0		
R12 [t4]	= 2023		
R13 [t5]	= 18		
R14 [t6]	= 24545038		
R15 [t7]	= 0		
R16 [s0]	= 0		
R17 [s1]	= 0		
R18 [s2]	= 0		
R19 [s3]	= 0		
R20 [s4]	= 0		
R21 [s5]	= 0		
R22 [s6]	= 0		
R23 [s7]	= 0		
R24 [t8]	= 0		
R25 [t9]	= 0		
R26 [k0]	= 0		
R27 [k1]	= 0		
		<pre> [00400000] 8fa40000 lw \$4, 0(\$29) ; 183: lw \$a0 0(\$sp) # argc [00400004] 27a50004 addiu \$5, \$29, 4 ; 184: addiu \$a1 \$sp 4 # argv [00400008] 24a60004 addiu \$6, \$5, 4 ; 185: addiu \$a2 \$a1 4 # envp [0040000c] 00041080 sll \$2, \$4, 2 ; 186: sll \$v0 \$a0 2 [00400010] 00c23021 addu \$6, \$6, \$2 ; 187: addu \$a2 \$a2 \$v0 [00400014] 0c100009 jal 0x00400024 [main] ; 188: jal main [00400018] 00000000 nop ; 189: nop [0040001c] 3402000a ori \$2, \$0, 10 ; 191: li \$v0 10 [00400020] 0000000c syscall ; 192: syscall # syscall 10 (exit) [00400024] 3c011001 lui \$1, 4097 ; 11: lw \$t0, x1 # load x [00400028] 8c280000 lw \$8, 0(\$1) [0040002c] 34090006 ori \$9, \$0, 6 ; 12: li \$t1, 6 # load 6 [00400030] 71095002 mul \$10, \$8, \$9 ; 13: mul \$t2, \$t0, \$t1 # 6x [00400034] 214afffb addi \$10, \$10, -5 ; 14: sub \$t2, \$t2, 5 # 6x-5 [00400038] 71485002 mul \$10, \$10, \$8 ; 15: mul \$t2, \$t2, \$t0 # (6x-5)x [0040003c] 3c01ffff lui \$1, -1 ; 16: li \$t1, -21 # load -21 [00400040] 3429ffeb ori \$9, \$1, -21 [00400044] 01495020 add \$10, \$10, \$9 ; 17: add \$t2, \$t2, \$t1 # (6x-5)x - 21 [00400048] 3c011001 lui \$1, 4097 ; 18: sw \$t2, result1 # store result for x = 3 in result1 [0040004c] ac2a0008 sw \$10, 8(\$1) [00400050] 000a6821 addu \$13, \$0, \$10 ; 19: move \$t5, \$t2 # store result for x = 3 in \$t5 [00400054] 3c011001 lui \$1, 4097 ; 22: lw \$t4, x2 # load x [00400058] 8c2c0004 lw \$12, 4(\$1) [0040005c] 34090006 ori \$9, \$0, 6 ; 23: li \$t1, 6 # load 6 [00400060] 71895002 mul \$10, \$12, \$9 ; 24: mul \$t2, \$t4, \$t1 # 6x [00400064] 214afffb addi \$10, \$10, -5 ; 25: sub \$t2, \$t2, 5 # 6x-5 [00400068] 714c5002 mul \$10, \$10, \$12 ; 26: mul \$t2, \$t2, \$t4 # (6x-5)x [0040006c] 3c01ffff lui \$1, -1 ; 27: li \$t1, -21 # load -21 [00400070] 3429ffeb ori \$9, \$1, -21 [00400074] 01495020 add \$10, \$10, \$9 ; 28: add \$t2, \$t2, \$t1 # (6x-5)x - 21 [00400078] 3c011001 lui \$1, 4097 ; 29: sw \$t2, result2 # store result for x = 2023 in result2 [0040007c] ac2a000c sw \$10, 12(\$1) [00400080] 000a7021 addu \$14, \$0, \$10 ; 30: move \$t6, \$t2 # store result for x = 2023 in \$t6 [00400084] 3402000a ori \$2, \$0, 10 ; 33: li \$v0, 10 [00400088] 0000000c syscall ; 34: syscall </pre>	

