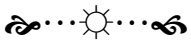
VIETNAM NATIONAL UNIVERSITY, HO CHI MINH CITY

UNIVERSITY OF TECHNOLOGY



FACULTY OF COMPUTER SCIENCE AND ENGINEERING

COURSE: COMPUTER ARCHITECTURE LAB (CO2008)

ASSIGNMENT REPORT

CALCULATOR

Class: CC02 – Semester 232

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I. BACKGROUND:

1. Introduce

Mathematical formulas often involve complex expressions that require a clear understanding of the order of operations. To represent these expressions, we use different notations, each with its own advantages and disadvantages. In this article, we will explore three common expression notations: infix, prefix, and postfix.

In this assignment, we will mention infix and postfix, let's talk about them now.

2. Theory of Infix expression

Infix expressions are mathematical expressions where the operator is placed between its operands. This is the most common mathematical notation used by humans.

For example: the expression "$2 + 3$" is an infix expression, where the operator "+" is placed between the operands "2" and "3".

Infix notation is easy to read and understand for humans, but it can be difficult for computers to evaluate efficiently. This is because the order of operations must be taken into account, and parentheses can be used to override the default order of operations.

Common way of writing Infix expressions:

Infix notation is the notation that we are most familiar with. For example, the expression "$2 + (3 * 4!)$" is written in infix notation.

In infix notation, operators are placed between the operands they operate on. For example, in the expression "$2 + 3$", the addition operator "+" is placed between the operands "2" and "3".

Parentheses are used in infix notation to specify the order in which operations should be performed. For example, in the expression "$(2 + 3) * 4$", the

parentheses indicate that the addition operation should be performed before the multiplication operation.

Operator precedence rules:

Infix expressions follow operator precedence rules, which determine the order in which operators are evaluated. For example, multiplication and division have higher precedence than addition and subtraction. This means that in the expression "$2 + 3 * 4$", the multiplication operation will be performed before the addition operation.

Here's the table summarizing the operator precedence rules for common mathematical operators:

Operator	Precedence
Parentheses ()	Highest
Exponents ^	High
Multiplication *	Medium
Division /	Medium
Addition +	Low
Subtraction -	Low

Advantages of Infix Expressions:

- More natural and easier to read and understand for humans.
- Widely used and supported by most programming languages and calculators.

Disadvantages Infix Expressions:

- Requires parentheses to specify the order of operations.
- Can be difficult to parse and evaluate efficiently.

3. Theory of Postfix expression

Postfix expressions are also known as Reverse Polish Notation *(RPN)*, are a mathematical notation where the operator follows its operands. This differs from the more common infix notation, where the operator is placed between its operands.

In postfix notation, operands are written first, followed by the operator. For example, the infix expression "5 + 2" would be written as "5 2 +" in postfix notation.

Advantages of Postfix Notation:

Also eliminates the need for parentheses.

Easier to read and understand for humans.

More commonly used than prefix notation.

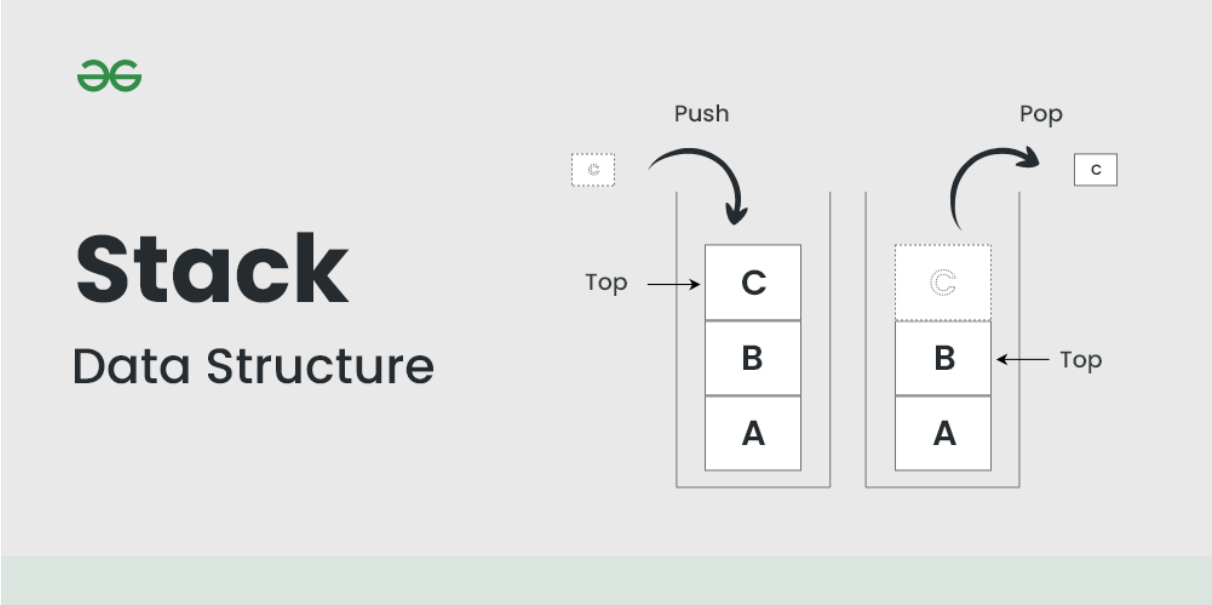
Disadvantages of Postfix Expressions:

