

Proposal for Improvement of Energy Consumption and Dependability of Memory Read Bit-Cells

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Abstract— Rapid advancement in technology also brings upon new technological setbacks. The rapid decrease in the size of integrated circuits comes with a risk of the dependability of these circuits. Proposed solutions to alleviate the risk of this rapid decrease in circuit size include: Energy Aware Sense Amplifiers (EASA), Variation Immune Sense Amplifiers (VISA), Pre-read and write Sense Amplifiers (PWSA), and Body-Voltage-Sensing-Based Short Pulse Reading Circuit (BVSC). Efficacy of each proposed solution is determined by calculating the energy of a given assembly code program that has been written to determine the number of occurrences of a word in a given string.

Keywords—SRAM, MRAM, EASA, VISA, PWSA, BVSC, Transmission Gates, Process Variation

I. PROJECT DESIGN

This program is designed to take a user-inputted string and return the number of occurrences of said string in the hard-coded paragraph, "UCF, its athletic program, and the university's alumni and sports fans are sometimes jointly referred to as the UCF Nation, and are represented by the mascot Knightro. The Knight was chosen as the university mascot in 1970 by student election. The Knights of Pegasus was a submission put forth by students, staff, and faculty, who wished to replace UCF's original mascot, the Citronaut, which was a mix between an orange and an astronaut. The Knights were also chosen over Vincent the Vulture, which was a popular unofficial mascot among students at the time. In 1994, Knightro debuted as the Knights official athletic mascot." This is accomplished by taking the hard-coded string and converting each letter to lowercase as well as converting the user-inputted string to lowercase as well. This rids of any discrepancies in cases when searching for then user-inputted string among the paragraph. The length of the user-inputted string is then calculated using a loop that iterates through each character while incrementing a counter. The hard-coded paragraph is then traversed using several loops that use the user-inputted string and its length to determine whether the necessary string has been found. If the word has been found then a counter is incremented to count the number of occurrences of said string. To print the user-inputted string and its number of occurrences on the same line the newline character at the end of the string must be removed. This is done by traversing to the end of the string and replacing the

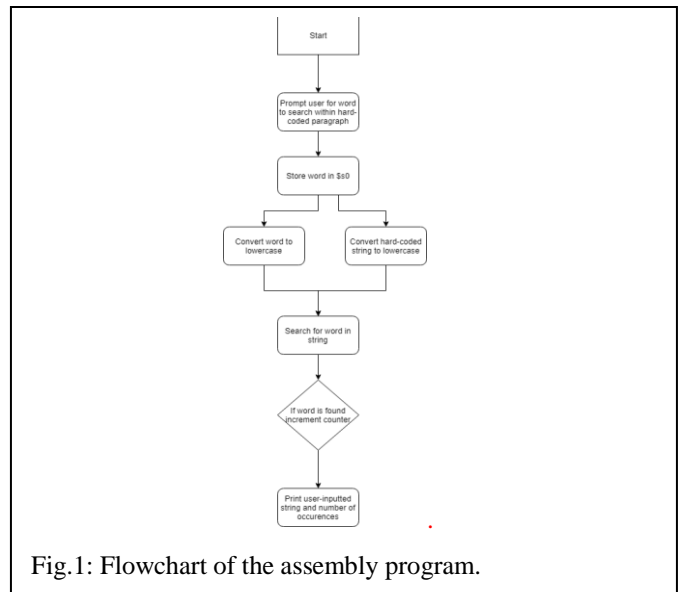


Fig.1: Flowchart of the assembly program.

```
Please input first word: knight
knight: 6
-- program is finished running (dropped off bottom) --

Please input first word: kNiGhT
knight: 6
-- program is finished running (dropped off bottom) --

Please input first word: hello
hello: 0
-- program is finished running (dropped off bottom) --
```

Fig.2: Sample outputs of assembly program.

newline character with the \$zero so it no longer produces a new line.

The inputs tested are knight, kNiGhT, and hello. The first two inputs were chosen to show that the discrepancy between cases is taken care of within the program and will not affect the output. The last input is chosen to show that a word that is not amongst the hard-coded paragraph will not be accounted for at the output. Overall, each input was chosen specifically to test the functionality of the code and whether the implementation of the code is producing the correct output.

II. MEMORY BIT-CELLS

For greater dependability along with low energy costs the proposed read circuits and amplifiers include: Energy Aware Sense Amplifiers (EASA), Variation Immune Sense Amplifiers (VISA), Pre-read and write Sense Amplifiers (PWSA), and Body-Voltage-Sensing-Based Short Pulse Reading Circuit (BVSC).

EASA's and VISA's both use Transmission Gates which provide optimal switching. Using transmission gates reduces the issues in reliability that are caused by PV or energy leakage. The originality in these designs comes from using these transmission gates to reduce leakage in energy in the path of MTJ devices. However, there is a disadvantage to this method. Adding transmission gates on the path of MTJ's adds more resistance and can result in read errors.

The PWSA's are presented for MRAM. The PWSA's combine read and write functions in a single circuit which allows for fast read and write operations. This minimizes bit error after data programming. The PWSA can potentially reduce write power consumption by up to 50%.

The BVSC is a short-pulse reading circuit based on a body-voltage sensing scheme that alleviates scaling issues. A body-voltage is a sensible solution for high-speed and dependability of advanced STT-RAMs.

III. RESULTS AND DISCUSSION

In this section, the energy consumption of the program is calculated using the below energy consumption per instruction values:

- 1) $ALU = 1 fJ$
- 2) $Branch = 3 fJ$
- 3) $Jump = 2 fJ$
- 4) $Memory = Read Energy (Refer to Table I) + Write Energy (50fJ)$
- 5) $Other = 5 fJ$

Herein, spintronic-based memory cells are used in the memory block as storage elements. The below table lists the required energy consumption to perform each memory write operation using the different circuits proposed in [1-3].

Table I: Energy consumption for a single bit-cell read operation in the designs provided in [1-3].

| Design | Energy Consumption For Each Bit-cell's Read Operation |
|----------|---|
| EASA [1] | 0.23 fJ |
| VISA [1] | 1.86 fJ |
| PWSA [2] | 36.0 fJ |
| BVSC [3] | 195.5 fJ |

Table II: Total Energy consumption for the assembly program using designs provided in [1-3].

| Design | Total Energy Consumption |
|----------|--------------------------|
| EASA [1] | 115595 fJ |
| VISA [1] | 118739 fJ |
| PWSA [2] | 184595 fJ |
| BVSC [3] | 492271 fJ |

IV. CONCLUSION

The Energy Aware Sense Amplifiers show a promising resolution to the shrinkage of integrated circuits. Calculations conducted and displayed in Table 2 show that the EASA's are the most efficient; however, this data is not conclusive. To consider the EASA's as the absolute resolution to the arising issues, more testing on a variety of programs should be conducted.

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