- o b: the value of f(3) is stored in R13 [t5] = 18

FP Regs	Int Regs [10]	Data	Text
Int Regs [10]		Data	
PC	= 4194440	User data segment [10000000]..[10040000]	
EPC	= 0	[10000000]..[1000ffff]	00000000
Cause	= 0	[10010000]	00000003 000007e7 00000012 0176870e v .
BadVAddr	= 0	[10010010]..[1003ffff]	00000000
Status	= 805371664	User Stack [7ffff760]..[80000000]	
HI	= 0	[7ffff760]	00000001 7ffff825 00000000 7fffffeeb %
LO	= 24545059	[7ffff770]	7fffffdb 7fffffbc 7fffff95 7fffff69 i . . .
R0 [r0]	= 0	[7ffff780]	7fffff3d 7fffff0c 7ffffed0 7ffffe9f =
R1 [at]	= 268500992	[7ffff790]	7ffffe88 7ffffe64 7ffffe32 7ffffe27 d . . . 2 . . . ' . . .
R2 [v0]	= 10	[7ffff7a0]	7ffffela 7ffffe04 7ffffdda 7ffffdc2
R3 [v1]	= 0	[7ffff7b0]	7ffffdaa 7ffffd73 7ffffd32 7ffffd24 s . . . 2 . . . \$. . .
R4 [a0]	= 1	[7ffff7c0]	7ffffb7e 7ffffb37 7ffffb1a 7ffffad3 ~ . . . 7
R5 [a1]	= 2147481444	[7ffff7d0]	7ffffac0 7ffffaa8 7ffffa8d 7ffffa6f o . . .
R6 [a2]	= 2147481452	[7ffff7e0]	7ffffa46 7ffffa28 7ffff9bd 7ffff9a6 F . . . (.
R7 [a3]	= 0	[7ffff7f0]	7ffff995 7ffff981 7ffff972 7ffff95c r . . . \ . . .
R8 [t0]	= 3	[7ffff800]	7ffff935 7ffff90f 7ffff8fa 7ffff8d6 5
R9 [t1]	= -21	[7ffff810]	7ffff8c7 7ffff8ac 7ffff872 7ffff860 r . . . ` . . .
R10 [t2]	= 24545038	[7ffff820]	00000000 2f3a4300 72657355 6e612f73 C : / U s e r s / a n
R11 [t3]	= 0	[7ffff830]	2f696861 75636f44 746e656d 65522f73 a h i / D o c u m e n t s / R e
R12 [t4]	= 2023	[7ffff840]	342f6f70 412f3034 67697373 6e656d6e p o / 4 4 0 / A s s i g n m e n
R13 [t5]	= 18	[7ffff850]	702f3174 31747261 2d34715f 00732e36 t l / p a r t l _ q 4 - 6 . s .
R14 [t6]	= 24545038	[7ffff860]	646e6977 433d7269 49575c3a 574f444e w i n d i r = C : \ W I N D O W
R15 [t7]	= 0	[7ffff870]	42560053 4d5f584f 495f4953 4154534e S . V B O X _ M S I _ I N S T A
R16 [s0]	= 0	[7ffff880]	505f4c4c 3d485441 505c3a43 72676f72 L L _ P A T H = C : \ P r o g r
R17 [s1]	= 0	[7ffff890]	46206d61 73656c69 61724f5c 5c656c63 a m _ F i l e s \ O r a c l e \
R18 [s2]	= 0	[7ffff8a0]	74726956 426c6175 005c786f 52455355 V i r t u a l B o x \ . U S E R
R19 [s3]	= 0	[7ffff8b0]	464f5250 3d454c49 555c3a43 73726573 P R O F I L E = C : \ U s e r s
R20 [s4]	= 0	[7ffff8c0]	616e615c 55006968 4e524553 3d454d41 \ a n a h i . U S E R N A M E =
R21 [s5]	= 0	[7ffff8d0]	68616e61 53550069 4f445245 4e49414d a n a h i . U S E R D O M A I N
R22 [s6]	= 0	[7ffff8e0]	414f525f 474e494d 464f5250 3d454c49 _ R O A M I N G P R O F I L E =
R23 [s7]	= 0	[7ffff8f0]	48414e41 502d4449 53550043 4f445245 A N A H I D - P C . U S E R D O
R24 [t8]	= 0	[7ffff900]	4e49414d 414e413d 2d444948 54004350 M A I N = A N A H I D - P C . T
R25 [t9]	= 0	[7ffff910]	433d504d 73555c3a 5c737265 68616e61 M P = C : \ U s e r s \ a n a h
R26 [k0]	= 0	[7ffff920]	70415c69 74614470 6f4c5c61 5c6c6163 i \ A p p D a t a \ L o c a l \
R27 [k1]	= 0	[7ffff930]	706d6554 4d455400 3a433d50 6573555c T e m p . T E M P = C : \ U s e

- c: the value of f(2023) is stored in R14 [t6] = 24545038

FP Regs	Int Regs [10]	Data	Text
Int Regs [10]		Text	
PC	= 4194440	[00400038] 71485002	mul \$t0, \$t0, \$8 ; 15: mul \$t2, \$t2, \$t0 # (6x-5)x
EPC	= 0	[0040003c] 3c01ffff	lui \$1, -1 ; 16: li \$t1, -21 # load -21
Cause	= 0	[00400040] 3429ffeb	ori \$9, \$1, -21
BadVAddr	= 0	[00400044] 01495020	add \$t0, \$t0, \$9 ; 17: add \$t2, \$t2, \$t1 # (6x-5)x - 21
Status	= 805371664	[00400048] 3c011001	lui \$1, 4097 ; 18: sw \$t2, result1 # store result for x = 3 in result1
HI	= 0	[0040004c] ac2a0008	sw \$t0, 8(\$1)
LO	= 24545059	[00400050] 000a6821	addu \$t3, \$0, \$t0 ; 19: move \$t5, \$t2 # store result for x = 3 in \$t5
R0 [r0]	= 0	[00400054] 3c011001	lui \$1, 4097 ; 22: lw \$t4, x2 # load x
R1 [at]	= 268500992	[00400058] 8c2c0004	lw \$t2, 4(\$1)
R2 [v0]	= 10	[0040005c] 34090006	ori \$9, \$0, 6 ; 23: li \$t1, 6 # load 6
R3 [v1]	= 0	[00400060] 71895002	mul \$t0, \$t2, \$t1 # 6x
R4 [a0]	= 1	[00400064] 214afffb	addi \$t0, \$t0, -5 ; 25: sub \$t2, \$t2, 5 # 6x-5
R5 [a1]	= 2147481444	[00400068] 714c5002	mul \$t0, \$t0, \$t2 ; 26: mul \$t2, \$t2, \$t4 # (6x-5)x
R6 [a2]	= 2147481452	[0040006c] 3c01ffff	lui \$1, -1 ; 27: li \$t1, -21 # load -21
R7 [a3]	= 0	[00400070] 3429ffeb	ori \$9, \$1, -21
R8 [t0]	= 3	[00400074] 01495020	add \$t0, \$t0, \$9 ; 28: add \$t2, \$t2, \$t1 # (6x-5)x - 21
R9 [t1]	= -21	[00400078] 3c011001	lui \$1, 4097 ; 29: sw \$t2, result2 # store result for x = 2023 in result2
R10 [t2]	= 24545038	[0040007c] ac2a000c	sw \$t0, 12(\$1)
R11 [t3]	= 0	[00400080] 000a7021	addu \$t4, \$0, \$t0 ; 30: move \$t6, \$t2 # store result for x = 2023 in \$t6
R12 [t4]	= 2023	[00400084] 3402000a	ori \$2, \$0, 10 ; 33: li \$v0, 10
R13 [t5]	= 18	[00400088] 0000000c	syscall ; 34: syscall
R14 [t6]	= 24545038	Kernel Text Segment [80000000]..[80010000]	
R15 [t7]	= 0	[80000180] 0001d821	addu \$t7, \$0, \$1 ; 90: move \$k1 \$at # Save \$at
R16 [s0]	= 0	[80000184] 3c019000	lui \$1, -28672 ; 92: sw \$v0 \$1 # Not re-entrant and we can't trust \$sp
R17 [s1]	= 0	[80000188] ac220200	sw \$2, 512(\$1)
R18 [s2]	= 0	[8000018c] 3c019000	lui \$1, -28672 ; 93: sw \$a0 \$2 # But we need to use these registers
R19 [s3]	= 0	[80000190] ac240204	sw \$4, 516(\$1)
R20 [s4]	= 0	[80000194] 401a6800	mfc0 \$t6, \$t3 ; 95: mfc0 \$k0 \$t3 # Cause register
R21 [s5]	= 0	[80000198] 001a2082	srl \$4, \$t6, 2 ; 96: srl \$a0 \$k0 2 # Extract ExcCode Field
R22 [s6]	= 0	[8000019c] 3084001f	andi \$4, \$4, 31 ; 97: andi \$a0 \$a0 0x1f
R23 [s7]	= 0	[800001a0] 34020004	ori \$2, \$0, 4 ; 101: li \$v0 4 # syscall 4 (print_str)
R24 [t8]	= 0	[800001a4] 3c049000	lui \$4, -28672 [__m1_] ; 102: la \$a0 __m1_
R25 [t9]	= 0	[800001a8] 0000000c	syscall ; 103: syscall
R26 [k0]	= 0	[800001ac] 34020001	ori \$2, \$0, 1 ; 105: li \$v0 1 # syscall 1 (print_int)
R27 [k1]	= 0		