Requires a stack-based algorithm for evaluation.

Can be less efficient than prefix notation in certain situations.

4. Theory of Stack

A Stack is a linear data structure that follows a particular order in which the operations are performed. The order may be LIFO(Last In First Out) or FILO(First In Last Out). LIFO implies that the element that is inserted last, comes out first and FILO implies that the element that is inserted first, comes out last.



II. OVERVIEW ABOUT ALGORITHM

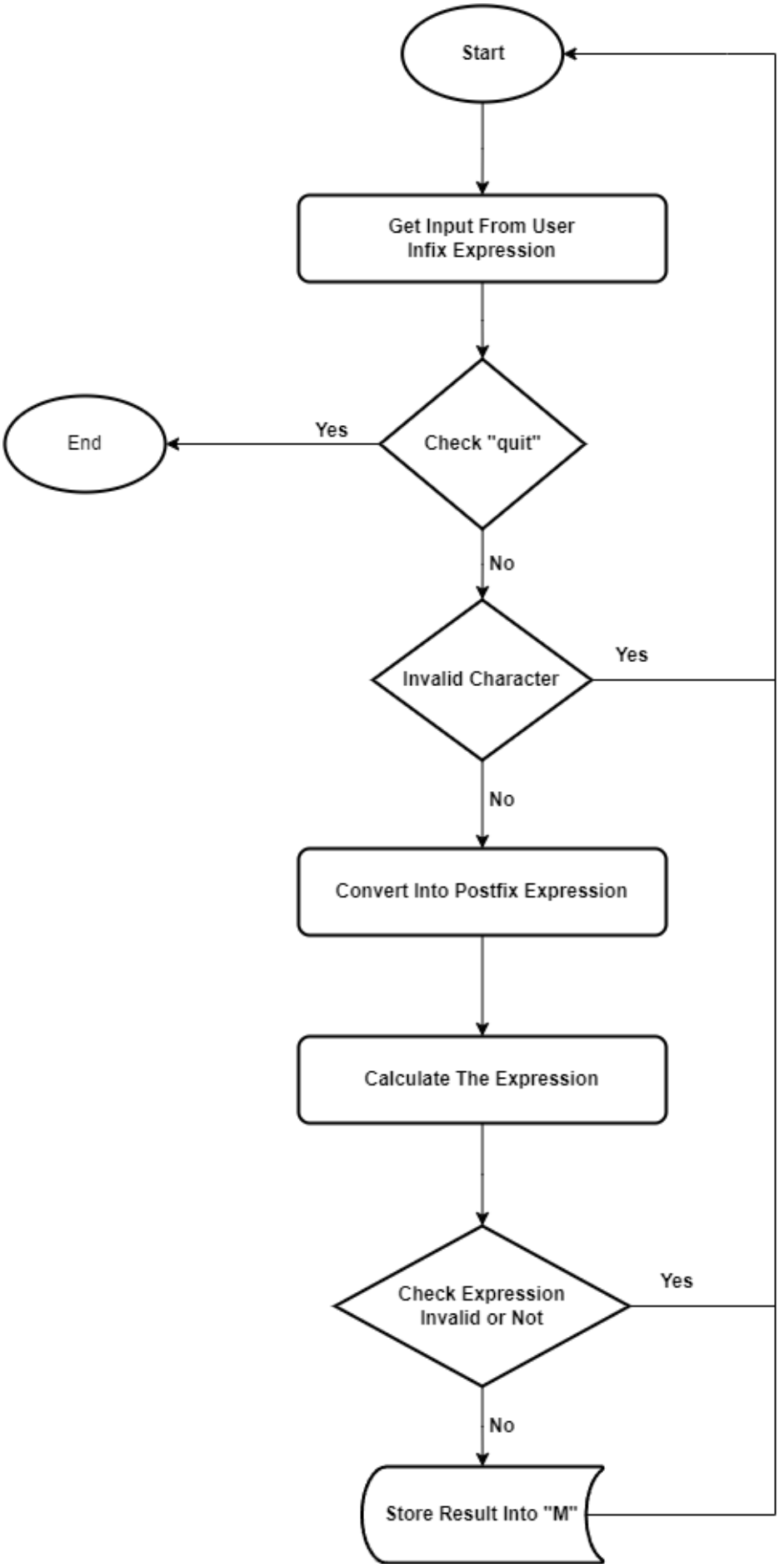
In this exercise, we will create a simple computer with simple calculation functions. The algorithm idea for mathematical expressions after being entered from the user is to convert the original expression - infix expression to a postfix expression.

