

TRƯỜNG ĐẠI HỌC BÁCH KHOA TP.HCM KHOA KHOA HỌC VÀ KỸ THUẬT MÁY TÍNH



BÁO CÁO BÀI TẬP LỚN KIẾN TRÚC MÁY TÍNH

Đề 6: Sắp xếp chuỗi. Cho một chuỗi số nguyên 20 phần tử. Sử dụng hợp ngữ assembly MIPS, viết thủ tục sắp xếp chuỗi đó theo tứ tự tăng dần theo giải thuật merge sort.

GV hướng dẫn: Trần Thanh Bình

Lóp: L05

Nhóm thực hiện :

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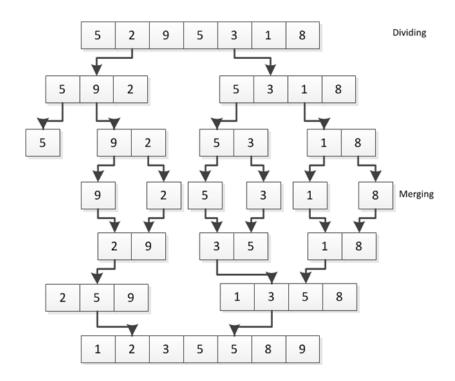
Divide and conquer là một trong số những mẫu thiết kế giải thuật chung được nhiều người biết đến nhất, và **merge sort** là một ứng dụng hay được tạo ra trên nền algorithm này.

Các giải thuật devide and conquer hoạt động theo các bước sau:

- Problem sẽ được chia thành nhiều cụm nhỏ, nên có kích thước bằng nhau.
- Chúng ta sẽ xử lý tuần tử các problem nhỏ, đa số dùng đệ quy.
- Trong một số trường hợp, kết quả của chúng sẽ được gộp để có kết quả.

Giải thuật Merge Sort

Merge sort là một ví dụ của giải thuật divide and conquer này. Sau khi chia đủ nhỏ, merge sort sẽ gộp hai dữ liệu đã sort thành một dữ liệu lớn hơn.



Ưu nhược điểm của Merge sort:

- Ưu: Độ phức tạp tốt hơn so với Insertion Sort, Selection Sort, Interchange Sort
- Nhược: Cần thêm bộ nhớ để chứa một mảng thứ 3

Hàm Merge sort:

```
merge sort:
slt $t6, $a1, $a2
bne $t6, $0, mergesort #if(a2 \le a1) return
jr $ra
mergesort:
add $s0, $a1, $a2
addi $s0, $s0, -1
                       \# \$s0 = (\$a1 + \$a2 - 1)/2
div $s0, $s0, 2
add $sp, $sp, -16
sw $ra, 12($sp)
                        # save address $ra
sw $a1, 8($sp)
                       # save address $a1
sw $a2, 4($sp)
                       # save address $a2
sw $s0, 0($sp)
move $a2, $s0
                       # \$a2 = \$s0
                        # merge sort(string, a1, a2)
jal merge sort
lw $s0, 0($sp)
lw $a2, 4($sp)
                       # save address $a2
                        \# $a1 = $s0 + 1
addi $a1, $s0, 1
jal merge sort
                       # merge sort(string, a1, a2)
lw $s0, 0($sp)
lw $a2, 4($sp)
                       # restore $a2
lw $a1, 8($sp)
                        # restore $a1
jal merge
                        # merge(string, a1, s0, a2)
lw $s0, 0($sp)
lw $a2, 4($sp)
                       # restore $a2
lw $a1, 8($sp)
lw $ra, 12($sp)
                       # restore $ra
add $sp, $sp, 16
jr $ra
```

```
.data
size: .word 20
arr1: .space 40
arr2: .space 40
###################### begin merge ######################
merge:
sub $s1, $s0, $a1
addi $s1, $s1, 1
                          # $s1 = $s0 - $a1 + 1
                          \# \$s2 = \$a2 - \$s0
sub $s2, $a2, $s0
mul $a1, $a1, 4
mul $a2, $a2, 4
mul $s0, $s0, 4
la $t1, arr1
                          # $t1 <- arr1[size]
la $t2, arr2
                          # $t2 <- arr2[size]
la $s3, string
add $s3, $s3, $a1
                           # string[a1]
                            # i = 0
li $t3, 0
loop T1:
lw $s4, 0($s3)
sw $s4, 0($t1)
                          # arr1[i] = string[a1+i]
addi $t3, $t3, 1
                            # i++
la $s3, 4($s3)
la $t1, 4($t1)
bne $t3, $s1, loop_T1  # if(i == s1) break
la $s3, string
add $s3, $s3, $s0
                         # string[s0]
la $s3, 4($s3)
                          # string[s0+1]
li $t3, 0
                           # i = 0
100p_T2:
lw $s4, 0($s3)
sw $s4, 0($t2)
                         # arr2[i] = string[s0+1+i]
                           # i++
addi $t3, $t3, 1
la $s3, 4($s3)
la $t2, 4($t2)
bne $t3, $s2, loop_T2 # if(i == s2) break
```