- d: the value of f(2023) is stored in R14 [t6] = 24545038

FP Reqs		Int Regs [10]	Data	Text
Int Regs [10]			Data	
PC	=	4194440	[7ffff7b0]	7ffffdaa 7ffffd73 7ffffd32 7ffffd24 s 2 \$
EPC	=	0	[7ffff7c0]	7ffffb7e 7ffffb37 7ffffb1a 7ffffad3 ~ 7
Cause	=	0	[7ffff7d0]	7ffffac0 7ffffaa8 7ffffa8d 7ffffa6f o
BadVAddr	=	0	[7ffff7e0]	7ffffa46 7ffffa28 7ffff9bd 7ffff9a6 F (.
Status	=	805371664	[7ffff7f0]	7ffff995 7ffff981 7ffff972 7ffff95c r \
			[7ffff800]	7ffff935 7ffff90f 7ffff8fa 7ffff8d6 5
HI	=	0	[7ffff810]	7ffff8c7 7ffff8ac 7ffff872 7ffff860 r `
LO	=	24545059	[7ffff820]	00000000 2f3a4300 72657355 6e612f73 C : / U s e r s / a n
			[7ffff830]	2f696861 75636f44 746e656d 65522f73 a h i / D o c u m e n t s / R e
R0 [r0]	=	0	[7ffff840]	342f6f70 412f3034 67697373 6e656d6e p o / 4 4 0 / A s s i g n m e n
R1 [at]	=	268500992	[7ffff850]	702f3174 31747261 2d34715f 00732e36 t l / p a r t l _ q 4 - 6 . s .
R2 [v0]	=	10	[7ffff860]	646e6977 433d7269 49575c3a 574f444e w i n d i r = C : \ W I N D O W
R3 [v1]	=	0	[7ffff870]	42560053 4d5f584f 495f4953 4154534e S . V B O X _ M S I _ I N S T A
R4 [a0]	=	1	[7ffff880]	505f4c4c 3d485441 505c3a43 72676f72 L L _ P A T H = C : \ P r o g r a
R5 [a1]	=	2147481444	[7ffff890]	46206d61 73656c69 61724f5c 5c656c63 a m _ F i l e s \ O r a c l e \
R6 [a2]	=	2147481452	[7ffff8a0]	74726956 426c6175 005c786f 52455355 V i r t u a l B o x \ . U S E R
R7 [a3]	=	0	[7ffff8b0]	464f5250 3d454c49 555c3a43 73726573 P R O F I L E = C : \ U s e r s
R8 [t0]	=	3	[7ffff8c0]	616e615c 55006968 4e524553 3d454d41 \ a n a h i . U S E R N A M E =
R9 [t1]	=	-21	[7ffff8d0]	68616e61 53550069 4f445245 4e49414d a n a h i . U S E R D O M A I N
R10 [t2]	=	24545038	[7ffff8e0]	414f525f 474e494d 464f5250 3d454c49 _ R O A M I N G P R O F I L E =
R11 [t3]	=	0	[7ffff8f0]	48414e41 502d4449 53550043 4f445245 A N A H I D - P C . U S E R D O
R12 [t4]	=	2023	[7ffff900]	4e49414d 414e413d 2d444948 54004350 M A I N = A N A H I D - P C . T
R13 [t5]	=	18	[7ffff910]	433d504d 73555c3a 5c737265 68616e61 M P = C : \ U s e r s \ a n a h
R14 [t6]	=	24545038	[7ffff920]	70415c69 74614470 6f4c5c61 5c6c6163 i \ A p p D a t a \ L o c a l \
R15 [t7]	=	0	[7ffff930]	706d6554 4d455400 3a433d50 6573555c T e m p . T E M P = C : \ U s e
R16 [s0]	=	0	[7ffff940]	615c7372 6968616e 7070415c 61746144 r s \ a n a h i \ A p p D a t a
R17 [s1]	=	0	[7ffff950]	636f4c5c 545c6c61 00706d65 74737953 \ L o c a l \ T e m p . S y s t
R18 [s2]	=	0	[7ffff960]	6f526d65 433d746f 49575c3a 574f444e e m R o o t = C : \ W I N D O W
R19 [s3]	=	0	[7ffff970]	79530053 6d657473 76697244 3a433d65 S . S y s t e m D r i v e = C :
R20 [s4]	=	0	[7ffff980]	53455300 4e4f4953 454d414e 6e6f433d . S E S S I O N N A M E = C o n
R21 [s5]	=	0	[7ffff990]	656c6f73 736c5200 50637653 3d74726f s o l e . R l s S v c P o r t =
R22 [s6]	=	0	[7ffff9a0]	31313232 55500032 43494c42 5c3a433d 2 2 1 1 2 . P U B L I C = C : \
R23 [s7]	=	0	[7ffff9b0]	72657355 75505c73 63696c62 4d535000 U s e r s \ P u b l i c . P S M
R24 [t8]	=	0	[7ffff9c0]	6c75646f 74615065 3a433d68 6f72505c o d u l e P a t h = C : \ P r o
R25 [t9]	=	0	[7ffff9d0]	6d617267 6c694620 575c7365 6f646e69 g r a m _ F i l e s \ W i n d o
R26 [k0]	=	0	[7ffff9e0]	6f507377 53726577 6c6c6568 646f4d5c w s P o w e r S h e l l \ M o d
R27 [k1]	=	0	[7ffff9f0]	73656c75 5c3a433b 444e4957 5c53574f u l e s ; C : \ W I N D O W S \

