MD5 Hashing Algorithm Collision Attack Lab Report

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Introduction:

Hash functions are an extremely useful form of cryptography that allows for the mathematical validation of input data without revealing the underlying data that is being validated (Microsoft, 2022). This feature can seek to provide data confidentiality and integrity, but also non-repudiation as hashing can be implemented to validate communications (Basta, 2018). Hashing algorithms are unique from other forms of encryption in that the encryption performed is not reversible and the encrypted signature is the element used for verification (Amazon, 2023). Further, hashing algorithms differ from symmetric and asymmetric encryption by encrypting data into cyphertext values of fixed size regardless of the input plaintext size (Long, 2019). While this feature is integral to the functioning of hashing algorithms, it also leads to the potential for collisions where two distinct input values map to the same hashed value (Shen et al., 2022). Several hashing algorithms that were once widely used have now been deprecated due to their susceptibility to collisions including the Message-Digest 5 (MD5) and the Secure Hash 1 (SHA1) algorithms, and in this lab collision attacks on MD5 will be examined as it is especially susceptible to collision attacks (Shen et al., 2022). Through exploring the vulnerabilities present within MD5 a greater understanding of secure hashing algorithms can be achieved and security professionals can be better equipped to mitigate vulnerabilities associated with hashing functions.

The MD5 algorithm seeks to encrypt data through five data modification steps. These steps include the padding of bits, appending the message length, initializing the message digest buffer, processing the input data, and returning a hashed value (Mohammed Ali &

Kadhim Farhan, 2020). The tasks in this lab highlight the importance of the values associated with the steps above and in doing so seeks to explore the effects of modifying the number of bytes passed to the algorithm, the effect of varying message lengths, and the transformation of the input data itself. This then extends to exploring the weaknesses of MD5 and gaining an understanding of the risks of implementing it today. While MD5 has been deprecated for modern use, exploring collisions within MD5 will allow a security professional to gain a better understanding of the workings of hashing algorithms and better understand the risks associated with weak implementations.

To accomplish this understanding, the lab begins by providing an introduction to the way that MD5 processes data and the importance of processing block size in this process. With this, the md5collgen function is used to generate two differing values that will form a collision when hashed with MD5. The output values of this function are then examined on the byte level and contrasted to gain insight into what data values change. This information is then built upon to establish how this vulnerability in MD5 could lead to malicious code passing as non-malicious code. After this, the lab practically establishes the fundamental concept that appending the same value to two identically hashed values will maintain hash congruency. This opens the possibility for examining code and modifying particular sections so that the hash value remains the same despite the code being fundamentally altered. Through these exercises, the lab seeks to highlight the importance of understanding vulnerabilities associated with hashing algorithms, and a security professional could use this knowledge to implement algorithms that minimize collisions and in doing so increase security.

Lab Procedure:

To begin this lab, the md5collgen function must first be installed (Screenshot1) and added to the system's executable files (Screenshot2) allowing the function to be used on the system. This function is a collision generator for MD5 taking an input value and returning a second output value that has the same MD5 hash signature but differing by several bytes from the original message. While the md5collgen function is unique to the tests performed in this lab, it aims to represent the potential for collisions, and the security implications of these collisions are explored in later lab tasks.

With the prerequisite steps then accomplished, the lab work can begin by generating a new prefix file (Screenshot3) and then passing this file to the md5collgen function to generate a collision with this file. The diff function can be used to verify that differences exist between the files (Screenshot5) but when the file hashes are checked with the md5sum function (Screenshot6) it can be seen that the hash values are identical. This highlights the problem at the core of the MD5 collision attack which is the ability for distinct values to hash to the same hash sum (Obaida et al., 2022). As hash values are irreversible (Alenezi, Alabdulrazzaq, & Mohammad, 2020) there is then no way for an observer of the hash value to identify which of the possible inputs for that hash value was passed to MD5. Further, and most relevant for this lab, there is also no way to verify if two given hash values truly originated from the same plaintext. This is a major security concern as it is then possible for malicious code to hold the same hash signature as benign code (Mohammed Ali & Kadhim Farhan, 2020). This can be verified in the lab by using the bless command to observe the binary executable files generated by md5collgen (Screenshot7) and noting the differences that exist between them (Screenshot8).

The first section of this lab then asks several questions and through exploring these questions, a better understanding of MD5 can be obtained. The first of these questions prompts the exploration of modifying the input file size to multiples of 64 bytes. MD5 processes data in 64-byte blocks (Alenezi et al., 2020) and if the input data is not a multiple of 64 bytes long, then extra zeros are appended until a multiple is reached. This can be verified by creating a file of 64 characters, each being a byte long (Screenshot9), and then passing that file to md5collgen to observe the output (Screenshot10). Observing this output reveals that no extra zeros are appended to the file (Screenshot11) whereas when the same procedure is performed with a non-multiple of 64-byte length file (Screenshot12), appended zeros can be observed (Screenshot13). When the binary executables for each of these files are compared against each other (Screenshot14)(Screenshot15), the bytes that can be observed as different are in the decimal byte positions of 84, 123, 148, 174, 175, 110, and 188. In each instance, the hexadecimal value was altered by only one bit. For example, the value 0x16 was changed to 0x96 at byte 84 and the value 0x34 was changed to 0xB4 at byte 174. Further, the transformation of each byte was by exactly 128 in value with the exception of the transformation from 0x5A to 0x59 producing a change value of 1. This feature of MD5 collisions is very interesting as it reveals the types of changes that produce similar hash values, such as transformations of exactly 128 in value. However, despite these differences, comparing the hash values continues to show identical values highlighting a collision has occurred with the mapping between the hashed values and the inputs (Screenshot16).

The second task of the lab then introduced a fundamental property of MD5 hashes being that if the same value is appended to two files with the same hash value, they will persist to have matching hash values (Long, 2019). This can be verified by concatenating the same value to the end of two values returned from md5collgen and comparing the hashed sums (Screenshot17). Doing so will then verify that this property is true and is further upheld when appended to either end of the file as long as it is appended to the same end on both files. This property is critical to collision attacks as it then allows for malicious code to be embedded within code that already hashes with the value to be achieved. As will be explored in the next steps, this vulnerability can then be exploited to modify code in both output and functionality.

Task three begins to explore this property by instructing for the generation of two input files that vary in data, but hash to the same value. To accomplish this task, a source code file was first created in C where I filled an array of length 200 with Xs (Screenshot18). The reason it was chosen to fill the array with exclusively one letter is so that the location of the array would be easier to spot in the binary executable file with many identical characters in sequence. After this, the source file was compiled into an executable (Screenshot19) and observed within the bless editor. Observing this file in bless, the revealed that the array started at decimal index 4113 (Screenshot20). The next step for this task was then to parse out the middle section of the file containing the array for modification with the md5collgen function before piecing the file back together through concatenation. For this reason, I would need to parse a 128-byte region from the section of the file containing the array, leaving the rest to be included in the prefix or suffix for the file. The prefix for the array needs to be a multiple of 64-bytes to ensure the file can be pieced back together without extra padding being added and for this reason, the start of the array at index 4113 was not a suitable start location. I then chose index 4160 as the starting index for this block and set the ending point 128 bytes later at index 4288. This was accomplished by first using the head and tail functions to gain the prefix and suffix outside of these bounds (Screenshot21) and then using the bless editor to remove the prefix (Screenshot22) and suffix (Screenshot23) and save the remaining 128 bytes as a new file (Screenshot24). Both the newly created prefix and suffix were then run through the md5collgen function to retrieve new values for each (Screenshot25) and these values were compared using the cmp command to identify differing characters (Screenshot26). As an intermediary step, all of the newly generated prefixes and suffixes were checked using md5sum to confirm that the hash values for these elements persisted to match up (Screenshot27). Following this, the 128-byte array value was parsed out of each prefix using the tail command (Screenshot28) before the prefixes, suffixes, and array values were concatenated back together to produce the new files. The hash values for each of these values were then compared and shown to match (Screenshot29) demonstrating the concatenation property (Screenshot30) and completing task three.

The final task then required the implementation of a file that not only represented a change in data but in functionality. Through using concatenation within a file, the fourth task demonstrates how a malicious file could be made to hash with a non-malicious file using MD5 collision exploitation (Long, 2019). To demonstrate this concept, I began by creating a file with two arrays of length 200 filled with Xs (Screenshot31). This file also prints that the code is safe when all of the values in each array match and that the code is malicious when they do not (Screenshot32). Using bless to examine the executable, the long string of Xs is easily located (Screenshot33). The two arrays can then be distinguished by adding 200 to the starting X index of 4112 to see that the second array begins at index 4312. However, as the prefix will need to be of a length divisible by 64, the starting bit for the middle section to be parsed out was switched to 4160 with the 128-bytes ending at index 4288. As before, the prefix and suffix could then be created through the use of the head and tail commands (Screenshot34) and made collision-ready (Screenshot35). The outputs from md5collgen could then be parsed to retrieve a value for both the “safe” and “malicious” code (Screenshot36) that hash to the same value (Screenshot37). With these extracted, the two files could then be built back together (Screenshot38) and as a concatenation is performed exclusively of elements with matching hash values, the final product maintains the matching hash values.

Lab Analysis:

This lab highlighted many interesting features such as the effect of the processing block size, byte transformation value, and concatenation properties of MD5 hashes. Having an understanding of the elements that affect the final hash value allows for the clever modification of values in such a way that the final hash remains unaltered (Long, 2019). This is a serious concern as the loss of the ability to validate that a hash came from a single input undermines the ability to use the hashing algorithm. The loss of this property would then disable the ability to compare hashes as two like hashes may have come from different sources or enable malicious code to masquerade as benign code with the same hash sum. The high rate of collisions in MD5 highlights a serious vulnerability (Mohammed Ali & Kadhim Farhan, 2020), and from this, it is then easy for a security professional to understand the deprecation of this algorithm (Obaida et al., 2022). While the MD5 function is no longer in use, studying the function provides a greater understanding of hashing functions as a whole and the security implications of hashing collisions.

When thinking of a common context in which hashing is regularly used such as password storage or database lookups (Shen et al., 2022), it is clear to see the potential dangers of MD5 collision exploits. If a password value is hashed but has several other inputs that could hash to that same value, then the security of the password is greatly diminished. Likewise, when searching a database through stored hash values, the hash values could be exploited to index into unintended areas of the database. For this reason, security professionals working in an environment where hash functions are used must understand the implications of their chosen hash function and ensure that vulnerabilities of collisions are mitigated.

Conclusion:

Despite the security concerns involved with deprecated hash functions, hashing remains an extremely relevant and useful form of modern cryptography (Microsoft, 2022). Understanding the vulnerabilities associated with collision attacks then allows a security professional to implement hash functions securely and address potential vulnerabilities before they are exploited. Further, non-deprecated algorithms could be chosen or modified to increase security and mitigate the risk of collisions (Alenezi et al., 2022). Growth in this knowledge can then be gained through researching and exploring deprecated algorithms such as MD5 or SHA1 and understanding the reasons why they are vulnerable to attack. Seeking to understand these algorithms can then promote the principles of integrity and non-repudiation through the secure application of hashing algorithms.

References

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https://www.proquest.com/docview/2692792776?accountid=12085&forcedol=true&forcedol=true&pq-origsite=summon

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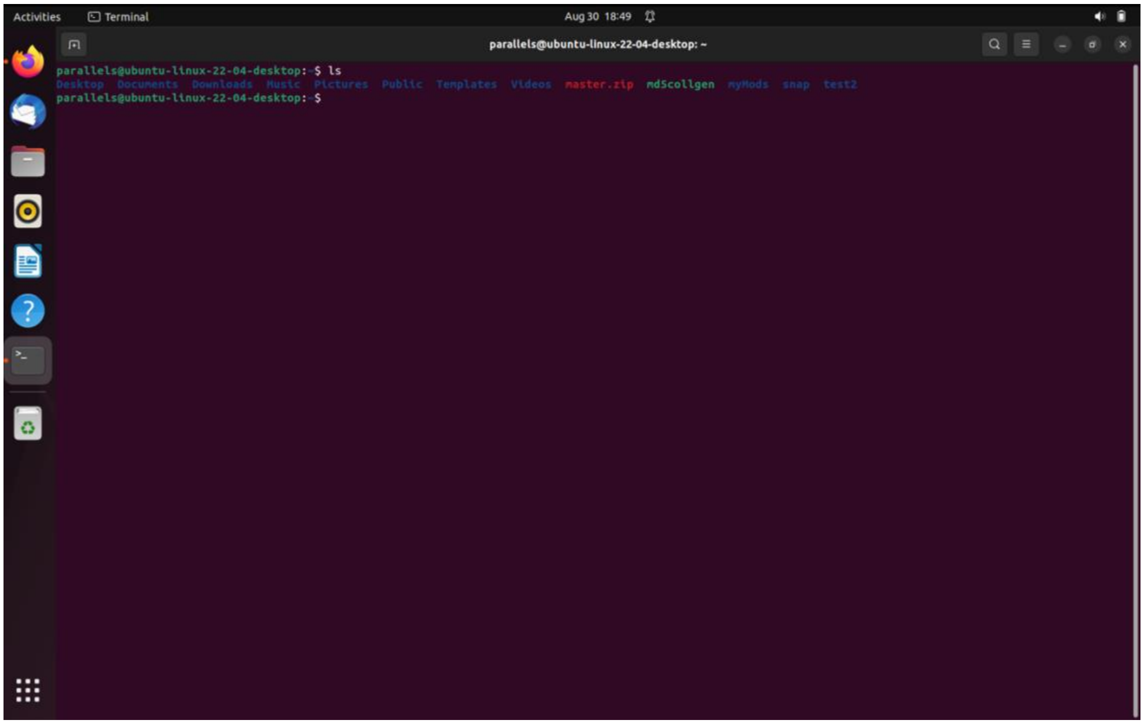
Screenshots: Task 1

Screenshot1: (Return to text)