After converting from infix expression to postfix expression, we will proceed to calculate from the expression in postfix. This process involves pulling out characters, converting them to real numbers, and calculating. Finally, the result will be saved in variable M for further calculations. This process will be repeated until the user enters the "quit" command line.

In more detail in checking, the algorithm will first check for "Valid" characters. If they are invalid, the program will ask the user to re-enter the expression. Otherwise, the program will continue to compile until the second round of testing. In this round, the algorithm will check the reasonableness in the order of expressions. If the expression is reasonable in the order, it will be calculated and saved in value “M”, otherwise, the program will ask the user to re-enter a new expression.

Regarding writing to the file, all input expressions as well as the results of those expressions into the “calc_log_txt” file, the program will write all user input expressions case, including incorrect character entries, incorrect math expressions errors due to the order of calculations, exiting the program “quit”, and the results of each calculation.

This is the flowchart about the overall algorithm:


Start
Get Input From User
Infix Expression
Check "quit"
Yes
End
No
Invalid Character
Yes
No
Convert Into Postfix Expression
Calculate The Expression
Check Expression
Invalid or Not
Yes
No
Store Result Into "M"

III. MORE DETAILS ON ALGORITHM PROCESSING

To facilitate a better understanding of how the program actually works, the functions of each block in the program, as well as special cases in algorithm processing, we will go deeper into the blocks in the program.

The program will operate in 3 main blocks:

Function block 1: Convert expression from infix to postfix.

Function block 2: Calculate from transformed expression.

Function block 3: Convert results to string format to write to file.

Function block 1:

Step 1: Read the input expression and save it into an array with a maximum size of 100bytes.

Step 2: Check the character sequence, if the input sequence is "quit", the program will end, otherwise the program will continue.

Step 3: After having the input expression, we will use a loop to convert the expression to postfix form.

During the process of iterating to each character, the program will simultaneously check the validity of the character, as well as the validity of the order of mathematical expressions. The program will ask the user to re-enter if such cases occur, otherwise it will continue to complete the conversion.

Note: Considered valid characters: "0 1 2 3 4 5 6 7 8 9 + - * / . M ^ ! ( )"

Some math expressions are considered errors: "(1 + 2))"; "! 3"; "∗ + − 3"; "(−5)!"; “12.34.34 + 23”; etc.

Step 4: Proceed to set the numbers and characters in postfix format. In this step, the program will perform the conversion. And in “Postfix_stack”, we will add a

"space" between operand – operand or operand – operator to mark for easy calculation.

- "Postfix_stack" will be the array containing the expression after conversion.
- "operator_stack" will be the array containing the operators.

Scan the symbols of the expression from left to right and for each symbol, do the following:

a. If symbol is an operand or a dot

- Put that symbol into "Posfix_stack"

b. If symbol is a left parenthesis

- Push it on the "operator_stack"

c. If symbol is a right parenthesis

- Pop all the operators from the stack upto the first left parenthesis and put it into "Postfix_stack"
- Discard the left and right parentheses

d. If symbol is an operator

- If the precedence of the operator in the stack are greater than or equal to the current operator, then

  Pop the operators out of the stack and put them onto the "Postfix_stack", and push the current operator onto the stack.

- else

  Push the current operator onto the "operator_stack".

- A special operator is "!", I will consider it like a number, so I will add it onto "Postfix_stack" without checking precedence.