Part 2 – MIPS Procedure Call. Relevant assembly file: part2.s

- **Q3:**
 - **a:**

Reqs

Int Regs [10]

Data

Text

Int Regs [10]

PC = 4194484

EPC = 0

Cause = 0

BadVAddr = 0

Status = 805371664

HI = 0

LO = 125122099

R0 [r0] = 0

R1 [at] = 268500992

R2 [v0] = 10

R3 [v1] = 0

R4 [a0] = 268500992

R5 [a1] = 2147481444

R6 [a2] = 2147481452

R7 [a3] = 0

R8 [t0] = 27397

R9 [t1] = 0

R10 [t2] = 0

R11 [t3] = 0

R12 [t4] = 0

R13 [t5] = 0

R14 [t6] = 0

R15 [t7] = 0

R16 [s0] = 0

R17 [s1] = 0

R18 [s2] = 0

R19 [s3] = 0

R20 [s4] = 0

R21 [s5] = 0

R22 [s6] = 0

R23 [s7] = 0

R24 [t8] = 0

R25 [t9] = 0

R26 [k0] = 0

R27 [k1] = 0

User Text Segment [00400000]..[00440000]

```

[00400000] 8fa40000 lw $4, 0($29)           ; 183: lw $a0 0($sp) # argv
[00400004] 27a50004 addiu $5, $29, 4       ; 184: addiu $a1 $sp 4 # argv
[00400008] 24a60004 addiu $6, $5, 4       ; 185: addiu $a2 $a1 4 # envp
[0040000c] 00041080 sll $2, $4, 2         ; 186: sll $v0 $a0 2
[00400010] 00c23021 addu $6, $6, $2       ; 187: addu $a2 $a2 $v0
[00400014] 0c100013 jal 0x0040004c [main] ; 188: jal main
[00400018] 00000000 nop                  ; 189: nop
[0040001c] 3402000a ori $2, $0, 10        ; 191: li $v0 10
[00400020] 0000000c syscall              ; 192: syscall # syscall 10 (exit)
[00400024] 23bdfffc addi $29, $29, -4     ; 15: addi $sp, $sp, -4 # allocate space on the stack
[00400028] afbf0000 sw $31, 0($29)       ; 16: sw $ra, 0($sp) # save return address
[0040002c] 34010006 ori $1, $0, 6        ; 18: mul $t0, $a0, 6 # 6x
[00400030] 70814002 mul $8, $4, $1
[00400034] 2108fffb addi $8, $8, -5       ; 19: sub $t0, $t0, 5 # 6x-5
[00400038] 71041002 mul $2, $8, $4       ; 20: mul $v0, $t0, $a0 # (6x-5)x
[0040003c] 2042ffeb addi $2, $2, -21     ; 21: sub $v0, $v0, 21 # (6x-5)x - 21
[00400040] 8fbf0000 lw $31, 0($29)       ; 23: lw $ra, 0($sp) # restore return address
[00400044] 23bd0004 addi $29, $29, 4       ; 24: addi $sp, $sp, 4 # deallocate space on the stack
[00400048] 03e00008 jr $31               ; 25: jr $ra # return to caller
[0040004c] 34090000 ori $9, $0, 0        ; 28: li $t1, 0 # set x to 0 initially to start the loop
[00400050] 34020004 ori $2, $0, 4        ; 32: li $v0, 4 # system call for print string
[00400054] 3c041001 lui $4, 4097 [inputPrompt]; 33: la $a0, inputPrompt # load input prompt string
[00400058] 0000000c syscall              ; 34: syscall
[0040005c] 34020005 ori $2, $0, 5        ; 37: li $v0, 5 # system call for read integer
[00400060] 0000000c syscall              ; 38: syscall
[00400064] 00024821 addu $9, $0, $2       ; 39: move $t1, $v0 # store user input in $t1
[00400068] 11200012 beq $9, $0, 72 [exit-0x00400068]
[0040006c] 21240000 addi $4, $9, 0       ; 45: addi $a0, $t1, 0 # move x to $a0
[00400070] 0c100009 jal 0x00400024 [calculateFx]; 46: jal calculateFx # jump to calculateFx procedure
[00400074] 3c011001 lui $1, 4097         ; 49: sw $v0, result # store result in memory
[00400078] ac220038 sw $2, 56($1)
[0040007c] 34020004 ori $2, $0, 4        ; 50: li $v0, 4 # system call for print string
[00400080] 3c011001 lui $1, 4097 [resultPrompt]; 51: la $a0, resultPrompt # load result prompt string
[00400084] 34240022 ori $4, $1, 34 [resultPrompt]

```

Console

```

Enter a value for x (0 to exit): 3
Result for x = 18
Enter a value for x (0 to exit): 2023
Result for x = 24545038
Enter a value for x (0 to exit): 4567
Result for x = 125122078
Enter a value for x (0 to exit): 0

```

- **b:**

Reqs

Int Regs [10]

Data

Text

Int Regs [10]

PC = 4194484

EPC = 0

Cause = 0

BadVAddr = 0

Status = 805371664

HI = 0

LO = 125122099

R0 [r0] = 0

R1 [at] = 268500992

R2 [v0] = 10

R3 [v1] = 0

R4 [a0] = 268500992

R5 [a1] = 2147481444

R6 [a2] = 2147481452

R7 [a3] = 0

R8 [t0] = 27397

R9 [t1] = 0

R10 [t2] = 0

R11 [t3] = 0

R12 [t4] = 0

R13 [t5] = 0

R14 [t6] = 0

R15 [t7] = 0

R16 [s0] = 0

R17 [s1] = 0

R18 [s2] = 0

R19 [s3] = 0

R20 [s4] = 0

R21 [s5] = 0

R22 [s6] = 0

R23 [s7] = 0

R24 [t8] = 0

R25 [t9] = 0

R26 [k0] = 0

R27 [k1] = 0

Data

User data segment [10000000]..[10040000]

[10000000]..[1000ffff] 00000000

[10010000] 65746e45 20612072 756c6176 6f662065 Enter a value fo

[10010010] 20782072 74203028 7865206f 3a297469 r x (0 to exit) :

[10010020] 65520020 746c7573 726f6620 3d207820 . Result for x =

[10010030] 000a0020 00000000 0775361e 00000000 6 u

[10010040]..[1003ffff] 00000000

User Stack [7ffff760]..[80000000]

[7ffff760] 00000001 7ffff82a 00000000 7fffffeb *

[7ffff770] 7fffffdb 7fffffbc 7fffff95 7fffff69 i . . .