TEST CASE 1:

.word 18, 9, 11, 20, 10, 8, 13, 19, 17, 7, 6, 12, 5, 16, 4, 15, 3, 2, 1, 14

Instruction	n Statistics, Version 1.	0 (Ingo Kofler)	×	Instruction Counter, Version 1.0 (Felipe Lessa)							
Total:	8414			Counting the	e number of	instructions	exec				
ALU:	4894	58%		Instructions so far:	8414						
Jump:	271	3%		R-type:	2251	26%					
Branch:	812	10%		I-type:	5970	70%					
Memory:	1188	14%		J-type:		2%					
Other:	1249	15%		у-туре.	193	2 /0					
Disconne	Tool Co	ntrol Reset Clos	e	Disconnect from	Tool Contr		ose				

18 9 11 20 10 8 13 19 17 7 6 12 5 16 4 15 3 2 1 14 9 18 11 20 10 8 13 19 17 7 6 12 5 16 4 15 3 2 1 14 9 18 11 10 20 8 13 19 17 7 6 12 5 16 4 15 3 2 1 14 9 18 10 11 20 8 13 19 17 7 6 12 5 16 4 15 3 2 1 14 9 10 11 18 20 8 13 19 17 7 6 12 5 16 4 15 3 2 1 14 9 10 11 18 20 8 13 19 17 7 6 12 5 16 4 15 3 2 1 14 9 10 11 18 20 8 13 19 7 17 6 12 5 16 4 15 3 2 1 14 9 10 11 18 20 8 13 7 17 19 6 12 5 16 4 15 3 2 1 14 9 10 11 18 20 7 8 13 17 19 6 12 5 16 4 15 3 2 1 14 7 8 9 10 11 13 17 18 19 20 6 12 5 16 4 15 3 2 1 14 7 8 9 10 11 13 17 18 19 20 6 12 5 16 4 15 3 2 1 14 7 8 9 10 11 13 17 18 19 20 6 12 5 4 16 15 3 2 1 14 7 8 9 10 11 13 17 18 19 20 6 12 4 5 16 15 3 2 1 14 7 8 9 10 11 13 17 18 19 20 4 5 6 12 16 15 3 2 1 14 7 8 9 10 11 13 17 18 19 20 4 5 6 12 16 3 15 2 1 14 7 8 9 10 11 13 17 18 19 20 4 5 6 12 16 3 15 2 1 14 7 8 9 10 11 13 17 18 19 20 4 5 6 12 16 3 15 1 2 14 7 8 9 10 11 13 17 18 19 20 4 5 6 12 16 1 2 3 14 15 7 8 9 10 11 13 17 18 19 20 1 2 3 4 5 6 12 14 15 16 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Thời gian thực thi: execution time
$$= \frac{CPI \times Intrustions}{Clock \ rate}$$
$$= \frac{1 \times 8414}{2 \times 10^{9}}$$
$$= 4.207 \ (\mu s)$$

TEST CASE 2:

.word -18, 9, 11, 20, -10, 8, 13, -19, 17, 7, -6, 12, 5, -16, 4, 15, -3, 2, 1, -14

Instruction	n Statistics, Version 1.0) (Ingo Kofler)	Instruction Counter, Version 1.0 (Felipe Lessa)						
Total:	8424		Counting th	e number of	f instructions exec				
ALU:	4896	58%	Instructions so far:	8424					
Jump:	273	3%	R-type:	2252	26%				
Branch:	814	10%	7						
Memory:	1190	14%	I-type:	5976	70%				
Other:	1251	15%	J-type:	195	2%				
Disconne	Tool Co	Reset Close	Disconnect from	Tool Cont	rol Reset Close				