<u>*In addition*</u>, I also create an array for saving status of factorization. As you know, the expression "(-4)!" and "-4!" is different, one is error, another is negative result.

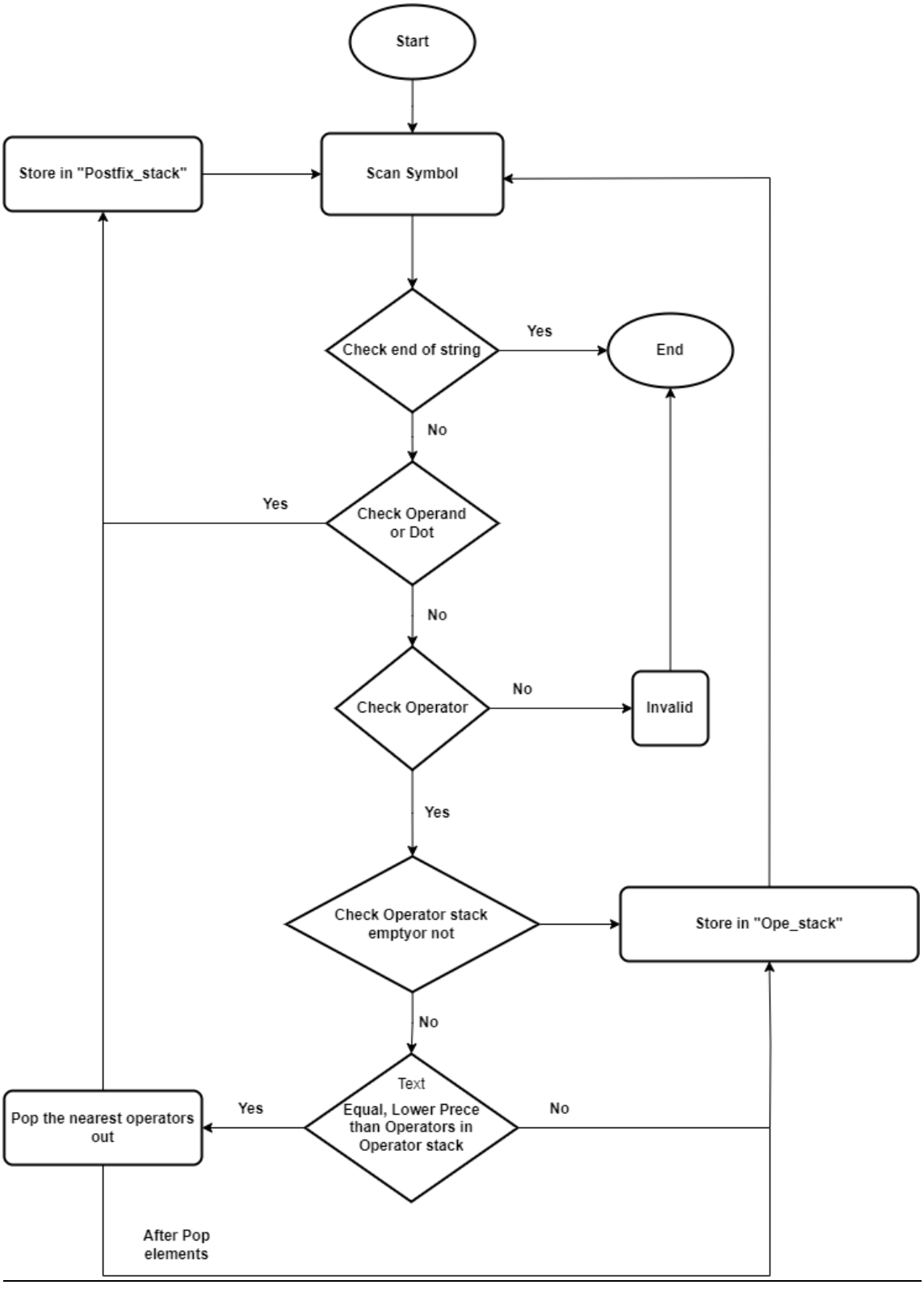
So the array will assign 1 to the expression which have open parenthesis before for checking negative number when calculate.

I also created a few functions to handle continuous plus - minus signs, such as

" $+--+--3$" will become "3";

"$-+--(3+4+5)$" will become " -12", etc.