[7ffff780] 7fffff3d 7fffff0c 7ffffed0 7ffffe9f =

[7ffff790] 7ffffe88 7ffffe64 7ffffe32 7ffffe27 d 2 '

[7ffff7a0] 7ffffela 7ffffe04 7ffffdda 7ffffdc2

[7ffff7b0] 7ffffdaa 7ffffd73 7ffffd32 7ffffd24 s 2 \$

[7ffff7c0] 7ffffb7e 7ffffb37 7ffffb1a 7ffffad3 ~ 7

[7ffff7d0] 7ffffac0 7ffffaa8 7ffffa8d 7ffffa6f o

[7ffff7e0] 7ffffa46 7ffffa28 7ffff9bd 7ffff9a6 F . . . (.

[7ffff7f0] 7ffff995 7ffff981 7ffff972 7ffff95c r \

[7ffff800] 7ffff935 7ffff90f 7ffff8fa 7ffff8d6 5

[7ffff810] 7ffff8c7 7ffff8ac 7ffff872 7ffff860 r \

[7ffff820] 00000000 00000000 3a430000 6573552f C : / U s e

[7ffff830] 612f7372 6968616e 636f442f 6e656d75 r s / a n a h i / D o c u m e n

[7ffff840] 522f7374 2f6f7065 2f303434 69737341 t s / R e p o / 4 4 0 / A s s i

[7ffff850] 656d6e67 2f31746e 74726170 00732e32 g n m e n t 1 / p a r t 2 . s .

[7ffff860] 646e6977 433d7269 49575c3a 574f444e w i n d i r = C : \ W I N D O W

[7ffff870] 42560053 4d5f584f 495f4953 4154534e S . V B O X _ M S I _ I N S T A

[7ffff880] 505f4c4c 3d485441 505c3a43 72676f72 L L _ P A T H = C : \ P r o g r

[7ffff890] 46206d61 73656c69 61724f5c 5c656c63 a m _ F i l e s \ O r a c l e \

[7ffff8a0] 74726956 426c6175 005c786f 52455355 V i r t u a l B o x \ . U S E R

[7ffff8b0] 464f5250 3d454c49 555c3a43 73726573 P R O F I L E = C : \ U s e r s

[7ffff8c0] 616e615c 55006968 4e524553 3d454d41 \ a n a h i . U S E R N A M E =

[7ffff8d0] 68616e61 53550069 4f445245 4e49414d a n a h i . U S E R D O M A I N

[7ffff8e0] 414f525f 474e494d 464f5250 3d454c49 _ R O A M I N G P R O F I L E =

[7ffff8f0] 48414e41 502d4449 53550043 4f445245 A N A H I D - P C . U S E R D O

[7ffff900] 4e49414d 414e413d 2d444948 54004350 M A I N = A N A H I D - P C . T

Console

Enter a value for x (0 to exit): 3
Result for x = 18
Enter a value for x (0 to exit): 2023
Result for x = 24545038
Enter a value for x (0 to exit): 4567
Result for x = 125122078
Enter a value for x (0 to exit): 0

Part 3 - MIPS Procedure Call Recursive. Relevant assembly file: part3.s

- Q4
 - a:

FP Regs	Int Regs [10]	Data	Text
Int Regs [10]			
PC	= 4194436		
EPC	= 0		
Cause	= 0		
BadVAddr	= 0		
Status	= 805371664		
HI	= 4		
LO	= 2004310016		
R0 [r0]	= 0		
R1 [at]	= 268500992		
R2 [v0]	= 10		
R3 [v1]	= 0		
R4 [a0]	= -1		
R5 [a1]	= 2147481444		
R6 [a2]	= 2147481452		
R7 [a3]	= 0		
R8 [t0]	= 1		
R9 [t1]	= 0		
R10 [t2]	= 0		
R11 [t3]	= 0		
R12 [t4]	= 0		
R13 [t5]	= 0		
R14 [t6]	= 0		
R15 [t7]	= 0		
R16 [s0]	= 2004310016		
R17 [s1]	= 0		
R18 [s2]	= 0		
R19 [s3]	= 0		
R20 [s4]	= 0		
R21 [s5]	= 0		
R22 [s6]	= 0		
R23 [s7]	= 0		
R24 [t8]	= 0		
R25 [t9]	= 0		
R26 [k0]	= 0		
R27 [k1]	= 0		

Text	User Text Segment [00400000]
[00400000] 8fa40000 lw \$4, 0(\$29)	; 183: lw \$a0 0(\$sp) # argc
[00400004] 27a50004 addiu \$5, \$29, 4	; 184: addiu \$a1 \$sp 4 # argv
[00400008] 24a60004 addiu \$6, \$5, 4	; 185: addiu \$a2 \$a1 4 # envp
[0040000c] 00041080 sll \$2, \$4, 2	; 186: sll \$v0 \$a0 2
[00400010] 00c23021 addu \$6, \$6, \$2	; 187: addu \$a2 \$a2 \$v0
[00400014] 0c100009 jal 0x00400024 [main]	; 188: jal main
[00400018] 00000000 nop	; 189: nop
[0040001c] 3402000a ori \$2, \$0, 10	; 191: li \$v0 10
[00400020] 0000000c syscall	; 192: syscall # syscall 10 (exit)
[00400024] 34080001 ori \$8, \$0, 1	; 8: li \$t0, 1 # initialize loop counter
[00400028] 34100000 ori \$16, \$0, 0	; 9: li \$s0, 0 # initialize factorial result
[0040002c] 34020004 ori \$2, \$0, 4	; 13: li \$v0, 4 # print string
[00400030] 3c041001 lui \$4, 4097 [input_prompt];	14: la \$a0, input_prompt
[00400034] 0000000c syscall	; 15: syscall
[00400038] 34020005 ori \$2, \$0, 5	; 18: li \$v0, 5 # read integer
[0040003c] 0000000c syscall	; 19: syscall
[00400040] 00022021 addu \$4, \$0, \$2	; 20: move \$a0, \$v0 # move input value to argument register
[00400044] 0480000f bltz \$4 60 [end_program-0x00400044]	
[00400048] 0c100022 jal 0x00400088 [calculate_factorial]	
[0040004c] 00028021 addu \$16, \$0, \$2	; 27: move \$s0, \$v0 # move factorial result to register s0
[00400050] 34020004 ori \$2, \$0, 4	; 30: li \$v0, 4 # print string
[00400054] 3c011001 lui \$1, 4097 [result_prompt];	31: la \$a0, result_prompt
[00400058] 3424003a ori \$4, \$1, 58 [result_prompt]	
[0040005c] 0000000c syscall	; 32: syscall
[00400060] 34020001 ori \$2, \$0, 1	; 33: li \$v0, 1 # print integer
[00400064] 00102021 addu \$4, \$0, \$16	; 34: move \$a0, \$s0 # move factorial result to argument register
[00400068] 0000000c syscall	; 35: syscall
[0040006c] 34020004 ori \$2, \$0, 4	; 38: li \$v0, 4 # print string
[00400070] 3c011001 lui \$1, 4097 [newline];	39: la \$a0, newline
[00400074] 3424004a ori \$4, \$1, 74 [newline]	
[00400078] 0000000c syscall	; 40: syscall
[0040007c] 0810000b j 0x0040002c [input_loop];	42: j input_loop # repeat loop
[00400080] 3402000a ori \$2, \$0, 10	; 45: li \$v0, 10 # exit program
[00400084] 0000000c syscall	; 46: syscall # call syscall to exit the program