-18 9 11 20 -10 8 13 -19 17 7 -6 12 5 -16 4 15 -3 2 1 -14 -18 9 11 20 -10 8 13 -19 17 7 -6 12 5 -16 4 15 -3 2 1 -14 -18 9 11 -10 20 8 13 -19 17 7 -6 12 5 -16 4 15 -3 2 1 -14 -18 9 -10 11 20 8 13 -19 17 7 -6 12 5 -16 4 15 -3 2 1 -14 -18 -10 9 11 20 8 13 -19 17 7 -6 12 5 -16 4 15 -3 2 1 -14 -18 -10 9 11 20 8 13 -19 17 7 -6 12 5 -16 4 15 -3 2 1 -14 -18 -10 9 11 20 8 13 -19 7 17 -6 12 5 -16 4 15 -3 2 1 -14 -18 -10 9 11 20 8 13 -19 7 17 -6 12 5 -16 4 15 -3 2 1 -14 -18 -10 9 11 20 -19 7 8 13 17 -6 12 5 -16 4 15 -3 2 1 -14 -19 -18 -10 7 8 9 11 13 17 20 -6 12 5 -16 4 15 -3 2 1 -14 -19 -18 -10 7 8 9 11 13 17 20 -6 12 5 -16 4 15 -3 2 1 -14 -19 -18 -10 7 8 9 11 13 17 20 -6 12 5 -16 4 15 -3 2 1 -14 -19 -18 -10 7 8 9 11 13 17 20 -6 12 -16 4 5 15 -3 2 1 -14 -19 -18 -10 7 8 9 11 13 17 20 -16 -6 4 5 12 15 -3 2 1 -14 -19 -18 -10 7 8 9 11 13 17 20 -16 -6 4 5 12 -3 15 2 1 -14 -19 -18 -10 7 8 9 11 13 17 20 -16 -6 4 5 12 -3 15 2 -14 1 -19 -18 -10 7 8 9 11 13 17 20 -16 -6 4 5 12 -3 15 -14 1 2 -19 -18 -10 7 8 9 11 13 17 20 -16 -6 4 5 12 -14 -3 1 2 15 -19 -18 -10 7 8 9 11 13 17 20 -16 -14 -6 -3 1 2 4 5 12 15 -19 -18 -16 -14 -10 -6 -3 1 2 4 5 7 8 9 11 12 13 15 17 20

Thời gian thực thi: execution time
$$= \frac{CPI \times Intrustions}{Clock \ rate}$$
$$= \frac{1 \times 8424}{2 \times 10^{9}}$$
$$= 4.212 \ (\mu s)$$

TEST CASE 3:

.word 18,9,11,20,-10,8,13,19,17,100,-7,6,-12,5,-16,4,-15,-100,-1,56

Instruc	tion Statistics, Version	1.0 (Ingo Kofler)	Instruction Counter, Version 1.0 (Fe	lipe Lessa) X
Total:	8421		Counting the number o	f instructions execut
ALU:	4892	58%	Instructions so far: 8421	
Jump:	278	3%		
Branch:	810	9%	R-type: 2253	26%
Memory:	1190	14%	I-type: 5968	70%
Other:	1251	15%	J-type : 200	2%
Discor	Tool Co	Reset Close	Tool Co Disconnect from MIPS	ntrol Close

18 9 11 20 -10 8 13 19 17 100 -7 6 -12 5 -16 4 -15 -100 -1 56 9 18 11 20 -10 8 13 19 17 100 -7 6 -12 5 -16 4 -15 -100 -1 56 9 18 11 -10 20 8 13 19 17 100 -7 6 -12 5 -16 4 -15 -100 -1 56 9 18 -10 11 20 8 13 19 17 100 -7 6 -12 5 -16 4 -15 -100 -1 56 -10 9 11 18 20 8 13 19 17 100 -7 6 -12 5 -16 4 -15 -100 -1 56 -10 9 11 18 20 8 13 19 17 100 -7 6 -12 5 -16 4 -15 -100 -1 56 -10 9 11 18 20 8 13 19 17 100 -7 6 -12 5 -16 4 -15 -100 -1 56 -10 9 11 18 20 8 13 17 19 100 -7 6 -12 5 -16 4 -15 -100 -1 56 -10 9 11 18 20 8 13 17 19 100 -7 6 -12 5 -16 4 -15 -100 -1 56 -10 8 9 11 13 17 18 19 20 100 -7 6 -12 5 -16 4 -15 -100 -1 56 -10 8 9 11 13 17 18 19 20 100 -7 6 -12 5 -16 4 -15 -100 -1 56 -10 8 9 11 13 17 18 19 20 100 -7 6 -12 -16 5 4 -15 -100 -1 56 -10 8 9 11 13 17 18 19 20 100 -7 6 -16 -12 5 4 -15 -100 -1 56 -10 8 9 11 13 17 18 19 20 100 -16 -12 -7 5 6 4 -15 -100 -1 56 -10 8 9 11 13 17 18 19 20 100 -16 -12 -7 5 6 -15 4 -100 -1 56 -10 8 9 11 13 17 18 19 20 100 -16 -12 -7 5 6 -15 4 -100 -1 56 -10 8 9 11 13 17 18 19 20 100 -16 -12 -7 5 6 -15 4 -100 -1 56 -10 8 9 11 13 17 18 19 20 100 -16 -12 -7 5 6 -100 -15 -1 4 56 -10 8 9 11 13 17 18 19 20 100 -100 -16 -15 -12 -7 -1 4 5 6 56 -100 -16 -15 -12 -10 -7 -1 4 5 6 8 9 11 13 17 18 19 20 56 100