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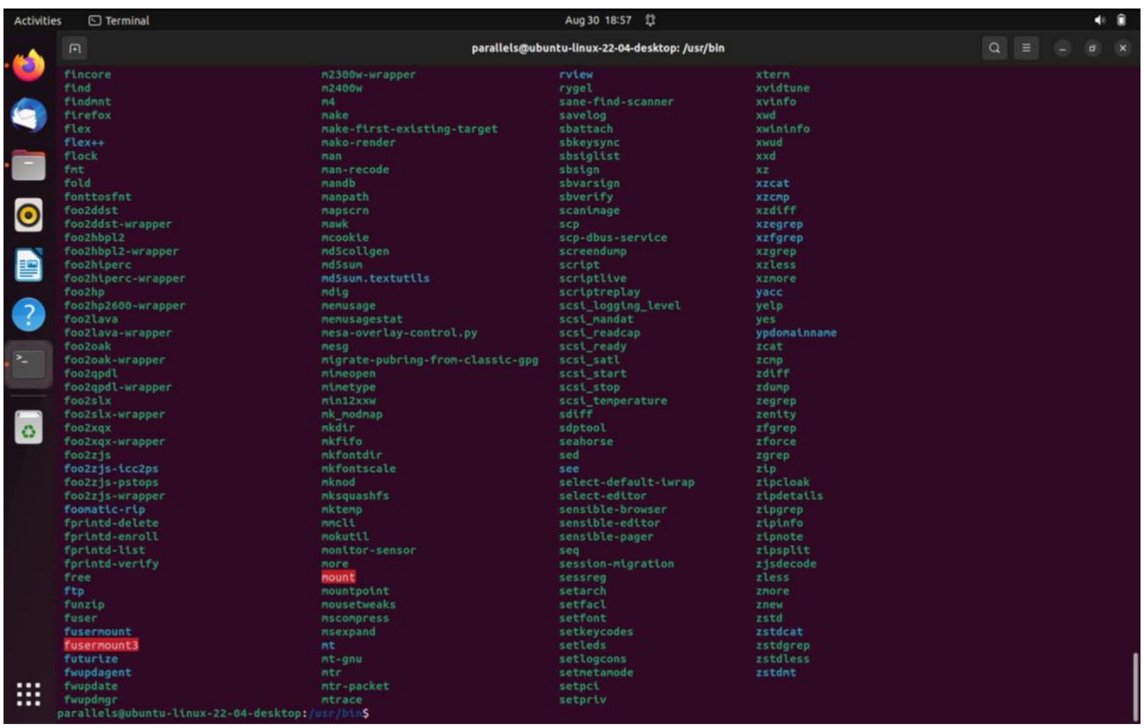

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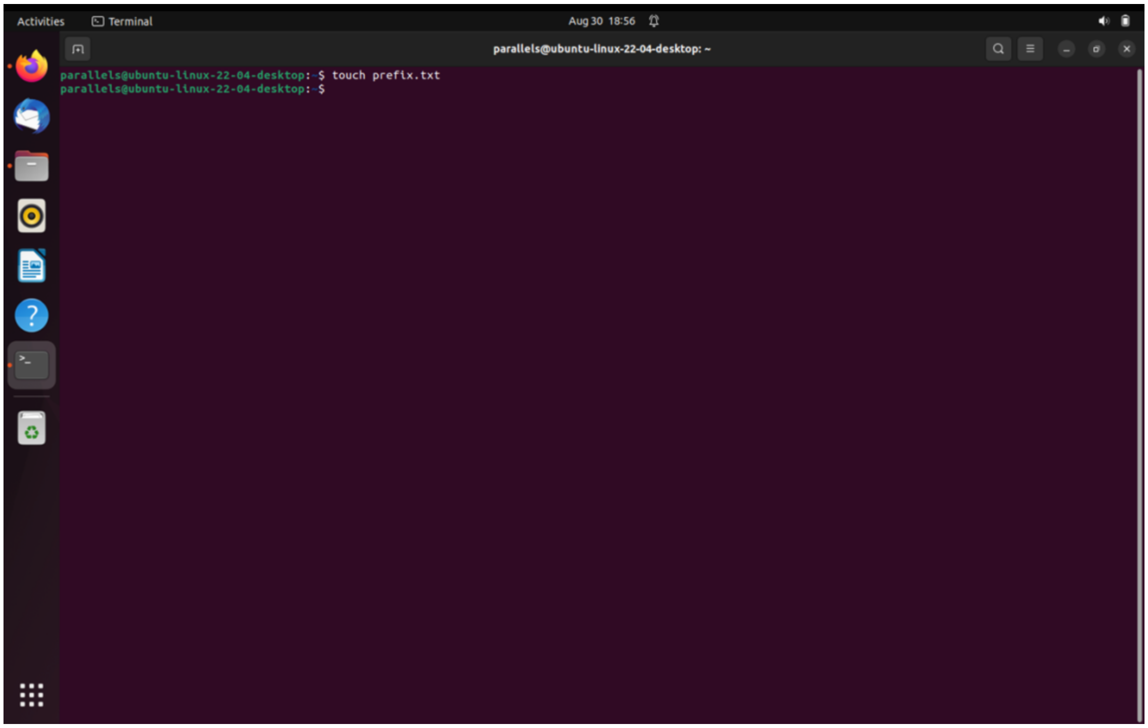

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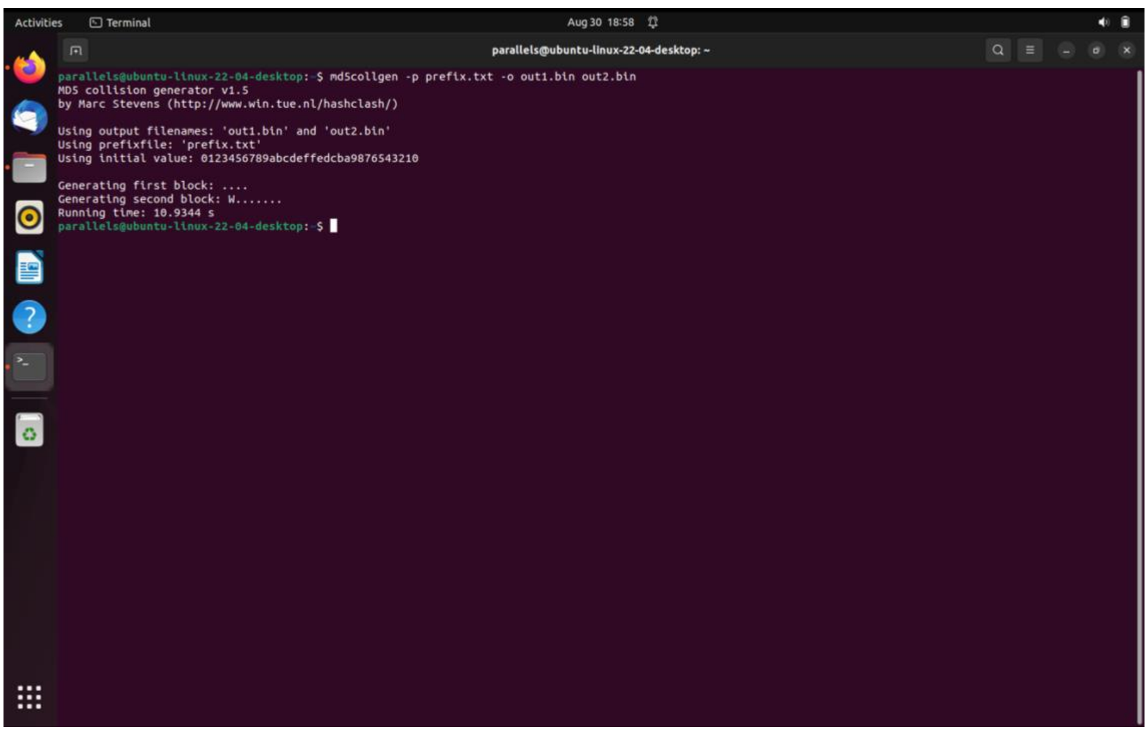

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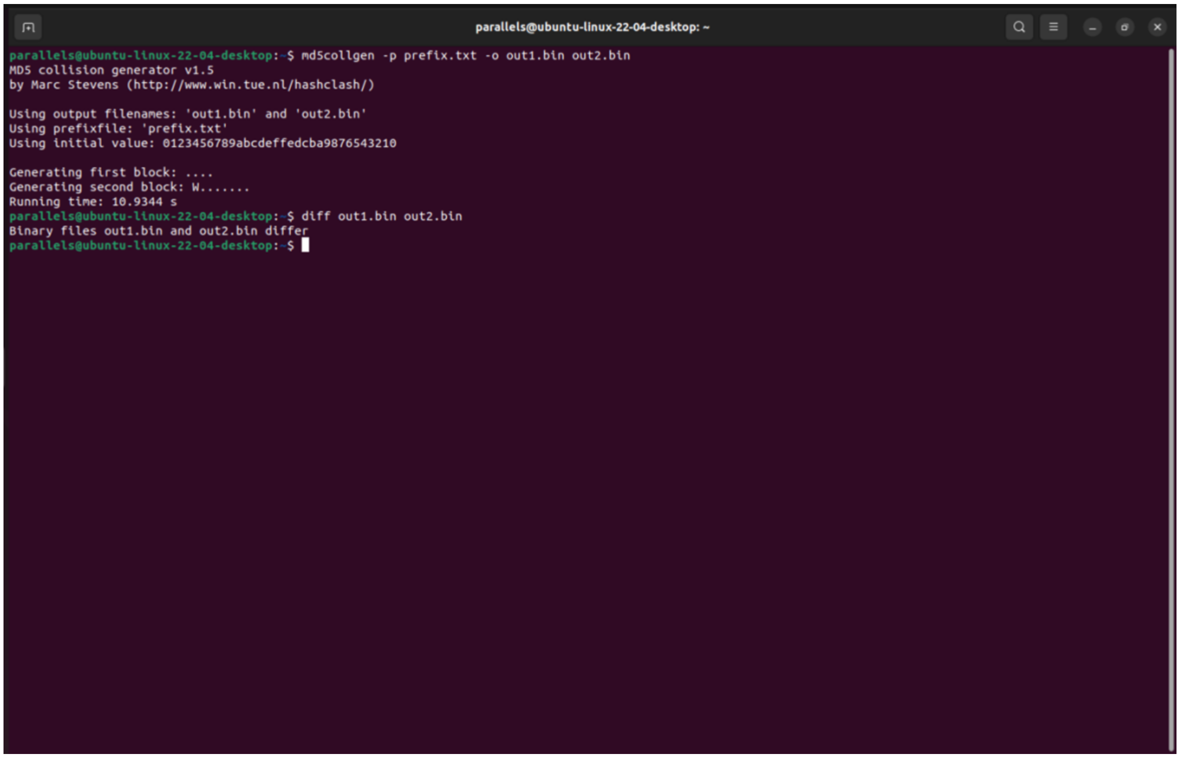

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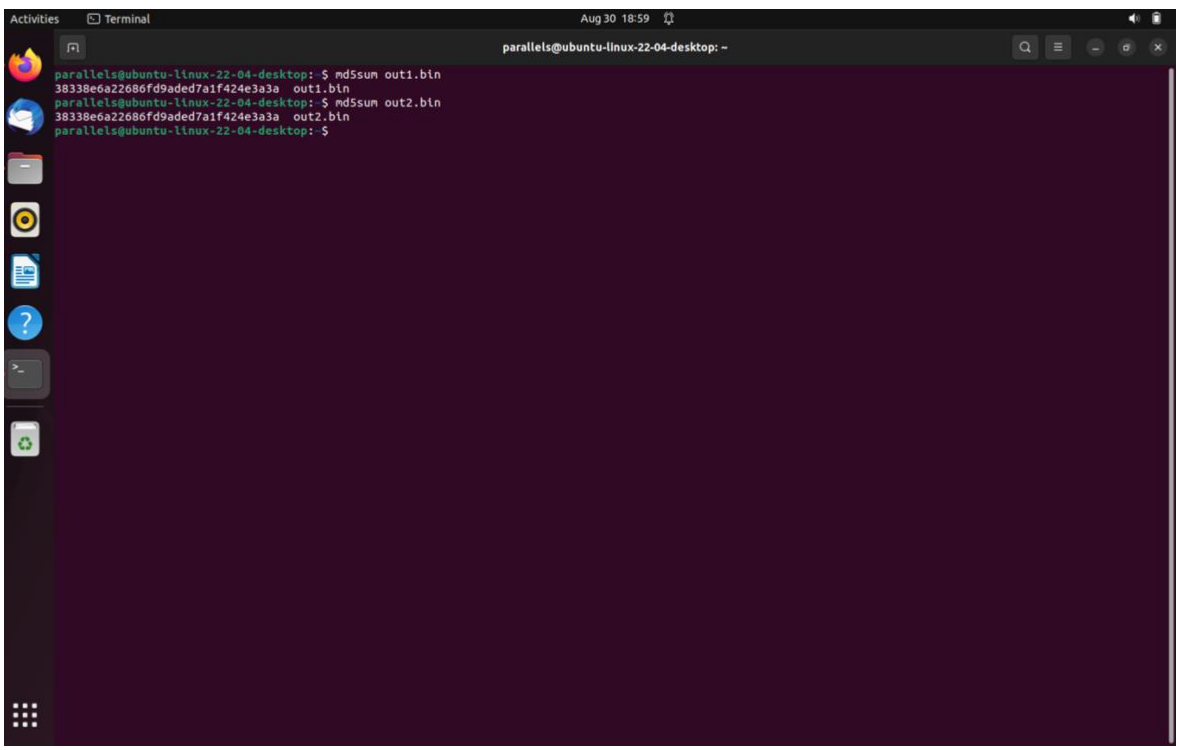