Console

```

Enter a non-negative integer to calculate its factorial: 5
Result for x = 120
Enter a non-negative integer to calculate its factorial: 15
Result for x = 2004310016
Enter a non-negative integer to calculate its factorial: -1
  
```

o b:

FP Reqs

Int Regs [10]

Data

Text

Int Regs [10]

PC = 4194436

EPC = 0

Cause = 0

BadVAddr = 0

Status = 805371664

HI = 4

LO = 2004310016

R0 [r0] = 0

R1 [at] = 268500992

R2 [v0] = 10

R3 [v1] = 0

R4 [a0] = -1

R5 [a1] = 2147481444

R6 [a2] = 2147481452

R7 [a3] = 0

R8 [t0] = 1

R9 [t1] = 0

R10 [t2] = 0

R11 [t3] = 0

R12 [t4] = 0

R13 [t5] = 0

R14 [t6] = 0

R15 [t7] = 0

R16 [s0] = 2004310016

R17 [s1] = 0

R18 [s2] = 0

R19 [s3] = 0

R20 [s4] = 0

R21 [s5] = 0

R22 [s6] = 0

R23 [s7] = 0

R24 [t8] = 0

R25 [t9] = 0

R26 [k0] = 0

R27 [k1] = 0

Data

User data segment [10000000]..[10040000]

[10000000]..[1000ffff] 00000000

[10010000] 65746e45 20612072 2d6e6f6e 6167656e Enter a non-negative integer to calculate its factorial: 5

[10010010] 65766974 746e6920 72656765 206f7420 tive integer to

[10010020] 636c6163 74616c75 74692065 61662073 calculate its fa

[10010030] 726f7463 3a6c6169 65520020 746c7573 torial: . Result

[10010040] 726f6620 3d207820 000a0020 00000000 for x =

[10010050]..[1003ffff] 00000000

User Stack [7ffff760]..[80000000]

[7ffff760] 00000001 7ffff82a 00000000 7fffffeb *

[7ffff770] 7fffffdb 7fffffbc 7fffff95 7fffff69 i . . .

[7ffff780] 7fffff3d 7fffff0c 7ffffed0 7ffffe9f =

[7ffff790] 7ffffe88 7ffffe64 7ffffe32 7ffffe27 d . . . 2 . . . ' . . .

[7ffff7a0] 7ffffela 7ffffe04 7ffffdda 7ffffdc2

[7ffff7b0] 7ffffdaa 7ffffd73 7ffffd32 7ffffd24 s . . . 2 . . . \$. . .

[7ffff7c0] 7ffffb7e 7ffffb37 7ffffb1a 7ffffad3 ~ . . . 7

[7ffff7d0] 7ffffac0 7ffffaa8 7ffffa8d 7ffffa6f o . . .

[7ffff7e0] 7ffffa46 7ffffa28 7ffff9bd 7ffff9a6 F . . . (.

[7ffff7f0] 7ffff995 7ffff981 7ffff972 7ffff95c r . . . \ . . .

[7ffff800] 7ffff935 7ffff90f 7ffff8fa 7ffff8d6 5

[7ffff810] 7ffff8c7 7ffff8ac 7ffff872 7ffff860 r . . . \ . . .

[7ffff820] 00000000 00000000 3a430000 6573552f C : / U s e

[7ffff830] 612f7372 6968616e 636f442f 6e656d75 r s / a n a h i / D o c u m e n

[7ffff840] 522f7374 2f6f7065 2f303434 69737341 t s / R e p o / 4 4 0 / A s s i

[7ffff850] 656d6e67 2f31746e 74726170 00732e33 g n m e n t 1 / p a r t 3 . s .

[7ffff860] 646e6977 433d7269 49575c3a 574f444e w i n d i r = C : \ W I N D O W

[7ffff870] 42560053 4d5f584f 495f4953 4154534e S . V B O X _ M S I _ I N S T A

[7ffff880] 505f4c4c 3d485441 505c3a43 72676f72 L L _ P A T H = C : \ P r o g r

[7ffff890] 46206d61 73656c69 61724f5c 5c656c63 a m _ F i l e s \ O r a c l e \

[7ffff8a0] 74726956 426c6175 005c786f 52455355 V i r t u a l B o x \ . U S E R

[7ffff8b0] 464f5250 3d454c49 555c3a43 73726573 P R O F I L E = C : \ U s e r s

[7ffff8c0] 616e615c 55006968 4e524553 3d454d41 \ a n a h i . U S E R N A M E =

[7ffff8d0] 68616e61 53550069 4f445245 4e49414d a n a h i . U S E R D O M A I N

[7ffff8e0] 414f525f 474e494d 464f5250 3d454c49 _ R O A M I N G P R O F I L E =

[7ffff8f0] 48414e41 502d4449 53550043 4f445245 A N A H I D - P C . U S E R D O

```

Enter a non-negative integer to calculate its factorial: 5
Result for x = 120
Enter a non-negative integer to calculate its factorial: 15
Result for x = 2004310016
Enter a non-negative integer to calculate its factorial: -1

```

Part 4 - Implementing MIPS Assembly Pseudocode. Relevant assembly file: part4.s

- Q1: this is my implementation

```

lw $t0, A    # $t0 = Memory[$rs]
lw $t1, B    # $t1 = Memory[$rt]
add $t2, $t0, $t1 # $t2 = $t0 + $t1
sw $t2, C    # Memory[$rd] = $t2

```

- In the first step of this implementation, the data is loaded from the memory location specified by \$rs into register \$t0 using the "lw" (load word) instruction. The address of the first memory location to be added is stored in \$rs.