Thời gian thực thi: execution time
$$= \frac{CPI \times Intrustions}{Clock \ rate}$$
$$= \frac{1 \times 8421}{2 \times 10^{9}}$$
$$= 4.2105 \ (\mu s)$$

TEST CASE 4:

.word 69,-8,7,35,68,19,23,45,58,-98,-13,44,66,16,22,3,-34,24,56,29

Instruct	tion Statistics, Version	1.0 (Ingo Kofler)	Instruction Counte	er, Version 1.0 (Felipe	e Lessa) X
Total:	8390		Counting the	number of i	instructions execut
ALU:	4887	59%	Instructions so far:	8390	
Jump:	273	3%	Dames	2245	009/
Branch:	805	9%	R-type:		26%
Memory:	1182	14%	I-type:		70%
Other:	1243	15%	J-type:	195	2%
Discon	Tool Co	Reset Close	Disconnect from	Tool Contr	Reset Close

69 -8 7 35 68 19 23 45 58 -98 -13 44 66 16 22 3 -34 24 56 29 -8 69 7 35 68 19 23 45 58 -98 -13 44 66 16 22 3 -34 24 56 29 -8 69 7 35 68 19 23 45 58 -98 -13 44 66 16 22 3 -34 24 56 29 -8 69 7 35 68 19 23 45 58 -98 -13 44 66 16 22 3 -34 24 56 29 -8 7 35 68 69 19 23 45 58 -98 -13 44 66 16 22 3 -34 24 56 29 -8 7 35 68 69 19 23 45 58 -98 -13 44 66 16 22 3 -34 24 56 29 -8 7 35 68 69 19 23 45 -98 58 -13 44 66 16 22 3 -34 24 56 29 -8 7 35 68 69 19 23 -98 45 58 -13 44 66 16 22 3 -34 24 56 29 -8 7 35 68 69 -98 19 23 45 58 -13 44 66 16 22 3 -34 24 56 29 -98 -8 7 19 23 35 45 58 68 69 -13 44 66 16 22 3 -34 24 56 29 -98 -8 7 19 23 35 45 58 68 69 -13 44 66 16 22 3 -34 24 56 29 -98 -8 7 19 23 35 45 58 68 69 -13 44 66 16 22 3 -34 24 56 29 -98 -8 7 19 23 35 45 58 68 69 -13 44 16 22 66 3 -34 24 56 29 -98 -8 7 19 23 35 45 58 68 69 -13 16 22 44 66 3 -34 24 56 29 -98 -8 7 19 23 35 45 58 68 69 -13 16 22 44 66 -34 3 24 56 29 -98 -8 7 19 23 35 45 58 68 69 -13 16 22 44 66 -34 3 24 29 56 -98 -8 7 19 23 35 45 58 68 69 -13 16 22 44 66 -34 3 24 29 56 -98 -8 7 19 23 35 45 58 68 69 -13 16 22 44 66 -34 3 24 29 56 -98 -8 7 19 23 35 45 58 68 69 -34 -13 3 16 22 24 29 44 56 66 -98 -34 -13 -8 3 7 16 19 22 23 24 29 35 44 45 56 58 66 68 69

Thời gian thực thi: execution time
$$= \frac{CPI \times Intrustions}{Clock \ rate}$$
$$= \frac{1 \times 8390}{2 \times 10^{9}}$$
$$= 4.195 \ (\mu s)$$

TEST CASE 5:

.word 564,267,-754,256,237,-872,21,-45,26,28,36,-75,16,186,-257,287,-999,127,-753,666

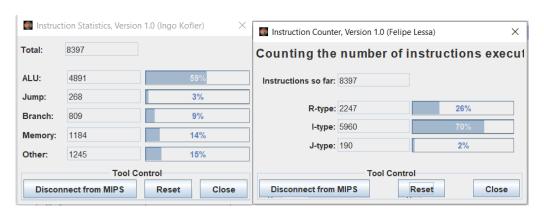
Instruc	tion Statistics, Version	1.0 (Ingo Kofler) X	Instruction Counte	er, Version 1.0 (Felip	e Lessa) ×
Total:	8378		Counting the	number of	instructions execut
ALU:	4883	58%	Instructions so far:	8378	
Jump:	273	3%			
Branch:	801	10%	R-type:	2243	26%
Memory:	1180	14%	I-type:	5940	70%
Other:	1241	15%	J-type:	195	2%
Tool Control				Tool Contr	rol
Discor	nnect from MIPS	Reset Close	Disconnect from	MIPS	Reset Close