Flowchart algorithm for function block 1: Convert into Postfix expression



Function block 2

In the second function block, we will calculate the results based on the postfix expression after completing function block 1. In this block, we will create a new

stack named “calculation” for saving the real value converted from string in “Postfix_stack”.

Step 1: Scan symbol from left to right. The “space” will distinguish elements from each other.

Step 2: Check symbol

If they are numbers, convert them to real numbers and save them to the “calculation” stack. The conversion process is performed as follows.

- If the sign is negative, we proceed to mark it with a register to finally do the "zero - expression" and store into “calculation”.
- *If it is an integer,* for the first digit, we convert it to a real number by adding 48 according to the ASCII code table, then we take "$0 * 10$" and add it to that number. From the 2nd digit onwards, we continue to convert through the ASCII code table, multiply the previously found number by 10 and add it to the current number. Finally, check the negative number and save the results to stack calculation.

  For example: 123 and -123. Positive number with 3 steps, negative number with 4 steps.

Step	Expression	Result
1	$0.10 + 1$	1
2	$1.10 + 2$	12
3	$12.10 + 3$	123
4	$0 - 123$	-123

- *If it is a decimal number,* we do the same for the integer part as for integers number. But in the decimal part, instead of multiplying by 10 like in the integer part, for the first decimal number we will divide the current number by 10 and add it with the integer part. From the 2nd decimal number onwards, we will divide by 10^2, and at the nth decimal

number, we will divide by 10^n and repeat the addition as above. Finally, check the negative number and save the results to stack calculation.

For example: 123.45 and −123.45 Positive number with 5 steps, negative number with 6 steps.

Step	Expression	Result
1	$0.10 + 1$	1
2	$1.10 + 2$	12
3	$12.10 + 3$	123
4	$4/10 + 123$	123.4
5	$5/100 + 123.4$	123.45
6	$0 - 123.45$	-123.45

- *If they are operators,* take the 2 closest elements in the stack calculation to perform the calculation by calculation functions. Then, save the newly received result back to the stack calculation.

  For example: 2.34 43 +

Step	Explain
1	$Take\ 2.34$
2	$Take\ 43$
3	$Plus: 2.43 + 43$

- *For operator "!",* we will only take the nearest 1 element to calculate. Before calculating, we will check whether the expression satisfies or not, as mentioned above, for example "-4!" would be satisfied but "(-4)!" it's the opposite. To verify this, we will check whether the mark is 1 or 0 in the register used for the mark. Then, the newly received results will be saved into the stack calculation.

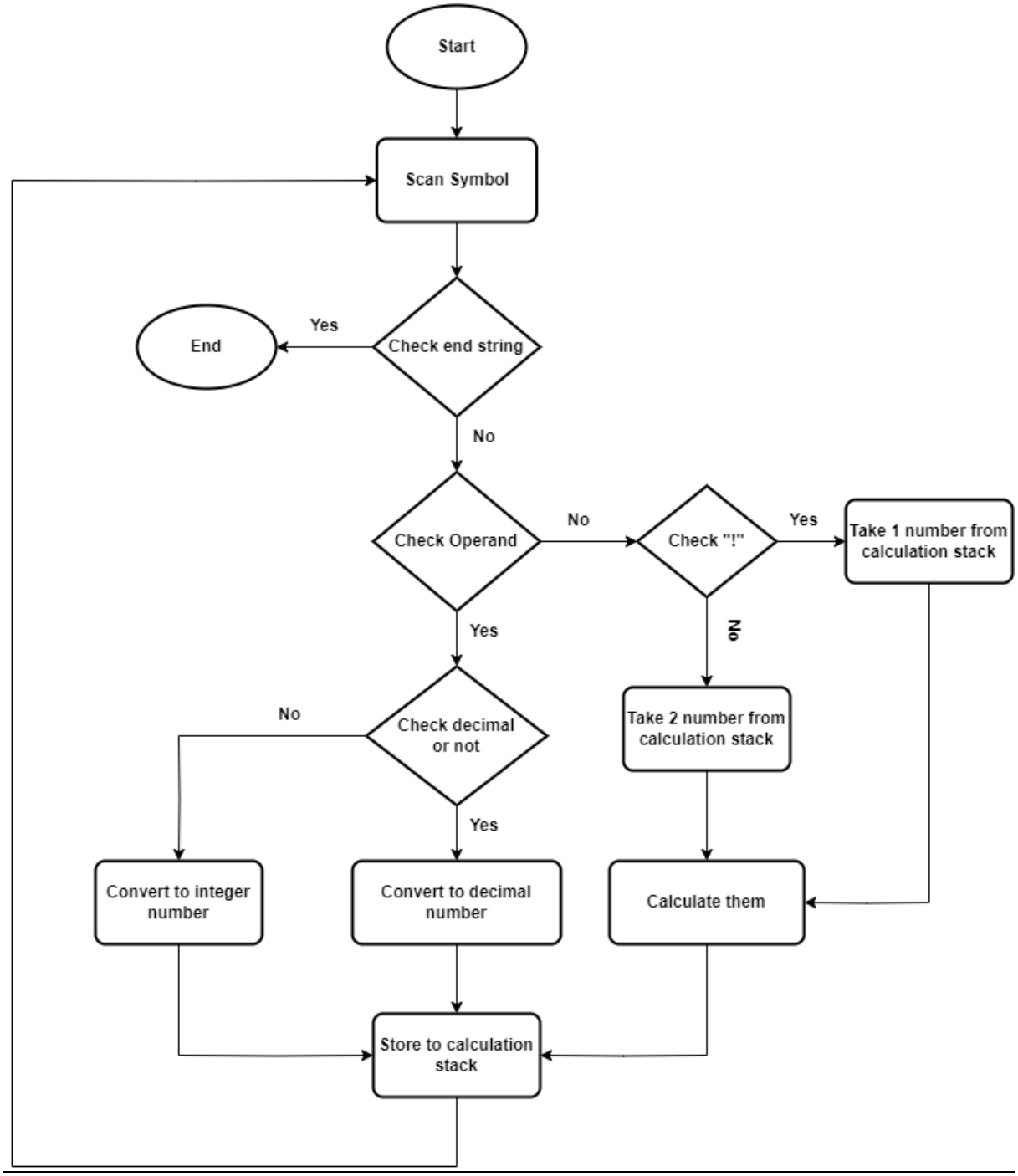
  For example: 3!