2. The second step loads the data from the memory location specified by \$rt into register \$t1 using the "lw" instruction. The address of the second memory location to be added is stored in \$rt.
3. The third step uses the "add" instruction to add the contents of \$t0 and \$t1 and store the result in \$t2. The "add" instruction adds the values in \$t0 and \$t1 and stores the result in \$t2.
4. Finally, in the fourth step, the "sw" (store word) instruction is used to store the contents of \$t2 into the memory location specified by \$rd. The address of the memory location where the result of the addition should be stored is stored in \$rd, and the "sw" instruction stores the contents of \$t2 into that memory location.

- **Q3:**

.data

A: .word 0

B: .word 0

C: .word 0

newline: .asciiz "\n"

prompt: .asciiz "Do you want to run again? (y/n) "

msg_A: .asciiz "Enter value for A: "

msg_B: .asciiz "Enter value for B: "

msg_result: .asciiz "Result: "

.text

main:

Prompt user to enter A and B values

li \$v0, 4

la \$a0, newline

syscall

li \$v0, 4

la \$a0, msg_A

syscall

li \$v0, 5

syscall

sw \$v0, A

```
li $v0, 4
la $a0, newline
syscall
```

```
li $v0, 4
la $a0, msg_B
syscall
```

```
li $v0, 5
syscall
sw $v0, B
```

```
# begin my pseudo-code implementation for addmem $rd, $rs, $rt
lw $t0, A    # $t0 = Memory[$rs]
lw $t1, B    # $t1 = Memory[$rt]
add $t2, $t0, $t1 # $t2 = $t0 + $t1
sw $t2, C    # Memory[$rd] = $t2
# end of my pseudo-code
```

```
# Display result on console screen
li $v0, 4
la $a0, msg_result
syscall
```

```
lw $a0, C
li $v0, 1
syscall
```

```
li $v0, 4
la $a0, newline
syscall
```

Ask user to rerun or not

li \$v0, 4

la \$a0, prompt

syscall

li \$v0, 12

syscall

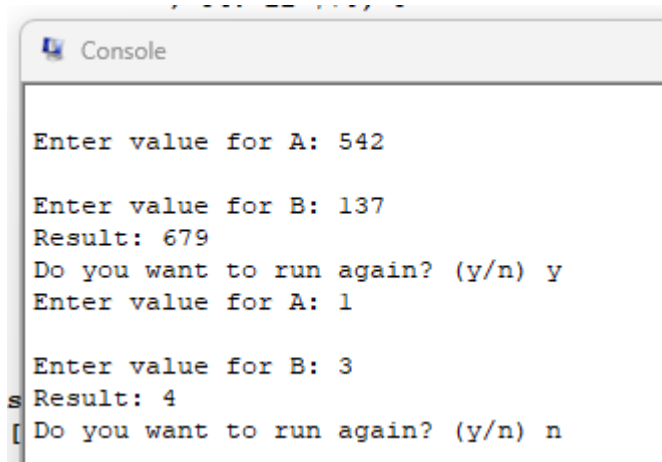
beq \$v0, 121, main # If user enters y, rerun program

Exit program if user enters n

li \$v0, 10

syscall

- **Q4:**

A screenshot of a console window titled "Console". The window displays the following text:

```
Enter value for A: 542
Enter value for B: 137
Result: 679
Do you want to run again? (y/n) y
Enter value for A: 1
Enter value for B: 3
Result: 4
Do you want to run again? (y/n) n
```

- **Q5:**

- **a:**

FP Regs	Int Regs [10]	Data	Text
Int Regs [10]		Text	
PC	= 4194548	[00400068] 3c011001	lui \$1, 4097 [msg_B] ; 31: la \$a0, msg_B
EPC	= 0	[0040006c] 34240043	ori \$4, \$1, 67 [msg_B]
Cause	= 0	[00400070] 0000000c	syscall ; 32: syscall
BadVAddr	= 0	[00400074] 34020005	ori \$2, \$0, 5 ; 34: li \$v0, 5
Status	= 805371664	[00400078] 0000000c	syscall ; 35: syscall
		[0040007c] 3c011001	lui \$1, 4097 ; 36: sw \$v0, B
HI	= 0	[00400080] ac220004	sw \$2, 4(\$1)
LO	= 0	[00400084] 3c011001	lui \$1, 4097 ; 39: lw \$t0, A # \$t0 = Memory[\$rs]
		[00400088] 8c280000	lw \$8, 0(\$1)
R0 [r0]	= 0	[0040008c] 3c011001	lui \$1, 4097 ; 40: lw \$t1, B # \$t1 = Memory[\$rt]
R1 [at]	= 121	[00400090] 8c290004	lw \$9, 4(\$1)
R2 [v0]	= 10	[00400094] 01095020	add \$10, \$8, \$9 ; 41: add \$t2, \$t0, \$t1 # \$t2 = \$t0 + \$t1
R3 [v1]	= 0	[00400098] 3c011001	lui \$1, 4097 ; 42: sw \$t2, C # Memory[\$rd] = \$t2
R4 [a0]	= 268501006	[0040009c] ac2a0008	sw \$10, 8(\$1)
R5 [a1]	= 2147481444	[004000a0] 34020004	ori \$2, \$0, 4 ; 46: li \$v0, 4
R6 [a2]	= 2147481452	[004000a4] 3c011001	lui \$1, 4097 [msg_result]; 47: la \$a0, msg_result
R7 [a3]	= 0	[004000a8] 34240057	ori \$4, \$1, 87 [msg_result]
R8 [t0]	= 542	[004000ac] 0000000c	syscall ; 48: syscall
R9 [t1]	= 137	[004000b0] 3c011001	lui \$1, 4097 ; 50: lw \$a0, C
R10 [t2]	= 679	[004000b4] 8c240008	lw \$4, 8(\$1)
R11 [t3]	= 0	[004000b8] 34020001	ori \$2, \$0, 1 ; 51: li \$v0, 1
R12 [t4]	= 0	[004000bc] 0000000c	syscall ; 52: syscall
R13 [t5]	= 0	[004000c0] 34020004	ori \$2, \$0, 4 ; 54: li \$v0, 4
R14 [t6]	= 0	[004000c4] 3c011001	lui \$1, 4097 [newline] ; 55: la \$a0, newline
R15 [t7]	= 0	[004000c8] 3424000c	ori \$4, \$1, 12 [newline]
R16 [s0]	= 0	[004000cc] 0000000c	syscall ; 56: syscall
R17 [s1]	= 0	[004000d0] 34020004	ori \$2, \$0, 4 ; 59: li \$v0, 4
R18 [s2]	= 0	[004000d4] 3c011001	lui \$1, 4097 [prompt] ; 60: la \$a0, prompt
R19 [s3]	= 0	[004000d8] 3424000e	ori \$4, \$1, 14 [prompt]
R20 [s4]	= 0	[004000dc] 0000000c	syscall ; 61: syscall
R21 [s5]	= 0	[004000e0] 3402000c	ori \$2, \$0, 12 ; 63: li \$v0, 12
R22 [s6]	= 0	[004000e4] 0000000c	syscall ; 64: syscall
R23 [s7]	= 0	[004000e8] 34010079	ori \$1, \$0, 121 ; 66: beq \$v0, 121, main # If user enters y, r
R24 [t8]	= 0	[004000ec] 1022ffce	beq \$1, \$2, -200 [main-0x004000ec]
R25 [t9]	= 0	[004000f0] 3402000a	ori \$2, \$0, 10 ; 69: li \$v0, 10
R26 [k0]	= 0	[004000f4] 0000000c	syscall ; 70: syscall
R27 [k1]	= 0		