564 267 -754 256 237 -872 21 -45 26 28 36 -75 16 186 -257 287 -999 127 -753 666 267 564 -754 256 237 -872 21 -45 26 28 36 -75 16 186 -257 287 -999 127 -753 666 267 564 -754 237 256 -872 21 -45 26 28 36 -75 16 186 -257 287 -999 127 -753 666 267 564 -754 237 256 -872 21 -45 26 28 36 -75 16 186 -257 287 -999 127 -753 666 -754 237 256 267 564 -872 21 -45 26 28 36 -75 16 186 -257 287 -999 127 -753 666 -754 237 256 267 564 -872 21 -45 26 28 36 -75 16 186 -257 287 -999 127 -753 666 -754 237 256 267 564 -872 21 -45 26 28 36 -75 16 186 -257 287 -999 127 -753 666 -754 237 256 267 564 -872 21 -45 26 28 36 -75 16 186 -257 287 -999 127 -753 666 -754 237 256 267 564 -872 -45 21 26 28 36 -75 16 186 -257 287 -999 127 -753 666 -872 -754 -45 21 26 28 237 256 267 564 36 -75 16 186 -257 287 -999 127 -753 666 -872 -754 -45 21 26 28 237 256 267 564 -75 36 16 186 -257 287 -999 127 -753 666 -872 -754 -45 21 26 28 237 256 267 564 -75 36 16 -257 186 287 -999 127 -753 666 -872 -754 -45 21 26 28 237 256 267 564 -75 36 -257 16 186 287 -999 127 -753 666 -872 -754 -45 21 26 28 237 256 267 564 -257 -75 16 36 186 287 -999 127 -753 666 -872 -754 -45 21 26 28 237 256 267 564 -257 -75 16 36 186 -999 287 127 -753 666 -872 -754 -45 21 26 28 237 256 267 564 -257 -75 16 36 186 -999 287 127 -753 666 -872 -754 -45 21 26 28 237 256 267 564 -257 -75 16 36 186 -999 287 -753 127 666 -872 -754 -45 21 26 28 237 256 267 564 -257 -75 16 36 186 -999 -753 127 287 666 -872 -754 -45 21 26 28 237 256 267 564 -999 -753 -257 -75 16 36 127 186 287 666 -999 -872 -754 -753 -257 -75 -45 16 21 26 28 36 127 186 237 256 267 287 564 666

Thời gian thực thi: execution time
$$= \frac{CPI \times Intrustions}{Clock \ rate}$$
$$= \frac{1 \times 8378}{2 \times 10^{9}}$$
$$= 4.189 \ (\mu s)$$

TEST CASE 6:

.word 1234, -4, 20, 235, -940, 9848, -30, -2, -2344, 98, 22, 50, 200, 111, 1, 0, 10, 14, -29, -30



1234 -4 20 235 -940 9848 -30 -2 -2344 98 22 50 200 111 1 0 10 14 -29 -30 -4 1234 20 235 -940 9848 -30 -2 -2344 98 22 50 200 111 1 0 10 14 -29 -30 -4 1234 20 -940 235 9848 -30 -2 -2344 98 22 50 200 111 1 0 10 14 -29 -30 -4 1234 -940 20 235 9848 -30 -2 -2344 98 22 50 200 111 1 0 10 14 -29 -30 -940 -4 20 235 1234 9848 -30 -2 -2344 98 22 50 200 111 1 0 10 14 -29 -30 -940 -4 20 235 1234 -30 9848 -2 -2344 98 22 50 200 111 1 0 10 14 -29 -30 -940 -4 20 235 1234 -30 9848 -2 -2344 98 22 50 200 111 1 0 10 14 -29 -30 -940 -4 20 235 1234 -30 9848 -2344 -2 98 22 50 200 111 1 0 10 14 -29 -30 -940 -4 20 235 1234 -2344 -30 -2 98 9848 22 50 200 111 1 0 10 14 -29 -30 -2344 -940 -30 -4 -2 20 98 235 1234 9848 22 50 200 111 1 0 10 14 -29 -30 -2344 -940 -30 -4 -2 20 98 235 1234 9848 22 50 200 111 1 0 10 14 -29 -30 -2344 -940 -30 -4 -2 20 98 235 1234 9848 22 50 200 1 111 0 10 14 -29 -30 -2344 -940 -30 -4 -2 20 98 235 1234 9848 22 50 1 111 200 0 10 14 -29 -30 -2344 -940 -30 -4 -2 20 98 235 1234 9848 1 22 50 111 200 0 10 14 -29 -30 -2344 -940 -30 -4 -2 20 98 235 1234 9848 1 22 50 111 200 0 10 14 -29 -30 -2344 -940 -30 -4 -2 20 98 235 1234 9848 1 22 50 111 200 0 10 14 -30 -29 -2344 -940 -30 -4 -2 20 98 235 1234 9848 1 22 50 111 200 0 10 -30 -29 14 -2344 -940 -30 -4 -2 20 98 235 1234 9848 1 22 50 111 200 -30 -29 0 10 14 -2344 -940 -30 -4 -2 20 98 235 1234 9848 -30 -29 0 1 10 14 22 50 111 200 -2344 -940 -30 -30 -29 -4 -2 0 1 10 14 20 22 50 98 111 200 235 1234 9848