Step	Explain
1	$Take$ 3
2	$Calculate$ 3!

Step 3: Save the final result to value "M".

Note: We check a number is a decimal number or not by convert it into integer, the program will round it to the integer part. After that, we subtract the initial number with the number has just been converted. It the result is zero, it means the initial number is in integer format, otherwise, it is in decimal number format.

Flowchart algorithm for function block 2: Calculate from transformed expression.



Function block 3

In function block 3, after obtaining the value of M, I converted the M value to string and wrote it to the “calc_log.txt” file, and at the same time output the M value to the screen.

Step 1: Screen the M value to the screen.

Step 2: Proceed to convert the format of M

- *First,* check whether M is negative or not. If M is negative, save the minus sign to write to the file.
- *Then,* check if M is an integer or a decimal number, the way to check is as mentioned in function block 2. After checking, if it is a decimal number, we use subtraction between the original number and the rounded number. Store the subtraction value into the register (this is decimal part).

  For example: 12.345

Step	Explain	Expression	Result
1	Convert into integer		12
2	Subtract	$12.345 - 12$	0.345
3	Save the integer part		12
4	Save the decimal part		0.345

- *Proceed to save the integer part:* Take the integer part and divide it by 10, the remainder will be saved in the "to_write_1" array, the result will be used to divide by 10. If we get the result as 0, the loop end.
- *Then,* take the elements in "to_write_1" and save them in "to_write_2" in reverse order.

  For example: Integer = 12. After the first division, we get a remainder of 2, the result is 1. After division by 2, we get a remainder of 1, the result is 0. The "to_write_1" array will now be is "2, 1". We have to change the position to "1, 2" to be satisfied.

Step	Expression	Remainder	Result
1	12/10	2	1
2	1/10	1	0 = end
3	to_write_1 = (21)		
4	to_write_2=(12		

- *Proceed to save the decimal part:* First, we save the "." sign in "to_write_2".
- *Then,* multiply the result of the first subtraction by 10, we will get a new number, round and subtract to get the next decimal part. The number after rounding will be converted into characters according to the ASCII code table and saved directly to "to_write_2", the process continues until there are 16 characters in the decimal part.