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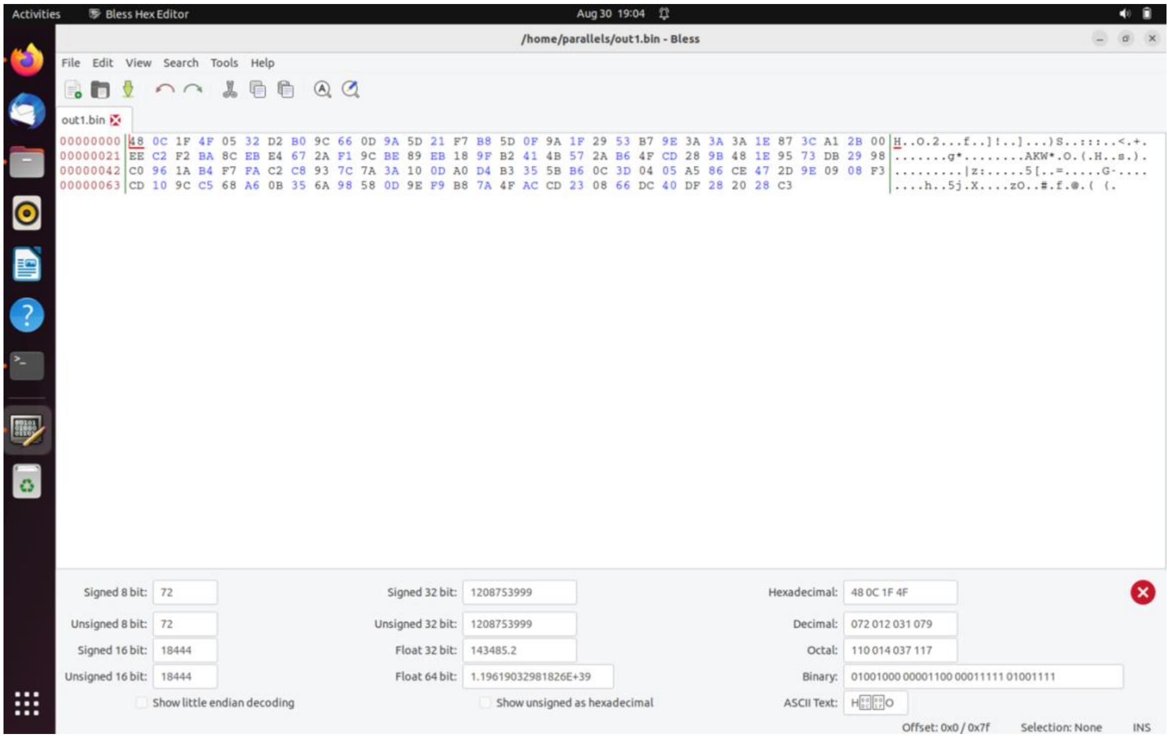

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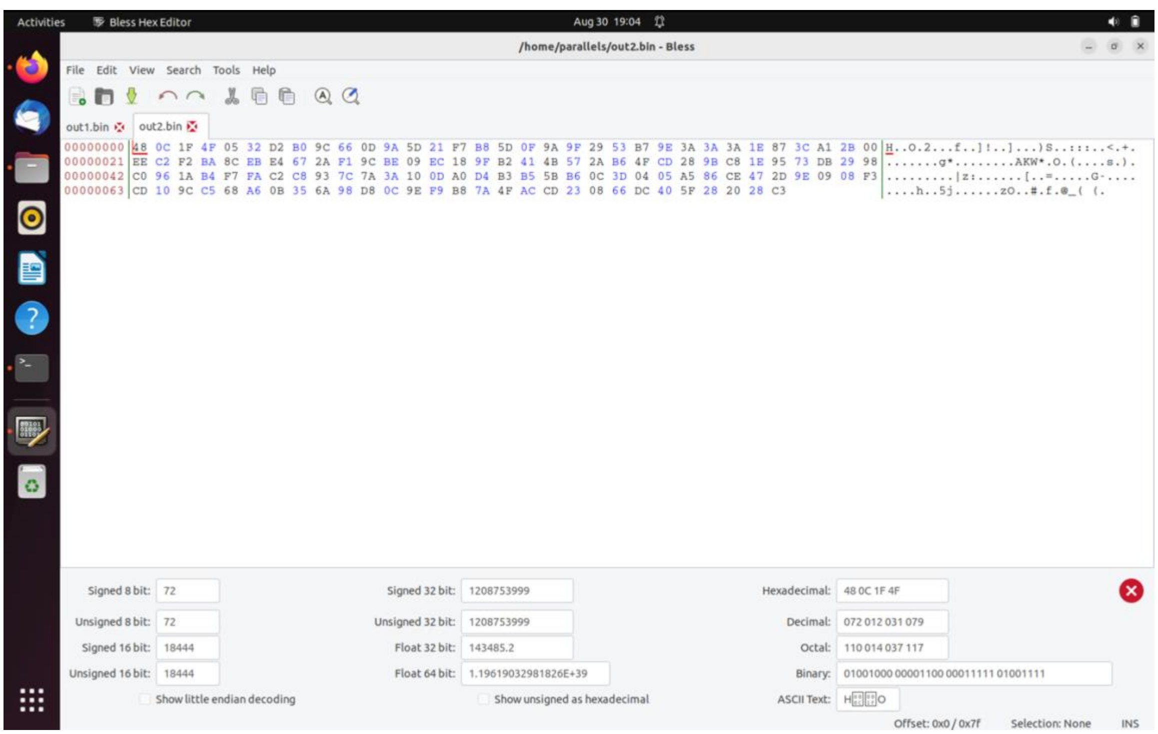

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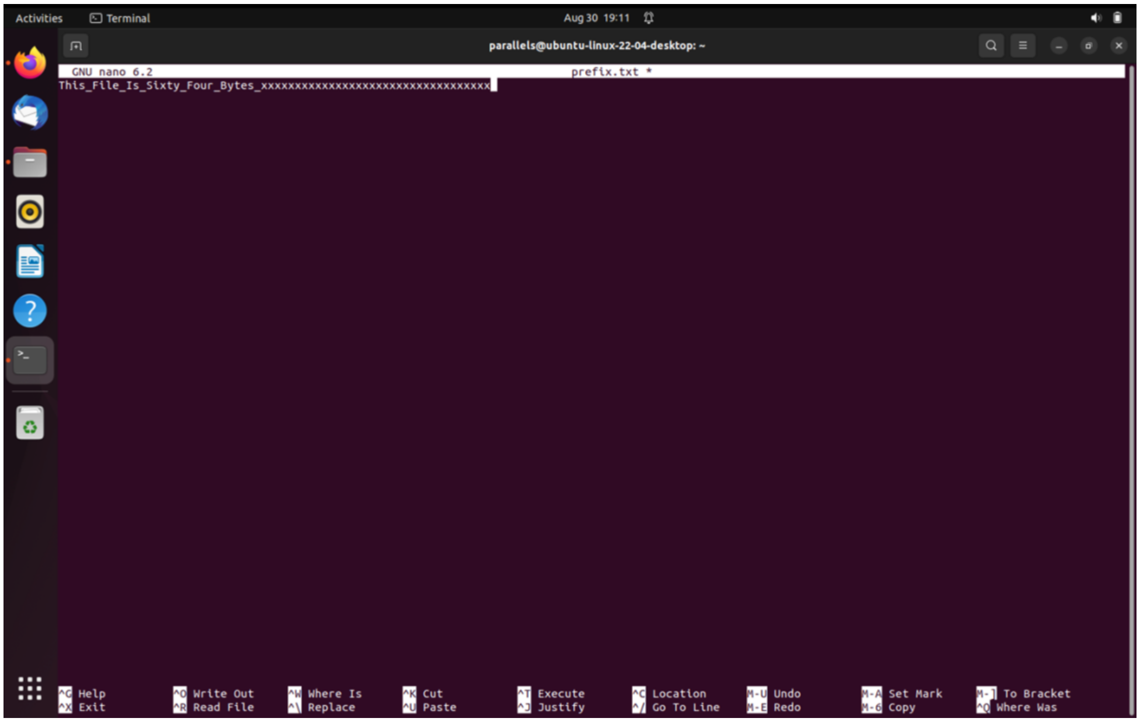

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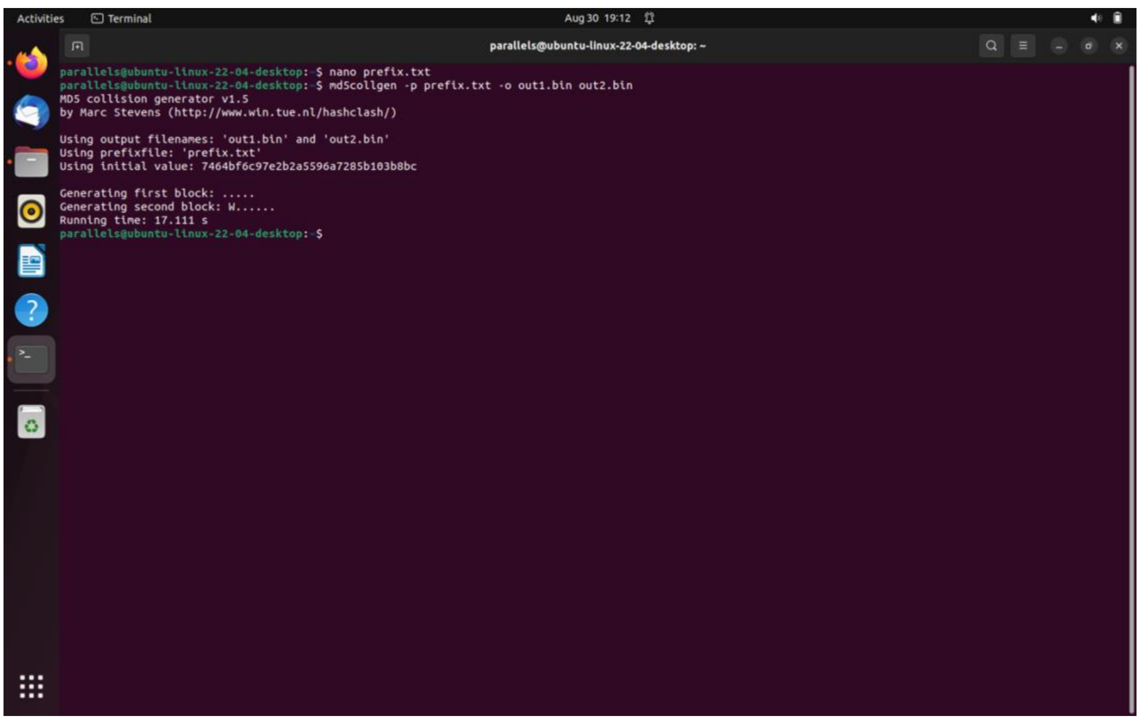

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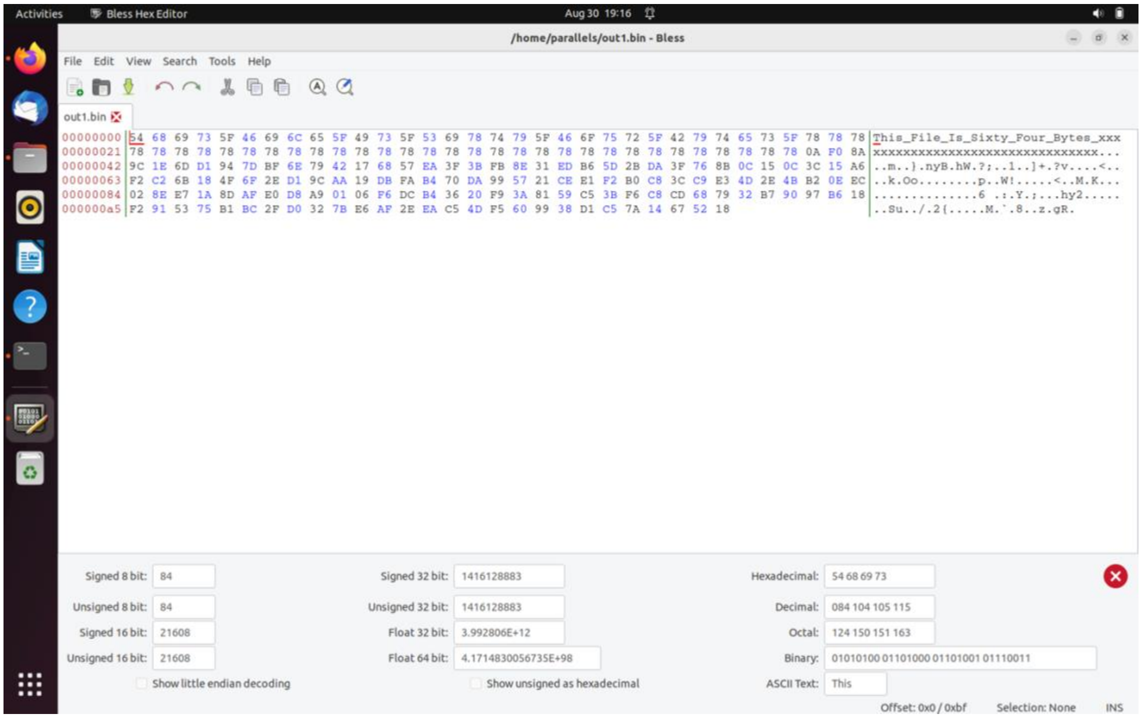

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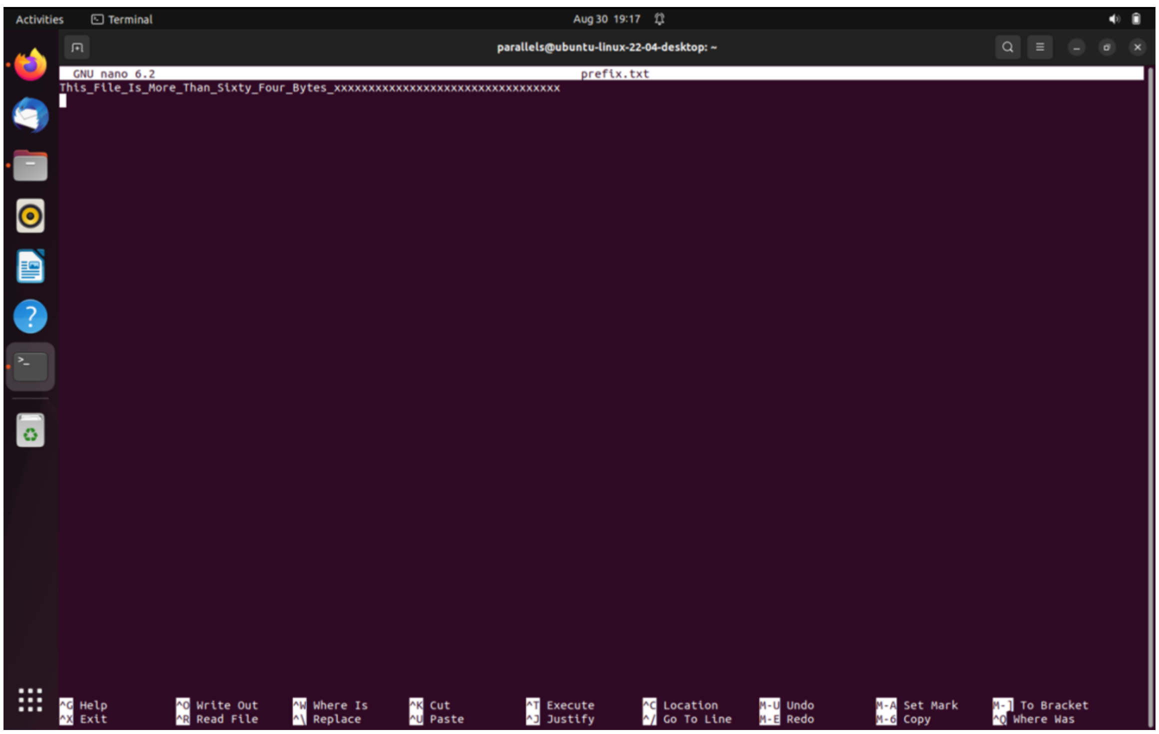