Thời gian thực thi: execution time $= \frac{CPI \times Intrustions}{Clock \ rate}$ $= \frac{1 \times 8397}{2 \times 10^{9}}$ $= 4.1985 \ (\mu s)$

TEST CASE 7:

.word 6, 7, 30, 450, 10, -49, -20, -154, -235, -390, -22, -456, -40, 29, 0, -23, 45, 290, 39, 99

Instruc	tion Statistics, Version	1.0 (Ingo Kofler)			
			Instruction Counter, V	ersion 1.0 (Felipe Le	essa) ×
Total:	8339		Counting the n	umber of in	structions executed
ALU:	4875	59%	Instructions so far:	8330	
Jump:	270	3%	mstructions so iai.	0333	
Branch:	793	9%	R-type:	2233	26%
Memory:	1170	14%	I-type:	5914	70%
Other:	1231	15%	J-type:	192	2%
Discor	Tool Co	ntrol Close	Disconnect from MIP	Tool Contr	Reset Close

6 7 30 450 10 -49 -20 -154 -235 -390 -22 -456 -40 29 0 -23 45 290 39 99 6 7 30 450 10 -49 -20 -154 -235 -390 -22 -456 -40 29 0 -23 45 290 39 99 6 7 30 10 450 -49 -20 -154 -235 -390 -22 -456 -40 29 0 -23 45 290 39 99 6 7 10 30 450 -49 -20 -154 -235 -390 -22 -456 -40 29 0 -23 45 290 39 99 6 7 10 30 450 -49 -20 -154 -235 -390 -22 -456 -40 29 0 -23 45 290 39 99 6 7 10 30 450 -49 -20 -154 -235 -390 -22 -456 -40 29 0 -23 45 290 39 99 6 7 10 30 450 -49 -20 -154 -390 -235 -22 -456 -40 29 0 -23 45 290 39 99 6 7 10 30 450 -49 -20 -390 -235 -154 -22 -456 -40 29 0 -23 45 290 39 99 6 7 10 30 450 -390 -235 -154 -49 -20 -22 -456 -40 29 0 -23 45 290 39 99 -390 -235 -154 -49 -20 6 7 10 30 450 -22 -456 -40 29 0 -23 45 290 39 99 -390 -235 -154 -49 -20 6 7 10 30 450 -456 -22 -40 29 0 -23 45 290 39 99 -390 -235 -154 -49 -20 6 7 10 30 450 -456 -22 -40 0 29 -23 45 290 39 99 -390 -235 -154 -49 -20 6 7 10 30 450 -456 -22 -40 0 29 -23 45 290 39 99 -390 -235 -154 -49 -20 6 7 10 30 450 -456 -40 -22 0 29 -23 45 290 39 99 -390 -235 -154 -49 -20 6 7 10 30 450 -456 -40 -22 0 29 -23 45 290 39 99 -390 -235 -154 -49 -20 6 7 10 30 450 -456 -40 -22 0 29 -23 45 290 39 99 -390 -235 -154 -49 -20 6 7 10 30 450 -456 -40 -22 0 29 -23 45 39 99 290 -390 -235 -154 -49 -20 6 7 10 30 450 -456 -40 -22 0 29 -23 39 45 99 290 -390 -235 -154 -49 -20 6 7 10 30 450 -456 -40 -23 -22 0 29 39 45 99 290 -456 -390 -235 -154 -49 -40 -23 -22 -20 0 6 7 10 29 30 39 45 99 290 450

Thời gian thực thi: execution time
$$= \frac{CPI \times Intrustions}{Clock \ rate}$$
$$= \frac{1 \times 8339}{2 \times 10^{9}}$$
$$= 4.1695 \ (\mu s)$$

TEST CASE 8:

.word -1000, 1000, 500, -500, 20, -20, 50, -50, 999, -999, 0, 1, 2, 3, 4, 5 -10, -11, -11, -12

Instruc	tion Statistics, Version	1.0 (Ingo Kofler)	Instruction Counter, Version 1.0 (Felipe Lessa)					
Total:	8378		Counting the n	umber of in	structions executed			
ALU:	4884	59%	Instructions so far:	8378				
Jump:	271	3%		0040	200/			
Branch:	802	9%	R-type:	2243	26%			
Memory:	1180	14%	I-type:	5942	70%			
Other:	1241	15%	J-type:	193	2%			
Discor	Tool C	Reset Close	Disconnect from MIF	Tool Contro	Reset Close			