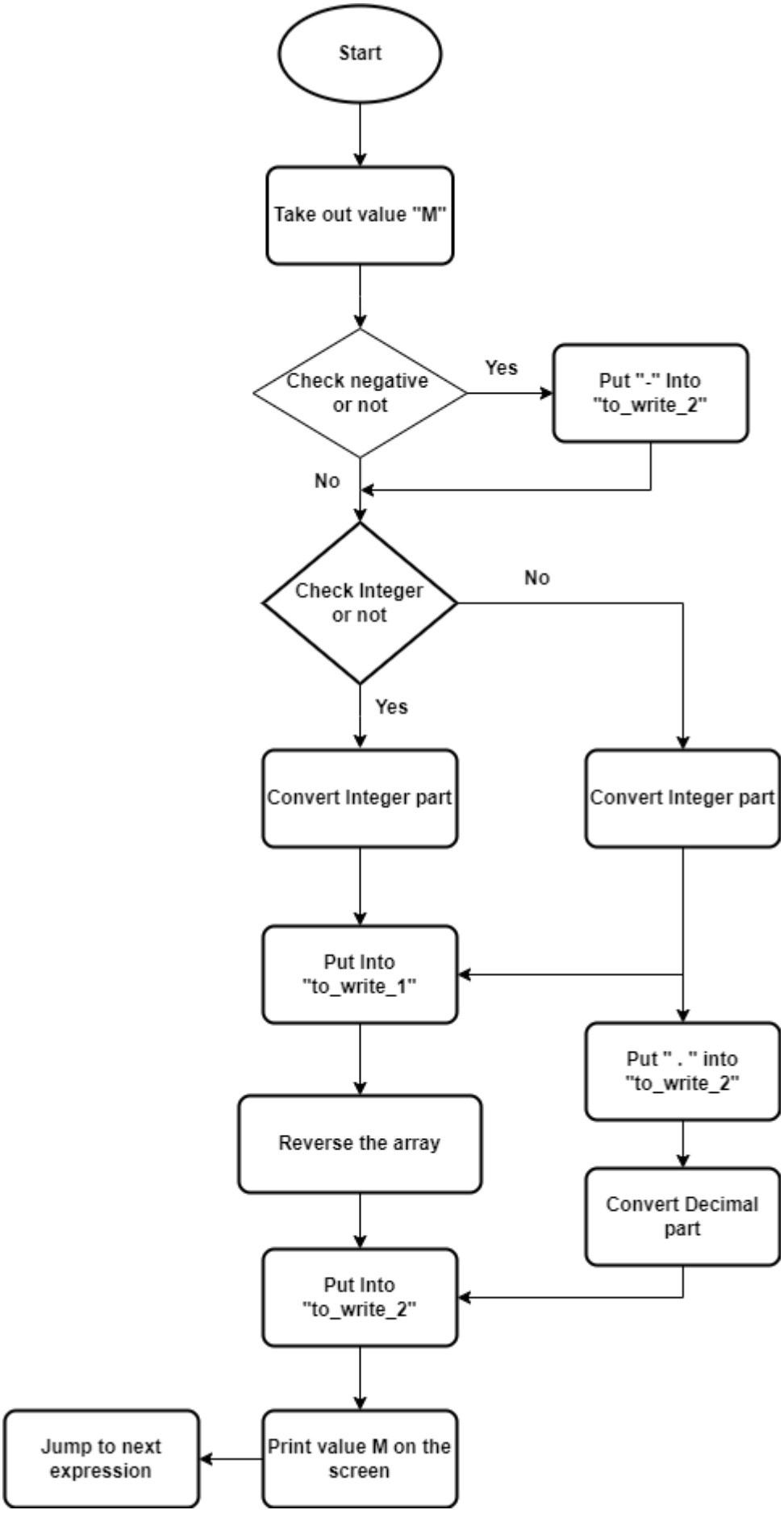
  For example: Decimal = 0.345. The result is the number in Convert column.

Step	Expression	Result 1	Convert	Subtract	Result 2
1	$0.345 * 10$	3.45	3	$3.45 - 3$	0.45
2	0.45*10	4.5	4	$4.5 - 4$	0.5
3	0.5*10	5	5	0	0
4	to_write_2=(.345)				

Step 3: Write "to_write_2" into "calc_log.txt"

Note: During the conversion process, it is necessary to create a variable to count the number of characters to avoid font errors during saving.

Flowchart algorithm for function block 3: Convert results to string format to write to file.