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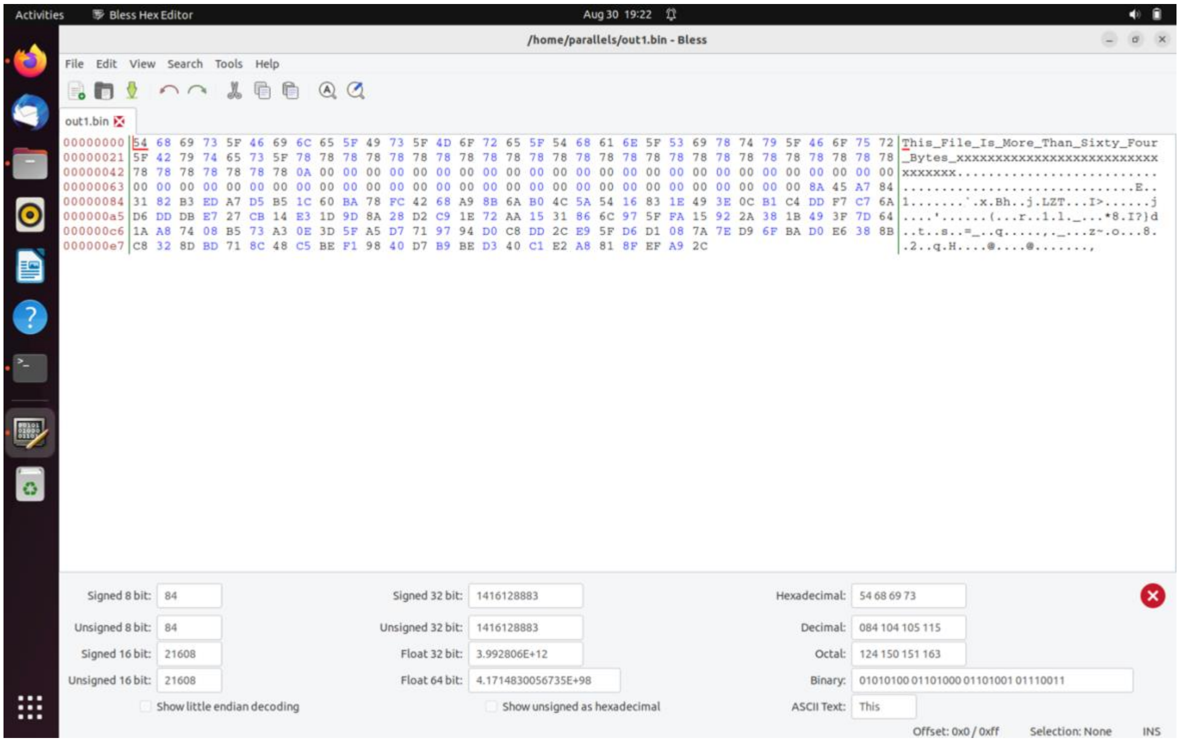

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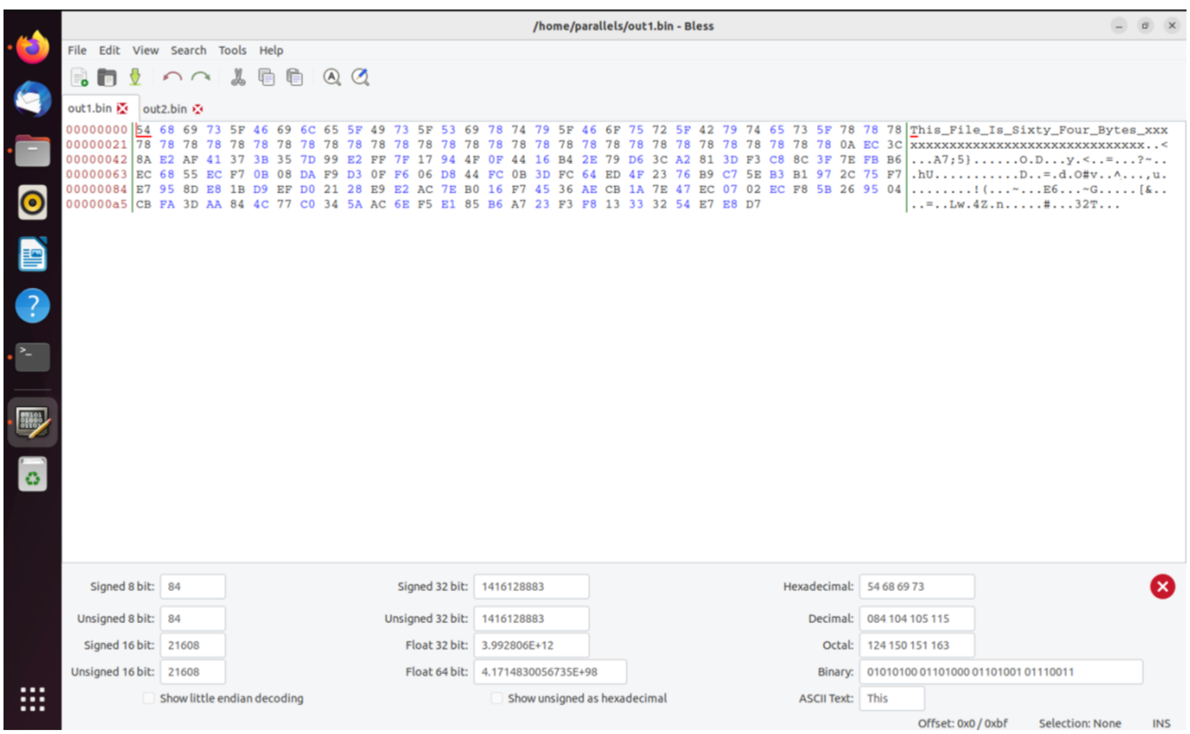

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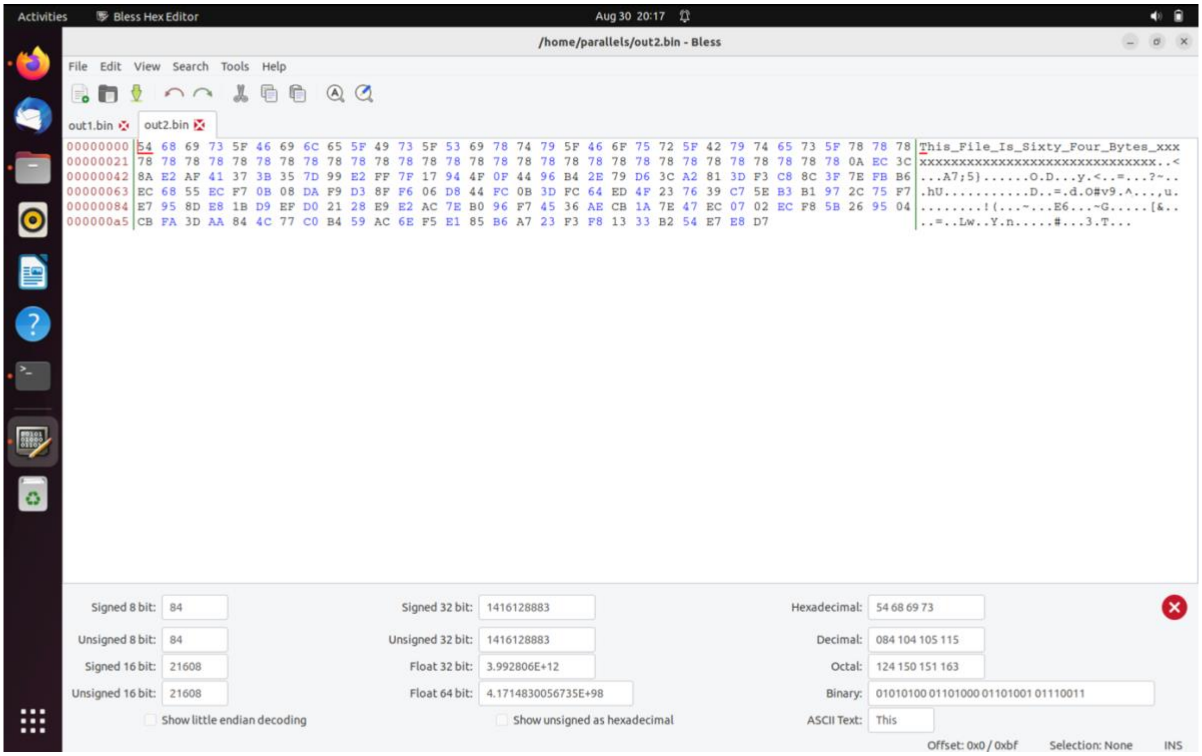

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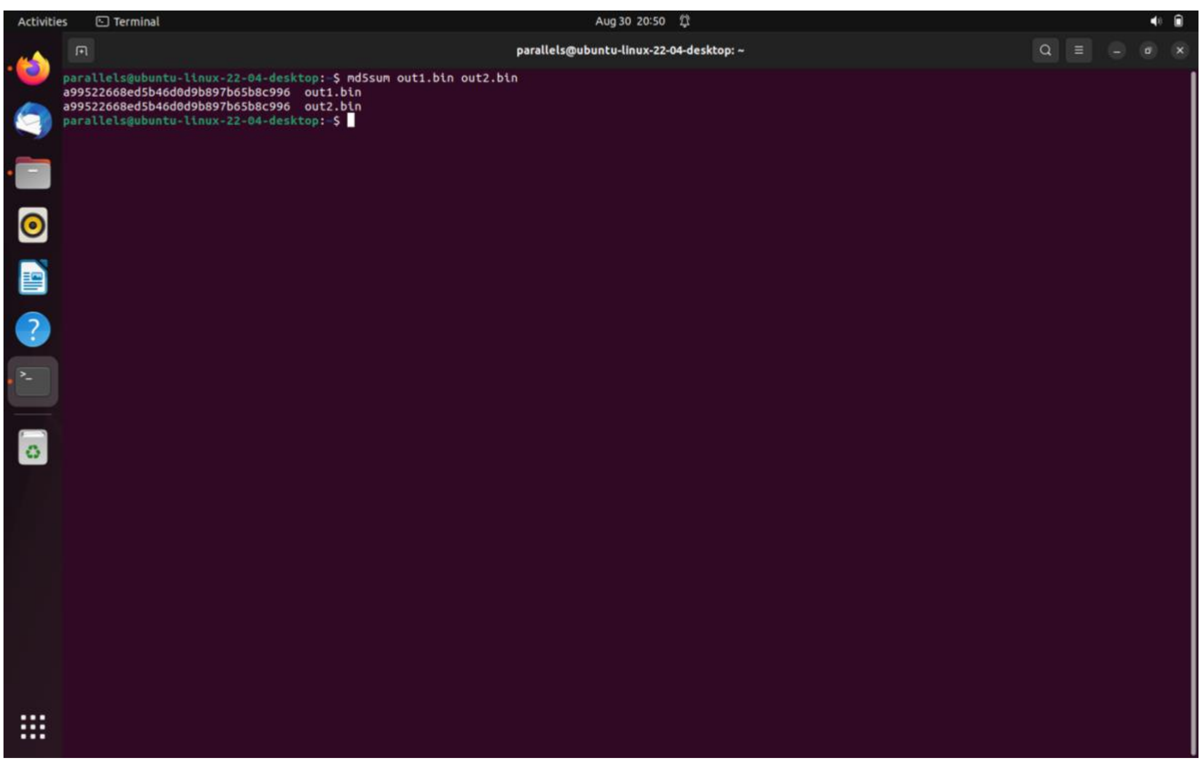

Screenshots: Task 2

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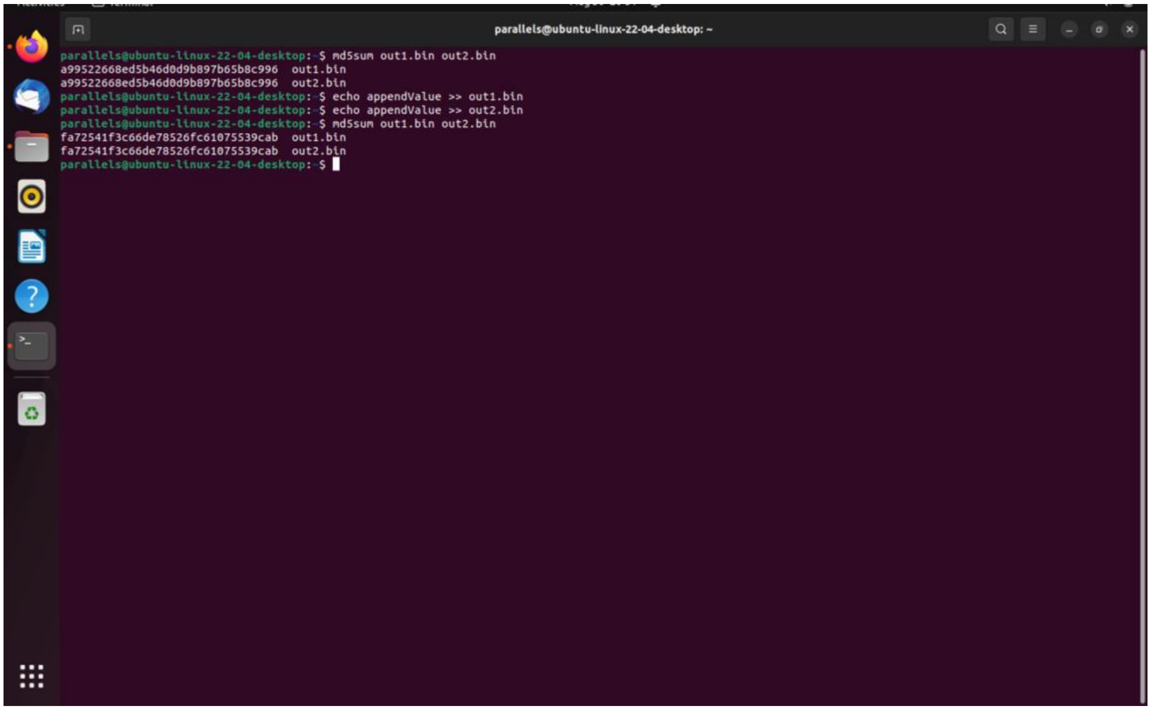