-1000 1000 500 -500 20 -20 50 -50 999 -999 0 1 2 3 4 5 -10 -11 -11 -12 -1000 1000 500 -500 20 -20 50 -50 999 -999 0 1 2 3 4 5 -10 -11 -11 -12 -1000 1000 500 -500 20 -20 50 -50 999 -999 0 1 2 3 4 5 -10 -11 -11 -12 -1000 1000 -500 20 500 -20 50 -50 999 -999 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -500 20 500 1000 -20 50 -50 999 -999 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -500 20 500 1000 -20 50 -50 999 -999 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -500 20 500 1000 -20 50 -50 -999 999 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -500 20 500 1000 -20 50 -999 -50 999 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -500 20 500 1000 -999 -50 -20 50 999 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -999 -500 -50 -20 20 50 500 999 1000 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -999 -500 -50 -20 20 50 500 999 1000 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -999 -500 -50 -20 20 50 500 999 1000 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -999 -500 -50 -20 20 50 500 999 1000 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -999 -500 -50 -20 20 50 500 999 1000 0 1 2 3 4 5 -10 -11 -11 -12 -1000 -999 -500 -50 -20 20 50 500 999 1000 0 1 2 3 4 -10 5 -11 -11 -12 -1000 -999 -500 -50 -20 20 50 500 999 1000 0 1 2 3 4 -10 5 -11 -12 -11 -1000 -999 -500 -50 -20 20 50 500 999 1000 0 1 2 3 4 -10 5 -12 -11 -11 -1000 -999 -500 -50 -20 20 50 500 999 1000 0 1 2 3 4 -12 -11 -11 -10 5 -1000 -999 -500 -50 -20 20 50 500 999 1000 -12 -11 -11 -10 0 1 2 3 4 5 -1000 -999 -500 -50 -20 -12 -11 -11 -10 0 1 2 3 4 5 20 50 500 999 1000

Thời gian thực thi: execution time
$$= \frac{CPI \times Intrustions}{Clock \ rate}$$
$$= \frac{1 \times 8378}{2 \times 10^{9}}$$
$$= 4.189 \ (\mu s)$$

TEST CASE 9:

.word 10, 10, 4, 100, 409, -30, -10, 0, 349, 03, -320, 904, 49, -30, 49, -403, -439, 39, 25, 30

Instruction	tion Statistics, Version	1.0 (Ingo Kofler)			
Total:	8371		Instruction Counter, Ve	ersion 1.0 (Felipe Le	essa) ×
			Counting the n	umber of in	structions executed
ALU:	4880	59%		0074	
Jump:	276	3%	Instructions so far:	83/1	
Branch:	798	9%	R-type:	2241	26%
Memory:	1178	14%	I-type:	5932	70%
Other:	1239	15%	J-type:	198	2%
Discor	Tool Co	Reset Close	Disconnect from MIF	Tool Contr	ol Close

10 10 4 100 409 -30 -10 0 349 3 -320 904 49 -30 49 -403 -439 39 25 30 10 10 4 100 409 -30 -10 0 349 3 -320 904 49 -30 49 -403 -439 39 25 30 10 10 4 100 409 -30 -10 0 349 3 -320 904 49 -30 49 -403 -439 39 25 30 10 10 4 100 409 -30 -10 0 349 3 -320 904 49 -30 49 -403 -439 39 25 30 4 10 10 100 409 -30 -10 0 349 3 -320 904 49 -30 49 -403 -439 39 25 30 4 10 10 100 409 -30 -10 0 349 3 -320 904 49 -30 49 -403 -439 39 25 30 4 10 10 100 409 -30 -10 0 3 349 -320 904 49 -30 49 -403 -439 39 25 30 4 10 10 100 409 -30 -10 0 3 349 -320 904 49 -30 49 -403 -439 39 25 30 4 10 10 100 409 -30 -10 0 3 349 -320 904 49 -30 49 -403 -439 39 25 30 -30 -10 0 3 4 10 10 100 349 409 -320 904 49 -30 49 -403 -439 39 25 30 -30 -10 0 3 4 10 10 100 349 409 -320 904 49 -30 49 -403 -439 39 25 30 -30 -10 0 3 4 10 10 100 349 409 -320 904 49 -30 49 -403 -439 39 25 30 -30 -10 0 3 4 10 10 100 349 409 -320 904 -30 49 49 -403 -439 39 25 30 -30 -10 0 3 4 10 10 100 349 409 -320 -30 49 49 904 -403 -439 39 25 30 -30 -10 0 3 4 10 10 100 349 409 -320 -30 49 49 904 -439 -403 39 25 30 -30 -10 0 3 4 10 10 100 349 409 -320 -30 49 49 904 -439 -403 39 25 30 -30 -10 0 3 4 10 10 100 349 409 -320 -30 49 49 904 -439 -403 25 30 39 -30 -10 0 3 4 10 10 100 349 409 -320 -30 49 49 904 -439 -403 25 30 39 -30 -10 0 3 4 10 10 100 349 409 -439 -403 -320 -30 25 30 39 49 49 904 -439 -403 -320 -30 -30 -10 0 3 4 10 10 25 30 39 49 49 100 349 409 904