Start
Take out value "M"
Check negative or not
Yes
Put "-" Into "to_write_2"
No
Check Integer or not
No
Yes
Convert Integer part
Convert Integer part
Put Into "to_write_1"
Put " . " into "to_write_2"
Reverse the array
Convert Decimal part
Put Into "to_write_2"
Jump to next expression
Print value M on the screen

IV. TEST RUN OF PROGRAM

Some test I have try with this program, I will screen the postfix expression onto screen for easier checking.

```
Please insert your expression: 2!+----(3+4+4)*2/123.34*32.34+(-(2^2)^3)*1093/9043
Postfix expression: 2 ! 3 4 + 4 + 2 * 123.34 / 32.34 * + 0 2 2 ^ 3 ^ - 1093 * 9043 / +
Result is: 0.03295893764223656
Please insert your expression: M*233/2+(2+5)!-(2^6^3)+12/233*12+23323.3432342/23.343-12
Postfix expression: M 233 * 2 / 2 5 + ! + 2 6 ^ 3 ^ - 12 233 / 12 * + 23323.3432342 23.343 / + 12 -
Result is: -256112.38434197023
Please insert your expression: quit

-- program is finished running --
```

```
Your initial expression: 2!+----(3+4+4)*2/123.34*32.34+(-(2^2)^3)*1093/9043
Result is: 0.0329589376422365
Your initial expression: M*233/2+(2+5)!-(2^6^3)+12/233*12+23323.3432342/23.343-12
Result is: -256112.3843419702316168
Your initial expression: quit
```

```
Please insert your expression: 2^64
Postfix expression: 2 64 ^
Result is: 1.8446744073709552E19
Please insert your expression: 2^200
Postfix expression: 2 200 ^
Result is: 1.6069380442589903E60
Please insert your expression: 2^-200
Postfix expression: 2 0 200 - ^
Result is: 6.223015277861142E-61
Please insert your expression: -2^200
```

```
Please insert your expression: 2^-200
Postfix expression: 2 0 200 - ^
Result is: 6.223015277861142E-61
Please insert your expression: -2^200
Postfix expression: 0 2 200 ^ -
Result is: -1.6069380442589903E60
Please insert your expression: quit

-- program is finished running --
```

```
Your initial expression: 2^64
Result is: 1844674407E10
Your initial expression: 2^200
Result is: 160693804E52
Your initial expression: 2^-200
Result is: 0.0000000000000000
Your initial expression: -2^200
Result is: -160693804E52
Your initial expression: quit
```

```
Please insert your expression: -23(32324)*2323
Postfix expression: 0 23 32324 * 2323 * -
Result is: -1.727038996E9
Please insert your expression: +---(3+4+5)*54
Postfix expression: 0 3 4 + 5 + 54 * -
Result is: -648.0
Please insert your expression: -(-(-(23+21-12.32(2!+3)+2^5
Postfix expression: 0 0 0 23 21 + 12.32 2 ! 3 + * - 2 5 ^ + ( - ( - ( -
Result is: -14.399999999999999
Please insert your expression: quit
```

```
Your initial expression: -23(32324)*2323
Result is: -1727038996
Your initial expression: +---(3+4+5)*54
Result is: -648
Your initial expression: -(-(-(23+21-12.32(2!+3)+2^5
Result is: -14.3999999999999985
Your initial expression: quit
```

```
Please insert your expression: M*2+345/23
Postfix expression: M 2 * 345 23 / +
Result is: 15.0
Please insert your expression: M*12.34+3^18
Postfix expression: M 12.34 * 3 18 ^ +
Result is: 3.874206741E8
Please insert your expression: M.2*2+(3)
Your expression got some errors, please try again
Please insert your expression: M+q
You inserted an invalid character in your expression
```

```
Your initial expression: M*2+345/23
Result is: 15
Your initial expression: M*12.34+3^18
Result is: 387420674.1000000238418579
Your initial expression: M.2*2+(3)
Your expression got some errors, please try again
Result is: 387420674.1000000238418579
Your initial expression: M+q
You inserted an invalid character in your expression
Result is: 387420674.1000000238418579
Your initial expression: M*23/345
Result is: 25828044.9400000050663948
Your initial expression: quit
```

V. SOME NOTES FOR USERS

Although the program is designed with diverse cases such as:

$+ - - - (3 + 4 + 5)$

or $-(-(-(3 + 4 + 5)$

or $5 * + - - - - -6$

or $2! + - - -3$, etc.

But we encourage users to enter the necessary expressions correctly and in the appropriate order because errors may still occur during the calculation process.

Pay special attention to the opening-closing parentheses in expressions.

For example, if you want to calculate: 2^{2^3} in computer, you have to write 2^(2^3) in MIPS.

REFERENCE

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