Screenshots: Task 3

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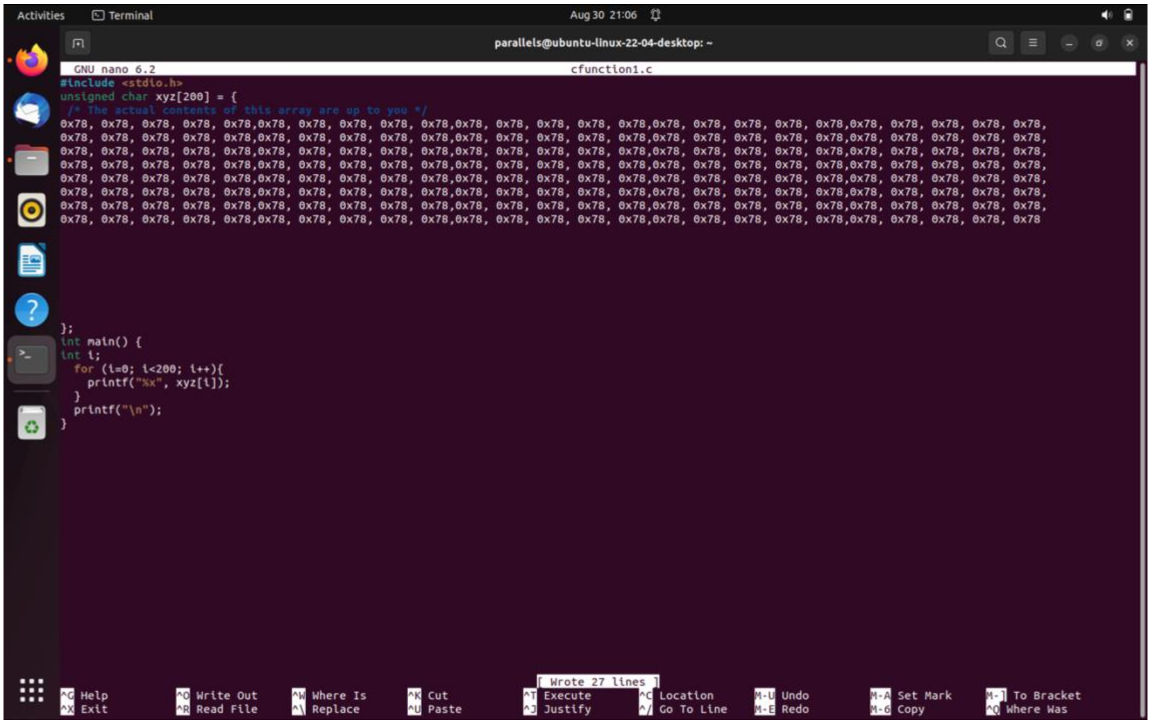

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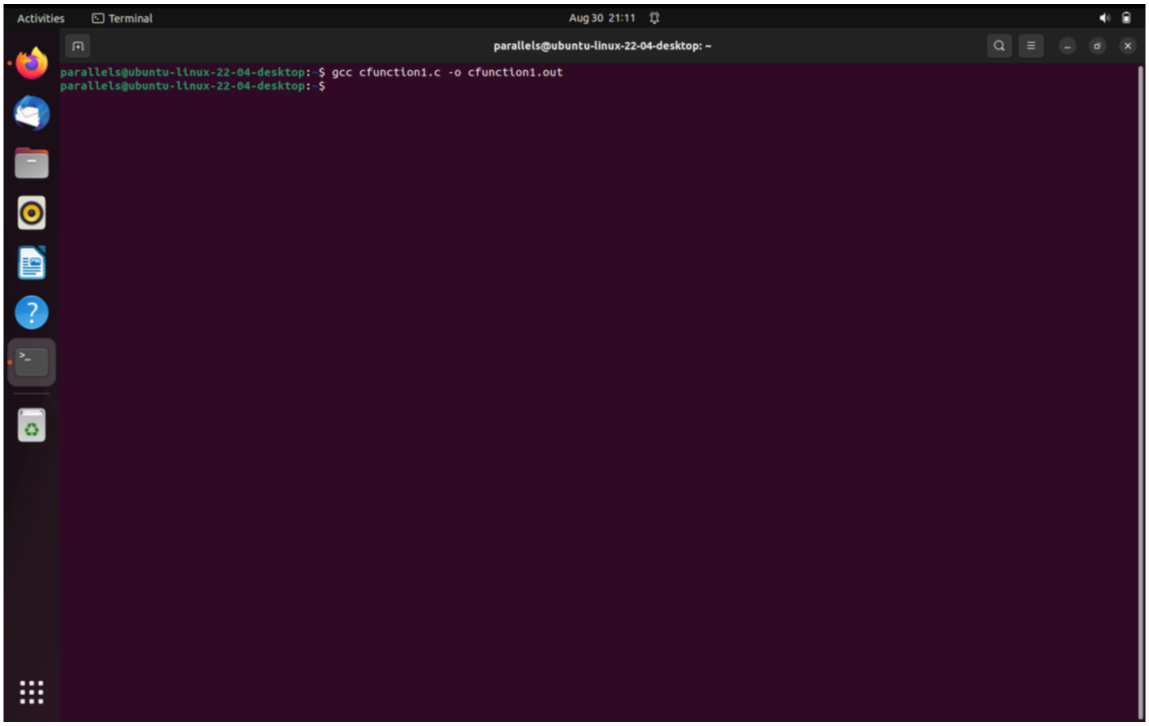

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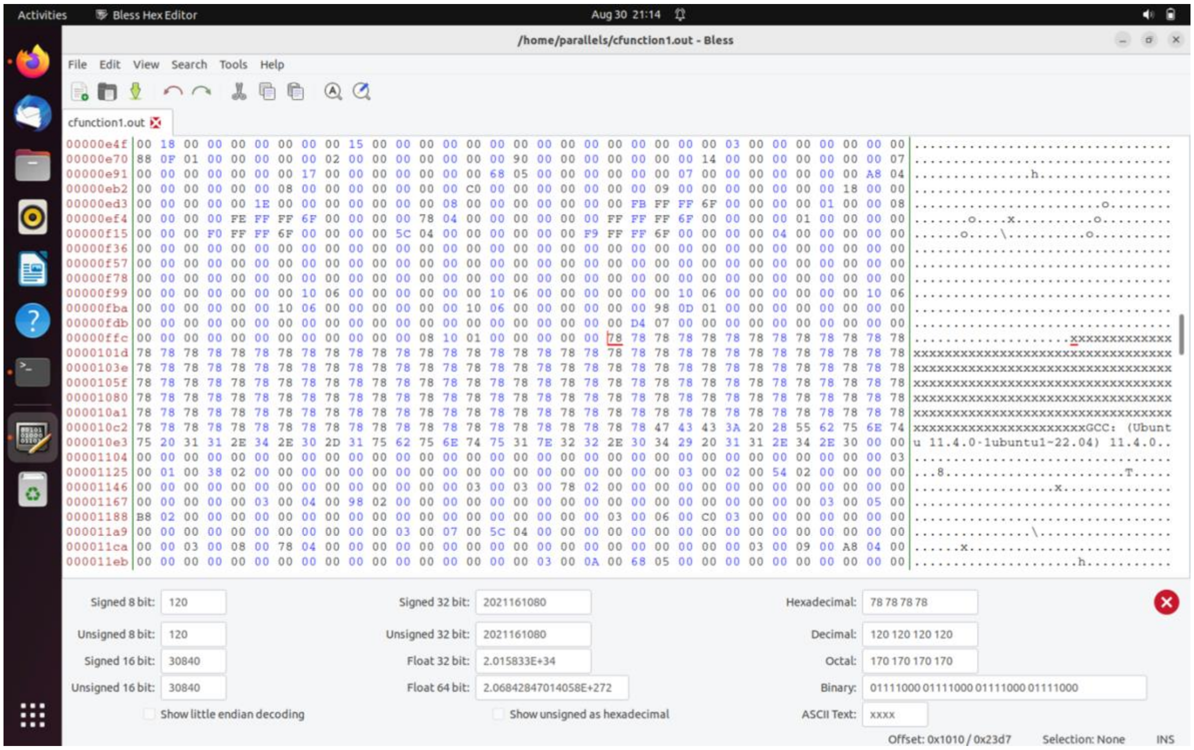

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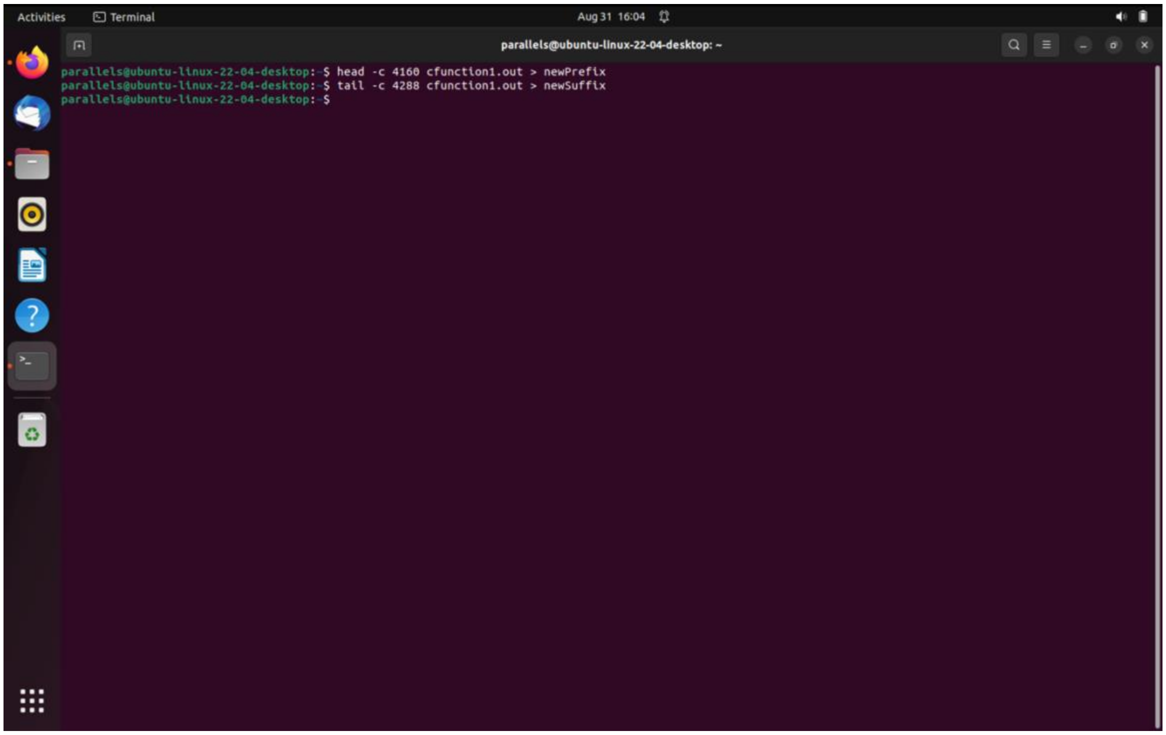

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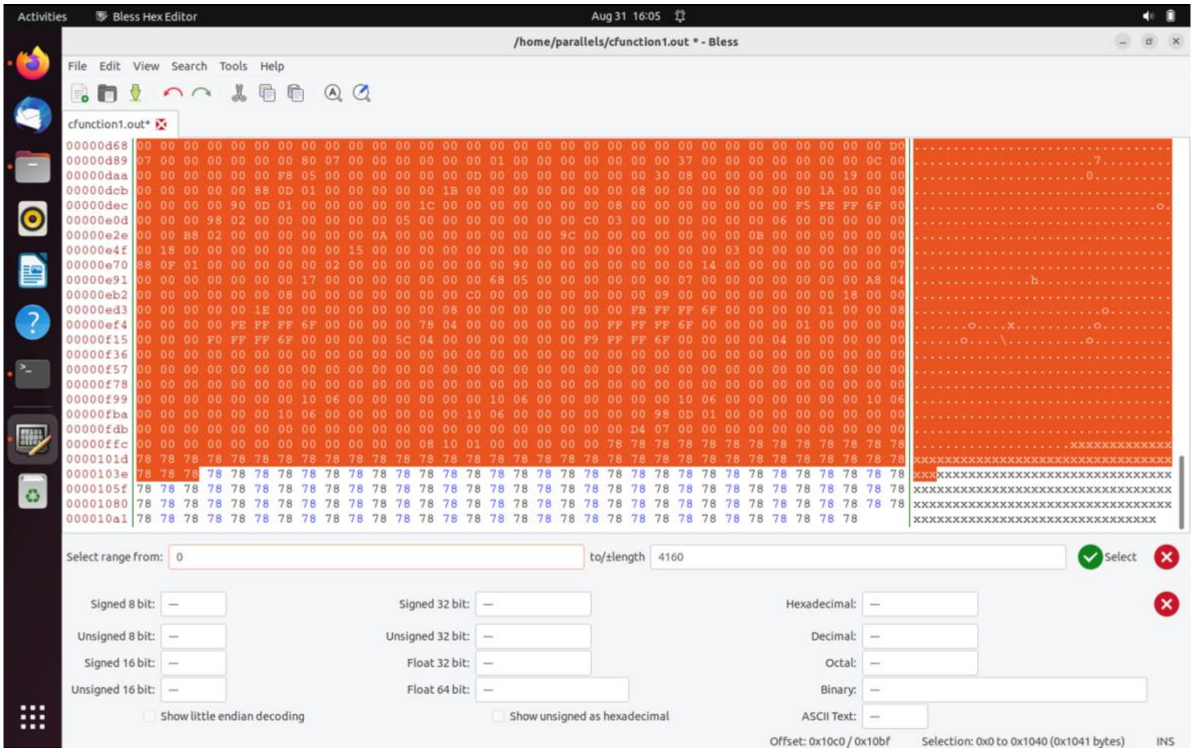

