Propositions to improving reliability and low energy consumption in individual memory read cells

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Abstract—As technological advancements continue to be made in the field of computers and computer systems, one issue is becoming more prominent and will obstruct these advancements. This issue is unreliability problems that can occur with the continuous shrinkage of integrated circuits as dictated by Moore's Law. To alleviate this issue and the underlying issues that can come with it, four propositions seeking increased reliability while maintaining satisfactory speeds and low energy consumption are examined and measured. These propositions are Energy Aware Sense Amplifiers (EASA) Variation Immune Sense Amplifiers (VISA) Pre-read and write sense amplifier (PWSA), and BODY-VOLTAGE-SENSING-BASED SHORT PULSE READING CIRCUIT (BVSC) To test how much energy is consumed for each proposition, an assembly code designed for counting how many times a word appears in a string is used. After calculations were conducted, the EASA proved to be the best of the other propositions due to its low energy consumption. The amplifier achieves an energy consumption of 112119 fj.

Keywords—*EASA, VISA, PWSA, BVSC, MRAM, Transmission gates, process variation (PV), Magnetic Tunnel Junction*

I. PROJECT DESIGN

The requested code essentially sought for a word inputted by the user to count how many times it appeared in a string. To implement this design, the string is first hard coded. Next, the code implemented a conversion of all letters in the string to lowercase. This would make searching for the word a lot easier to do. The next step is to convert the user's inputted word to all lowercase. This allows all cases of a word to be searched. Even with a combination of lowercase letters and uppercase letters the word is converted to all lowercase. Then, the word search implementation is coded. It traverses through the string looing for the letters inputted by the user. It goes through a true or false condition where if the letters continue to match the desired word, the code will continue in a loop until the full word is realized. Once the code detects a letter that is not related to the user's input, then the code moves to the next string of letters, starting the process all over again. Finally, the last portion of the code stores the amount of times the desired appeared.

The inputs are knight, KNIGHT, UcF, 43, and bakery The first input is used to generally check to see if the code works. The second input is used to test an all caps letter word to see whether the code works. The third input is a mixture of different cap sizes and it is used to see if the code still functions and
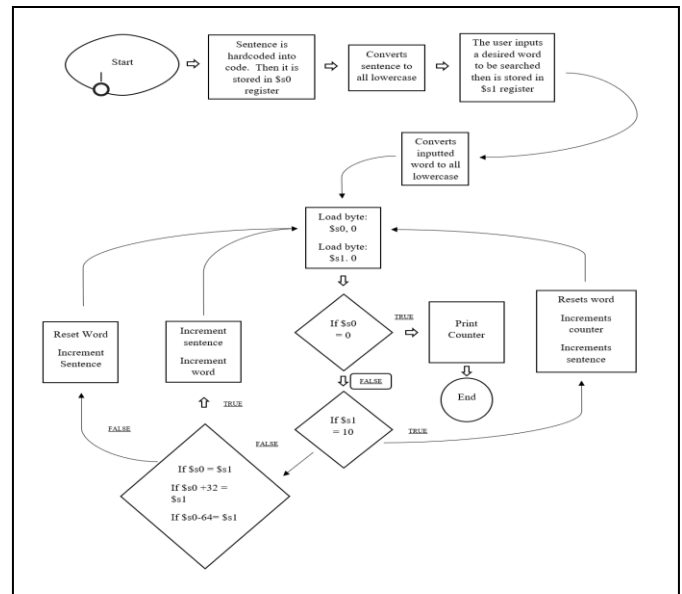

Fig.2: Sample outputs of assembly program.

```
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: UcF
ucf:3
-- program is finished running (dropped off bottom) --

Please input first word: 43
43:0
-- program is finished running (dropped off bottom) --

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

searches properly for the desired word. The fourth input is used to determine if the code will look for numbers. Finally the fifth input is used to see if the code properly displays the amount of times a word that does not appear in the string is used.

II. Memory Bit-Cells

Various read circuits and sense amplifiers seeking high reliability and low energy cost include EASA, VISA, PWSA, and BVSC. Energy Aware Sense Amplifiers (EASA) and Variation Immune Sense Amplifiers use Transmission Gates. These gates are efficient in full-swing switching and in reducing leakage energy. This is imperative since a reduce in leakage energy enhances the longevity of the circuit this amplifier is being applied to. Another issue that these amplifiers alleviate is reliability issues caused by process variation (PV). As technology tends to shrink (Moore's Law), PV increases; thus, this is essential for developing current/future advancements.

The pre-read and write sense amplifier (PWSA) combines read and write functions in a single circuit. The circuit is responsible for writing magnetoresistive RAM (MRAM) bits using GHz speed and magnetic tunnel junction. Using these design configurations, the PWSA circuit provides high speed, low power, and minimized bit error rate.

A Body-Voltage-Sensing-Based Short Pulse reading Circuit (BVSC) approaches the issues of reliability and improved performance that are expected from scaled devices. Since process variation increases with a decreased scale thus causing reliability problems, this circuit is proposed because it reduces such issues. BVSC allows a larger read margin while reducing probable disturbances. This is done by applying a narrow current pulse to the Magnetic Tunnel Junction.

III. Results and Discussion

Table 1 provides information related to how much energy is consumed using the four proposed designs. Table 2 provides information on the total amount of energy consumed when the code presented is executed.

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*

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]	112119 fj
VISA [1]	112201 fj
PWSA [2]	113988 fj
BVSC [3]	121883 fj

IV. Conclusion

The propositions to oppose unreliability and low power consumption are EASA, VISA, PWSA, and BVSC. Each proposition are great ideas to facing these issues; however, the EASA proposition leads them in terms of desired proficiency. It uses the least amount of total energy at 112119 fj. Additionally, I learned of the current issues to today's technology advancement. As dictated by Moore's Law, transistors shrink, which causes more unreliability issues. These issues can be energy leakage, higher error rate, etc.

References

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