○ **b:**

FP Reqs	Int Regs [10]	Data	Text
Int Regs [10]		Data	
PC = 4194548		User data segment [10000000]..[10040000]	
EPC = 0		[10000000]..[1000ffff]	00000000
Cause = 0		[10010000]	0000021e 00000089 000002a7 6f44000a D o
BadVAddr = 0		[10010010]	756f7920 6e617720 6f742074 6e757220 y o u w a n t t o r u n
Status = 805371664		[10010020]	61676120 203f6e69 6e2f7928 45002029 a g a i n ? (y / n) . E
		[10010030]	7265746e 6c617620 66206575 4120726f n t e r v a l u e f o r A
HI = 0		[10010040]	4500203a 7265746e 6c617620 66206575 : . E n t e r v a l u e f
LO = 0		[10010050]	4220726f 5200203a 6c757365 00203a74 o r B : . R e s u l t : .
		[10010060]..[1003ffff]	00000000
R0 [r0] = 0		User Stack [7ffff760]..[80000000]	
R1 [at] = 121		[7ffff760]	00000001 7ffff82a 00000000 7fffffeb *
R2 [v0] = 10		[7ffff770]	7fffffdb 7fffffbc 7fffff95 7fffff69 i . . .
R3 [v1] = 0		[7ffff780]	7fffff3d 7fffff0c 7ffffed0 7ffffe9f =
R4 [a0] = 268501006		[7ffff790]	7ffffe88 7ffffe64 7ffffe32 7ffffe27 d . . . 2 . . . ' . . .
R5 [a1] = 2147481444		[7ffff7a0]	7ffffela 7ffffe04 7ffffdda 7ffffdc2
R6 [a2] = 2147481452		[7ffff7b0]	7ffffdaa 7ffffd73 7ffffd32 7ffffd24 s . . . 2 . . . \$. . .
R7 [a3] = 0		[7ffff7c0]	7ffffb7e 7ffffb37 7ffffbla 7ffffad3 ~ . . . 7
R8 [t0] = 542		[7ffff7d0]	7ffffac0 7ffffaa8 7ffffa8d 7ffffa6f o . . .
R9 [t1] = 137		[7ffff7e0]	7ffffa46 7ffffa28 7ffff9bd 7ffff9a6 F . . . (.
R10 [t2] = 679		[7ffff7f0]	7ffff995 7ffff981 7ffff972 7ffff95c r . . . \ . . .
R11 [t3] = 0		[7ffff800]	7ffff935 7ffff90f 7ffff8fa 7ffff8d6 5
R12 [t4] = 0		[7ffff810]	7ffff8c7 7ffff8ac 7ffff872 7ffff860 r . . . ` . . .
R13 [t5] = 0		[7ffff820]	00000000 00000000 3a430000 6573552f C : / U s e
R14 [t6] = 0		[7ffff830]	612f7372 6968616e 636f442f 6e656d75 r s / a n a h i / D o c u m e n
R15 [t7] = 0		[7ffff840]	522f7374 2f6f7065 2f303434 69737341 t s / R e p o / 4 4 0 / A s s i
R16 [s0] = 0		[7ffff850]	656d6e67 2f31746e 74726170 00732e34 g n m e n t 1 / p a r t 4 . s .
R17 [s1] = 0		[7ffff860]	646e6977 433d7269 49575c3a 574f444e w i n d i r = C : \ W I N D O W
R18 [s2] = 0		[7ffff870]	42560053 4d5f584f 495f4953 4154534e S . V B O X _ M S I _ I N S T A
R19 [s3] = 0		[7ffff880]	505f4c4c 3d485441 505c3a43 72676f72 L L _ P A T H = C : \ P r o g r
R20 [s4] = 0		[7ffff890]	46206d61 73656c69 61724f5c 5c656c63 a m _ F i l e s \ O r a c l e \
R21 [s5] = 0		[7ffff8a0]	74726956 426c6175 005c786f 52455355 V i r t u a l B o x \ . U S E R
R22 [s6] = 0		[7ffff8b0]	464f5250 3d454c49 555c3a43 73726573 P R O F I L E = C : \ U s e r s
R23 [s7] = 0		[7ffff8c0]	616e615c 55006968 4e524553 3d454d41 \ a n a h i . U S E R N A M E =
R24 [t8] = 0		[7ffff8d0]	68616e61 53550069 4f445245 4e49414d a n a h i . U S E R D O M A I N
R25 [t9] = 0		[7ffff8e0]	414f525f 474e494d 464f5250 3d454c49 _ R O A M I N G P R O F I L E =