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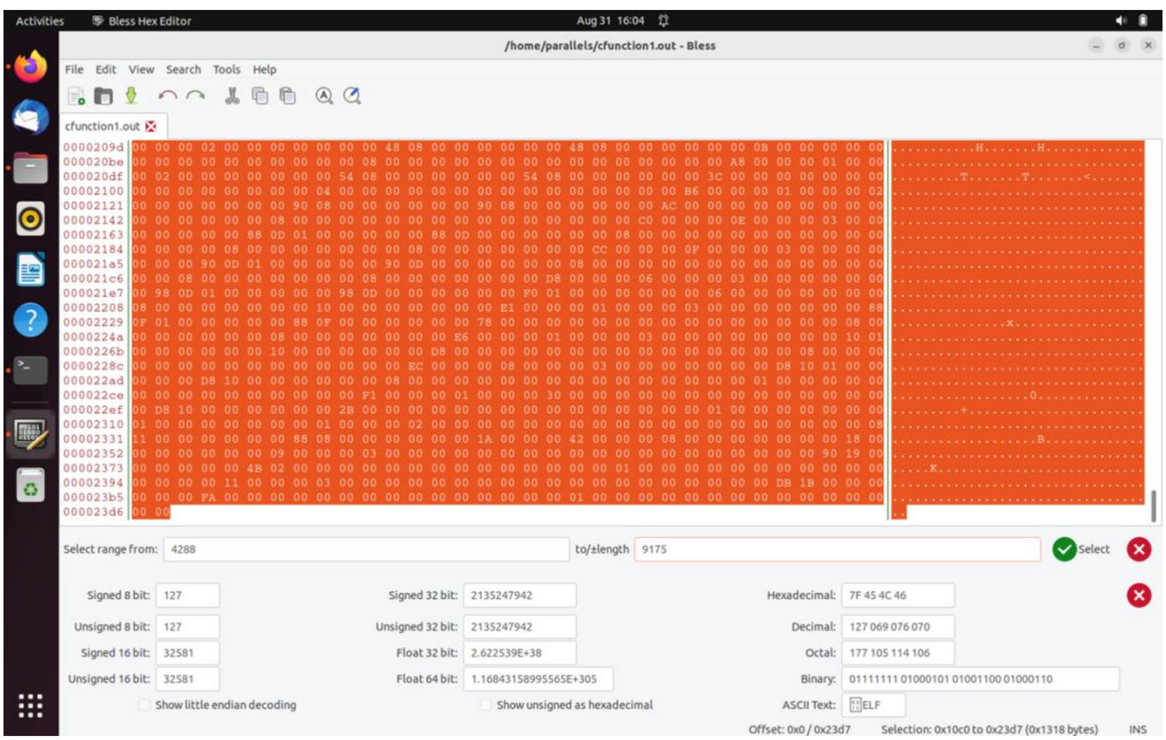

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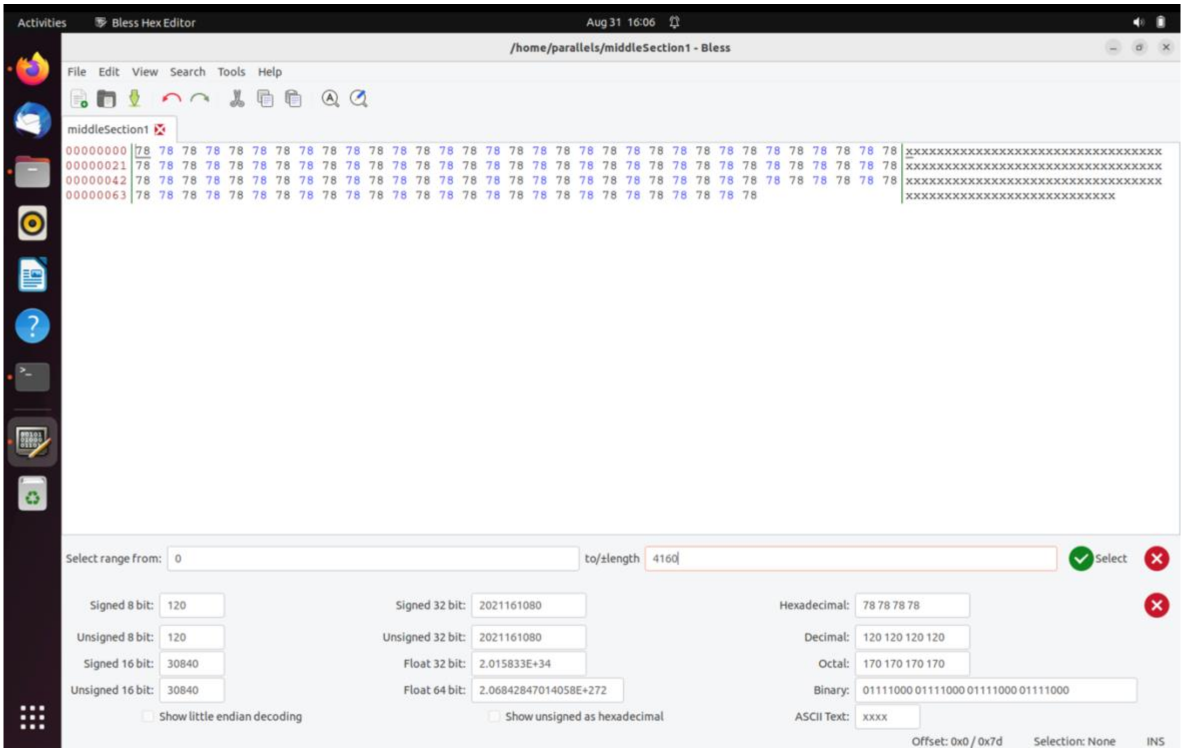

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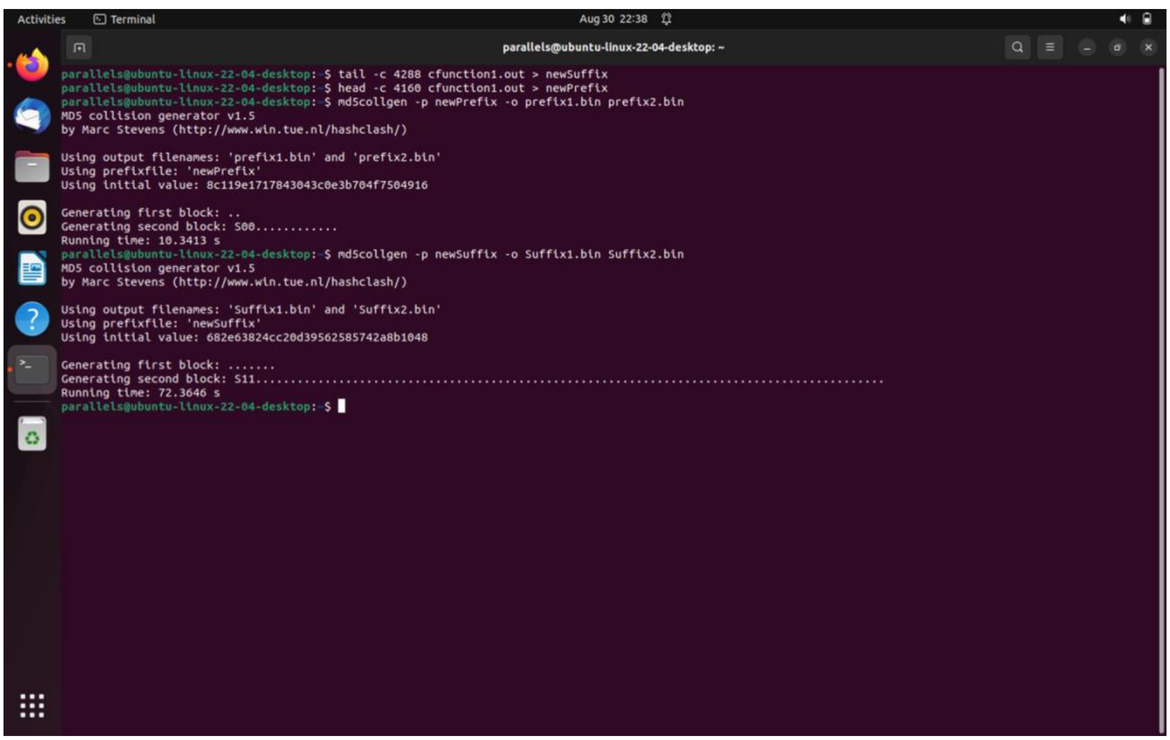

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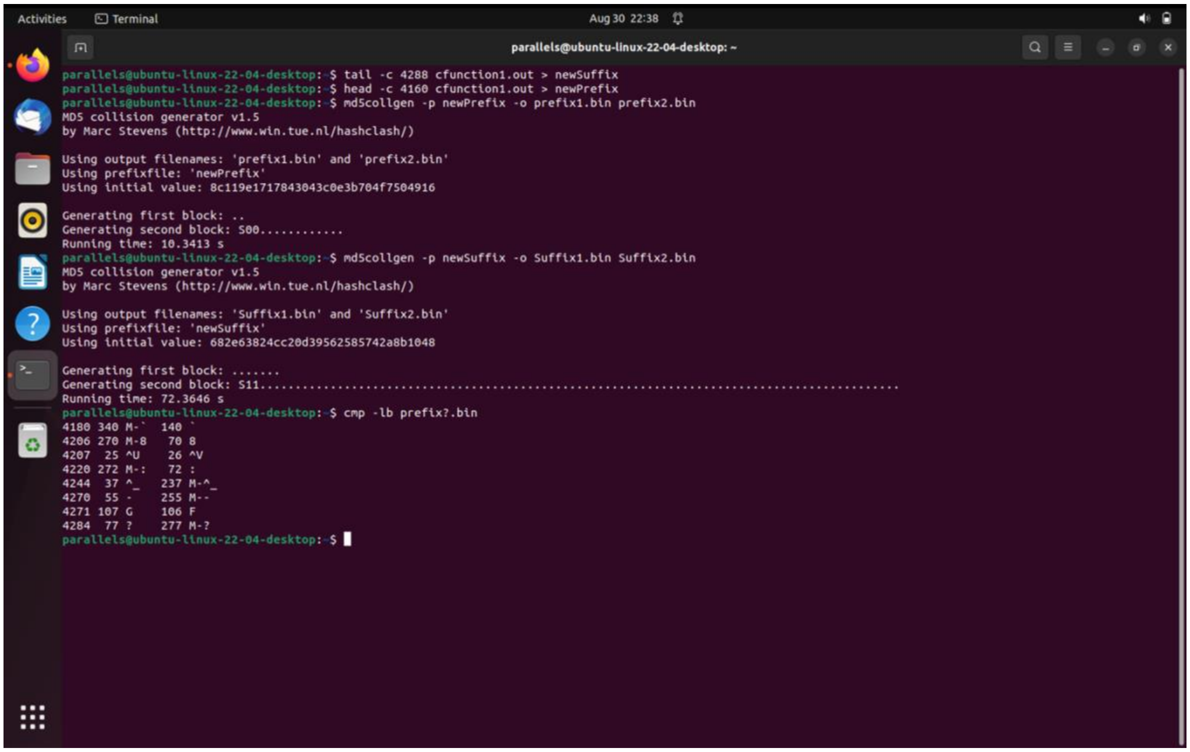

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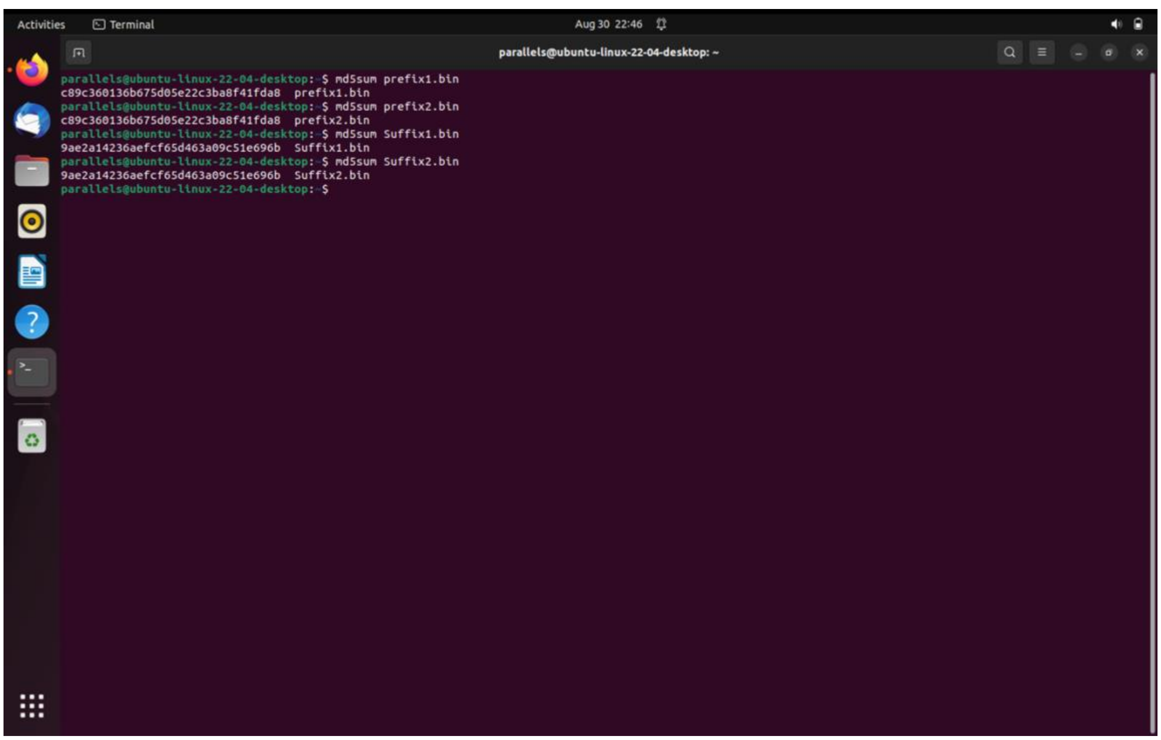