Thời gian thực thi: execution time
$$= \frac{CPI \times Intrustions}{Clock \ rate}$$
$$= \frac{1 \times 8371}{2 \times 10^{9}}$$
$$= 4.1855 \ (\mu s)$$

TEST CASE 10:

.word 0, 3495, 349, 02, -239, -23, -435, -3490, -2, -23, 10, 45, 35, 354, 390, 329, 109, 303, 490, 320

	Instruc	tion Statistics,	Vorcion 1	I O (Ingr	. Kofl	or)	×											
	ilistruc	tion statistics,	version	i.o (ilige	KOIII	51)		<pre>fr</pre>	nstruct	tion Co	ounter, V	ersion 1	1.0 (Felip	e Lessa)		>	_ <
	Total:	8381						Co	unt	ina	the n	umb	er of	inst	ructi	ons	executed	d
	ALU:	4885			5:	9%				9								
	Jump:							Instru	ctions	s so far:	8381							
	Branch:	803				1%					R-type:	2243				26%		
											l-type:					70%		
	Memory:	1180				4%					J-type:					2%		
	Other:	1241			1	5%					o-type.	104				270		
		7	ool Cor	ntrol									Tool C	ontrol				
	Discor	nnect from MIF	PS	Res	et	С	ose	D	iscon	nect f	rom MIF	PS		Re	set		Close	
0	3495 34	9 2 -239	-23	-435	-34	90 -	-2 -23	10	45	35	354	390	329	109	303	490	320	
0	3495 34	9 2 -239	-23	-435	-34	90 -	2 -23	10	45	35	354	390	329	109	303	490	320	
0	3495 34	9 -239 2	-23	-435	-34	90 -	2 -23	10	45	35	354	390	329	109	303	490	320	
0	3495 -23	39 2 349	-23	-435	-34	90 -	2 -23	10	45	35	354	390	329	109	303	490	320	
-23	39 0 2 3	349 3495	-23	-435	-34	90 -	2 -23	10	45	35	354	390	329	109	303	490	320	
-23	39 0 2 3	349 3495	-435	-23	-34	90 -	2 -23	10	45	35	354	390	329	109	303	490	320	
-23	39 0 2 3	349 3495	-435	-23	-34	90 -	-23 -2	10	45	35	354	390	329	109	303	490	320	
-23	39 0 2 3	349 3495	-435	-23	-34	90 -	-23 -2	10	45	35	354	390	329	109	303	490	320	
-23	39 0 2 3	349 3495	-349	0 -43	35 -	23 -	-23 -2	10	45	35	354	390	329	109	303	490	320	
-34	490 -435	5 -239 -23	3 -23	-2 (2	349	3495	10	45	35	354	390	329	109	303	490	320	
-34	490 -435	5 -239 -23	3 -23	-2 (2	349	3495	10	45	35	354	390	329	109	303	490	320	
-34	490 -435	5 -239 -23	3 -23	-2 (2	349	3495	10	45	35	354	390	329	109	303	490	320	
-34	490 -435	5 -239 -23	3 -23	-2 (2	349	3495	10	45	35	354	390	329	109	303	490	320	
-34	490 -435	5 -239 -23	3 -23	-2 (2	349	3495	10	35	45	354	390	329	109	303	490	320	
-34	490 -435	5 -239 -23	3 -23	-2 (2	349	3495	10	35	45	354	390	109	329	303	490	320	
-34	490 -435	5 -239 -23	3 -23	-2 (2	349	3495	10	35	45	354	390	109	329	303	320	490	
-34	490 -435	5 -239 -23	3 -23	-2 (2	349	3495	10	35	45	354	390	109	329	303	320	490	
-34	490 -435	5 -239 -23	3 -23	-2 (2	349	3495	10	35	45	354	390	109	303	320	329	490	

-3490 -435 -239 -23 -23 -2 0 2 349 3495 10 35 45 109 303 320 329 354 390 490 -3490 -435 -239 -23 -23 -2 0 2 10 35 45 109 303 320 329 349 354 390 490 3495

Thời gian thực thi: execution time
$$= \frac{CPI \times Intrustions}{Clock\ rate}$$
$$= \frac{1 \times 8381}{2 \times 10^{9}}$$
$$= 4.1905\ (\mu s)$$