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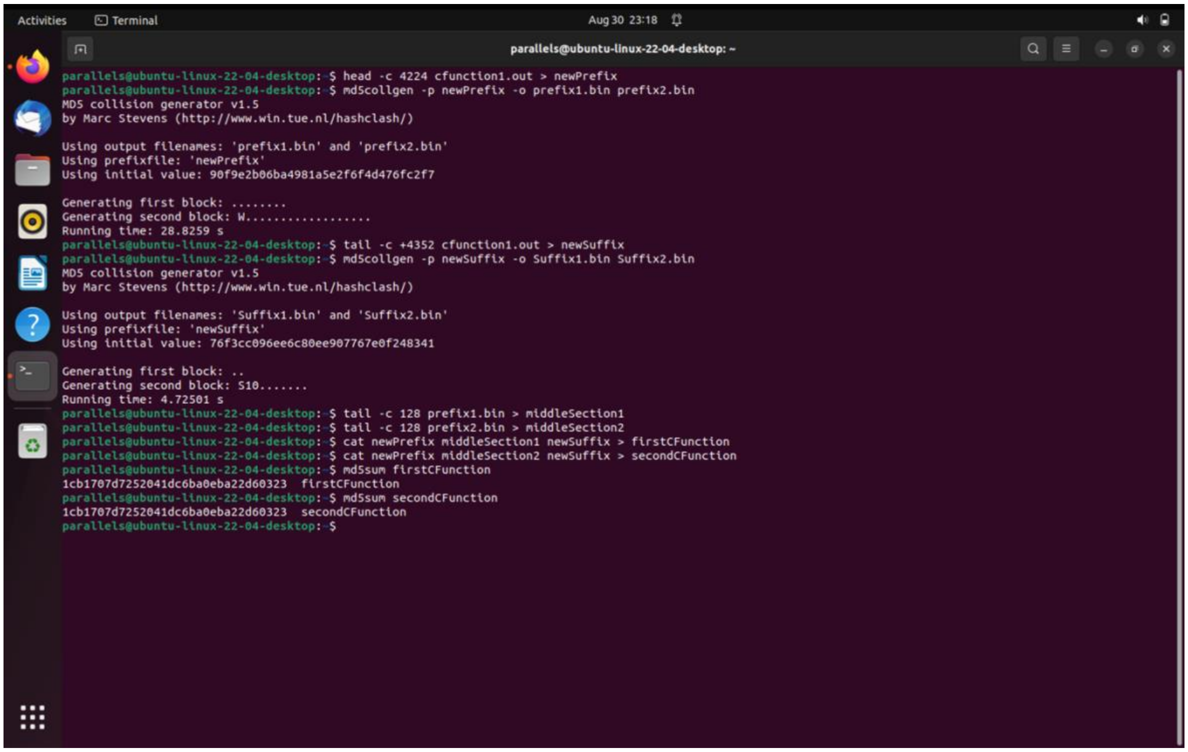

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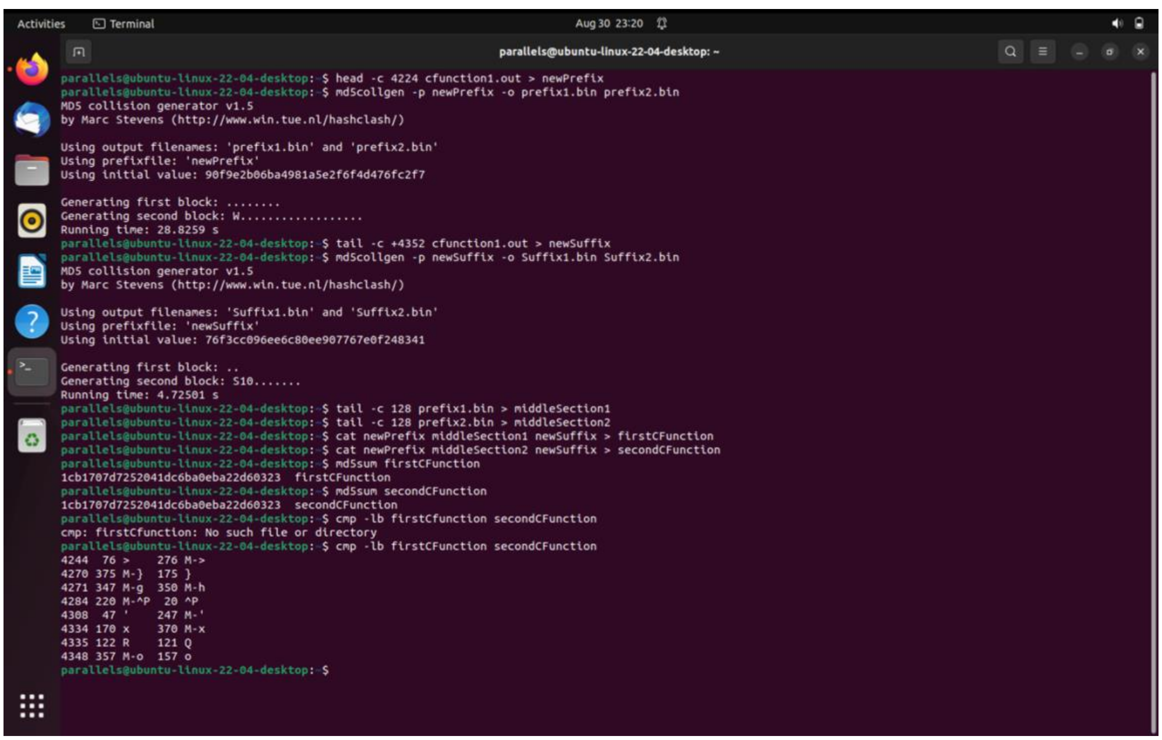

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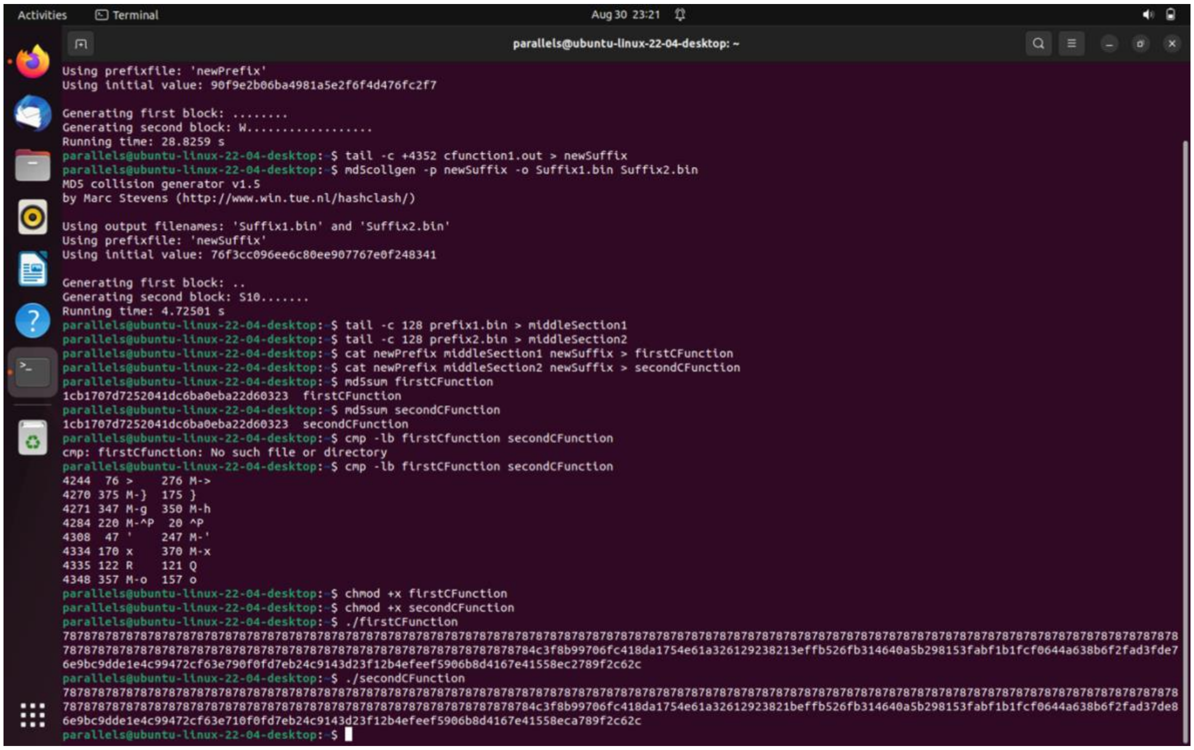

Screenshots: Task 4

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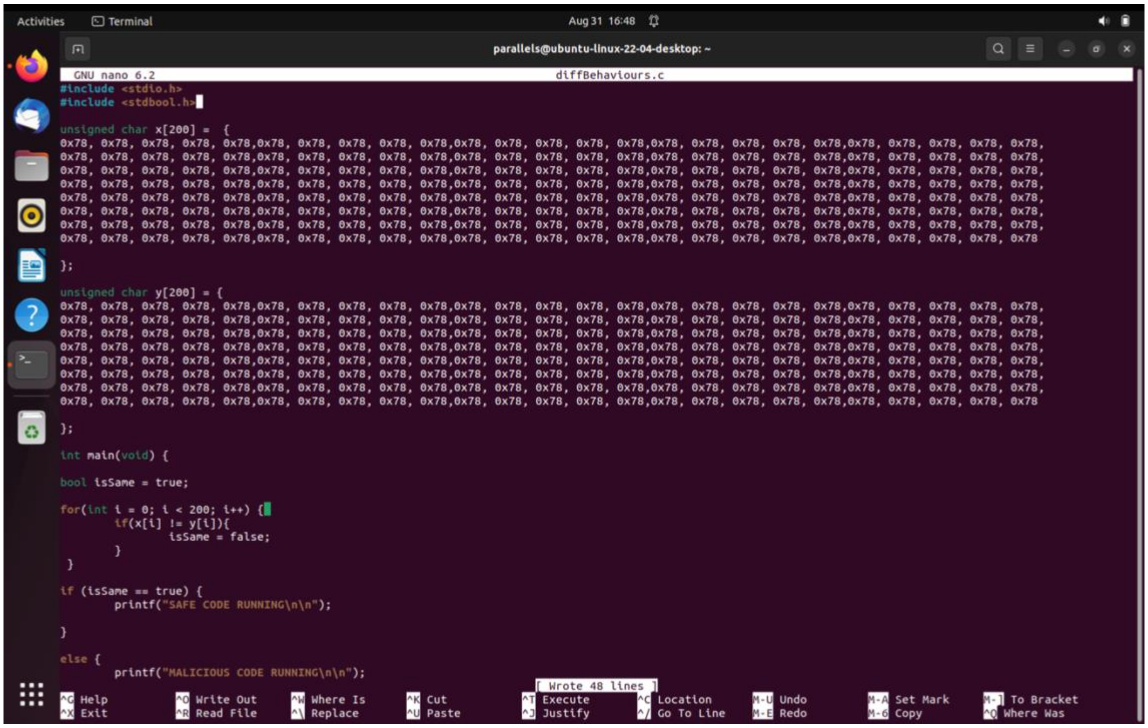

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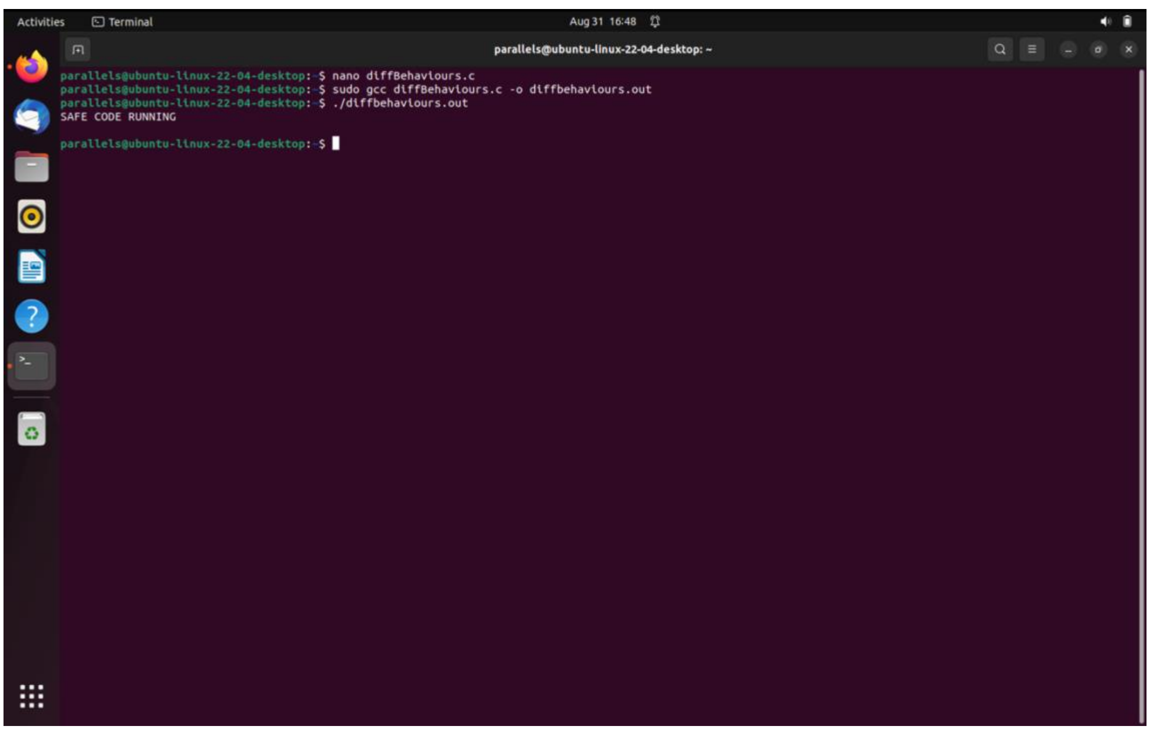

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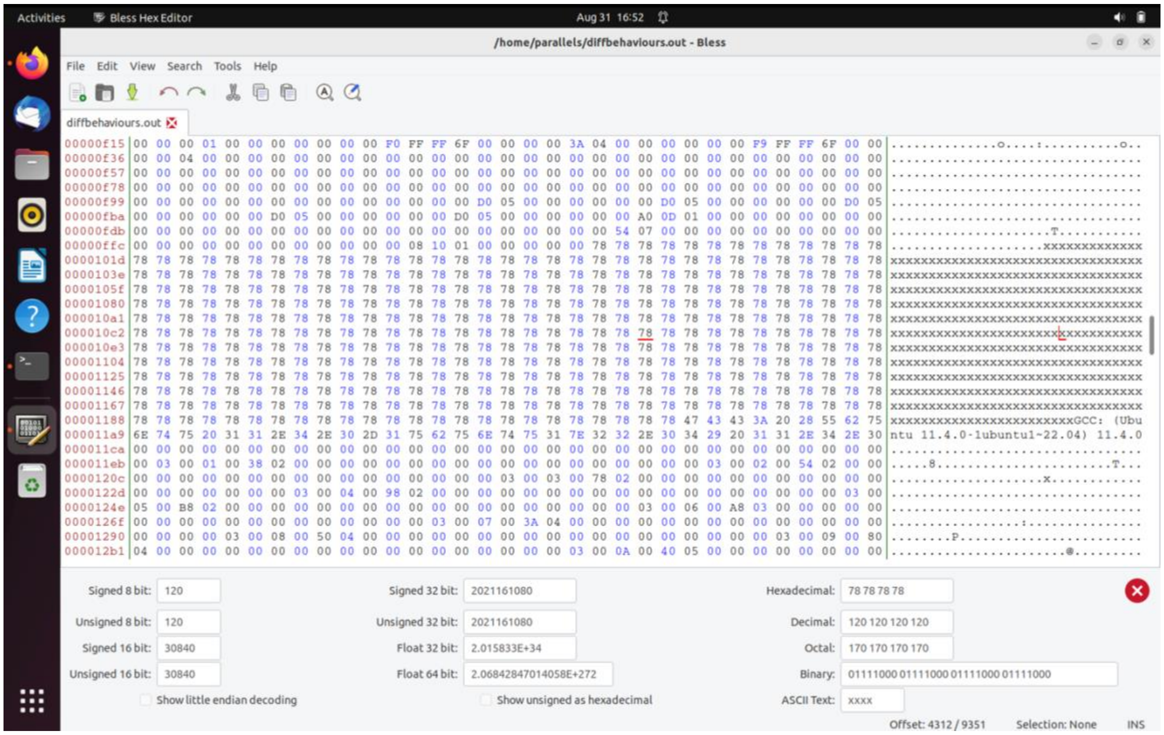

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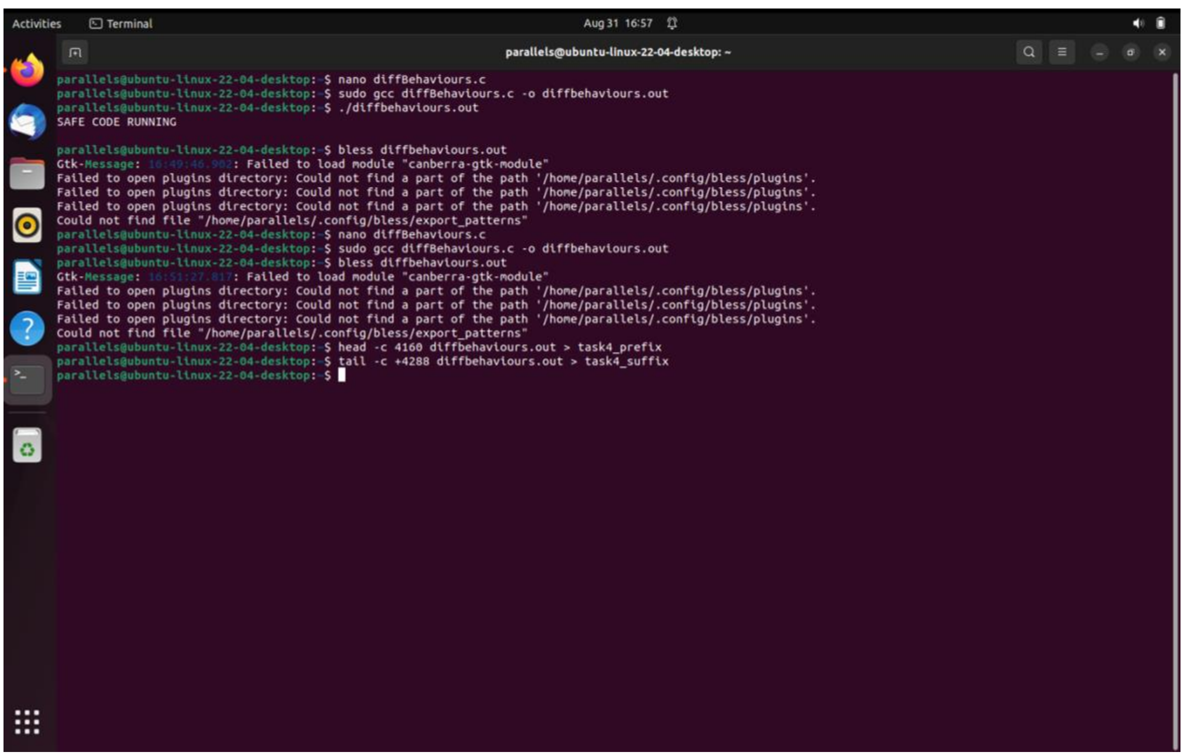

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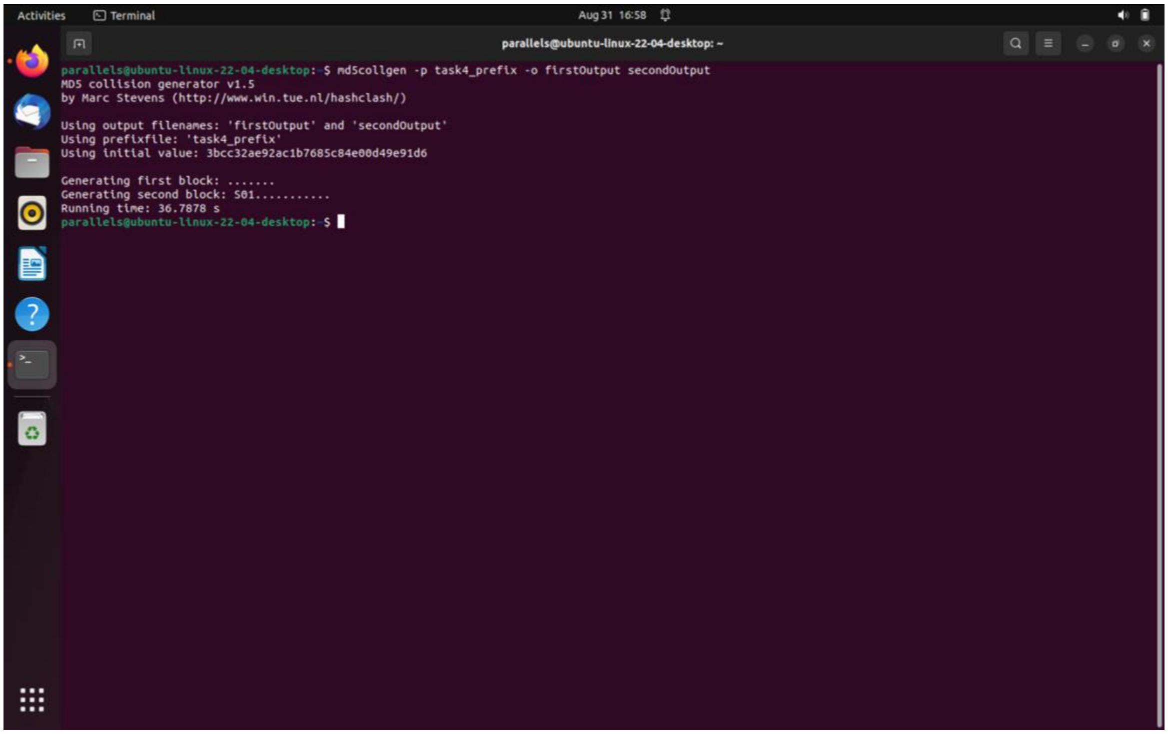

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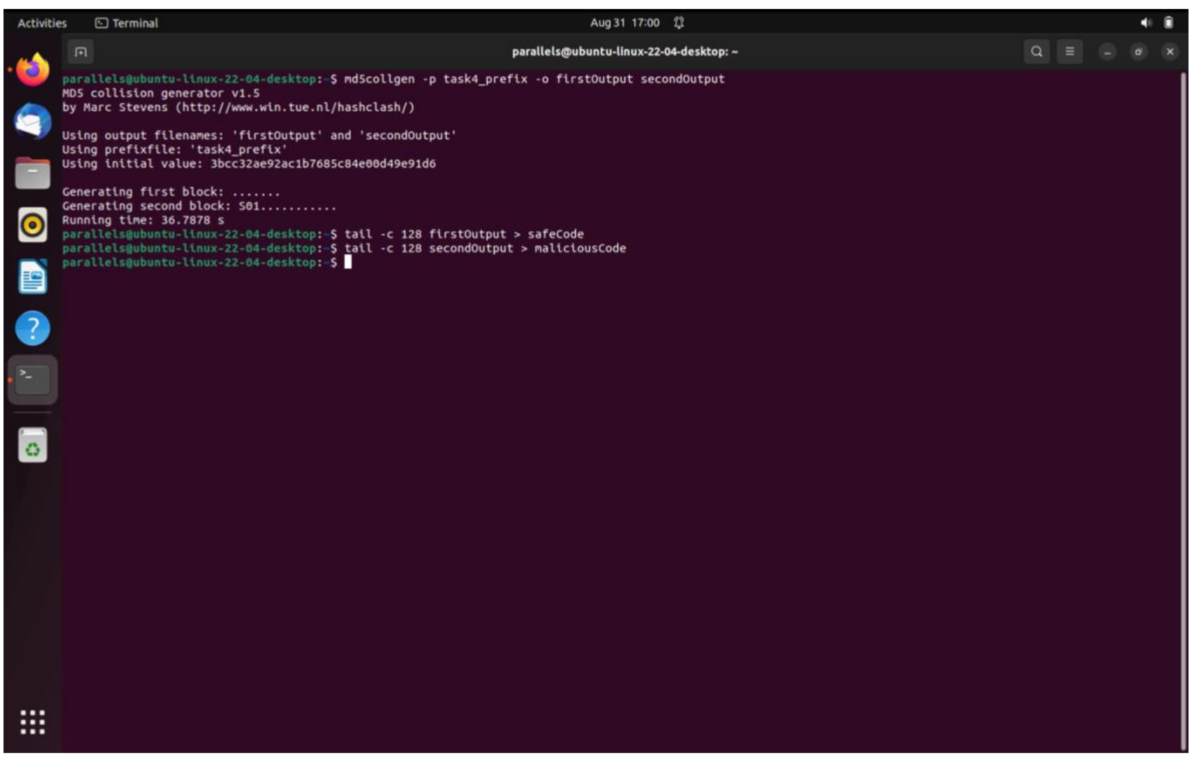

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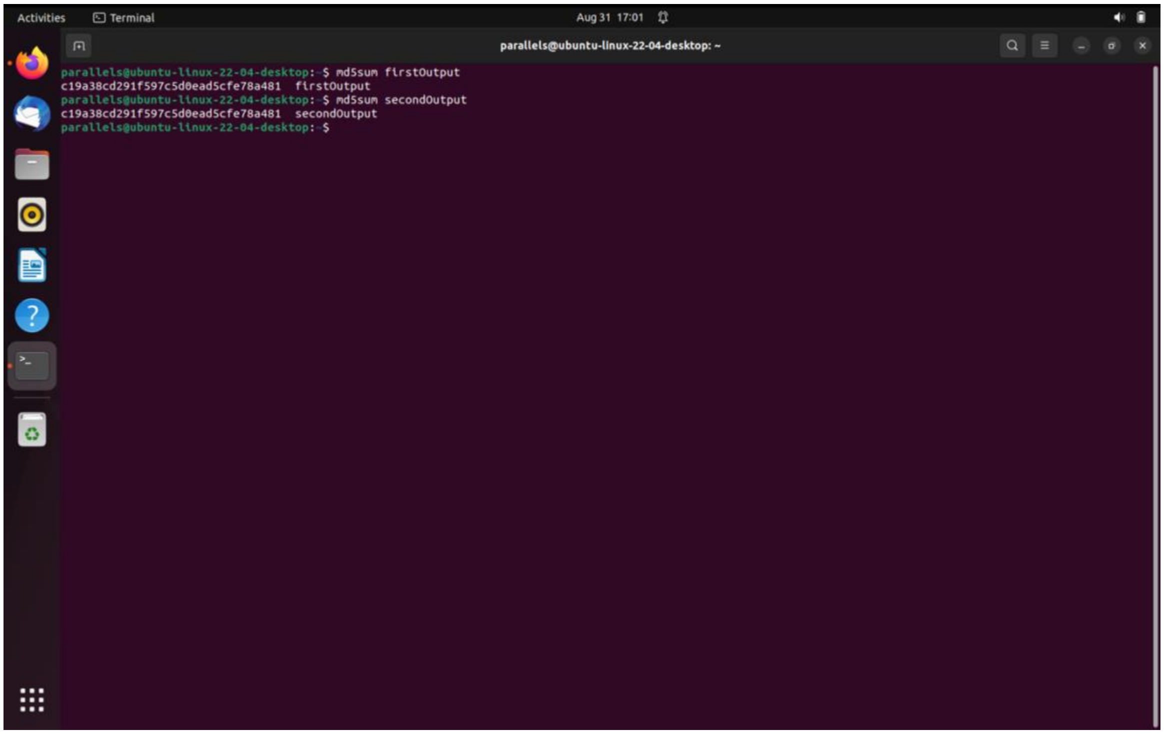

Screenshot38: (Return to text)