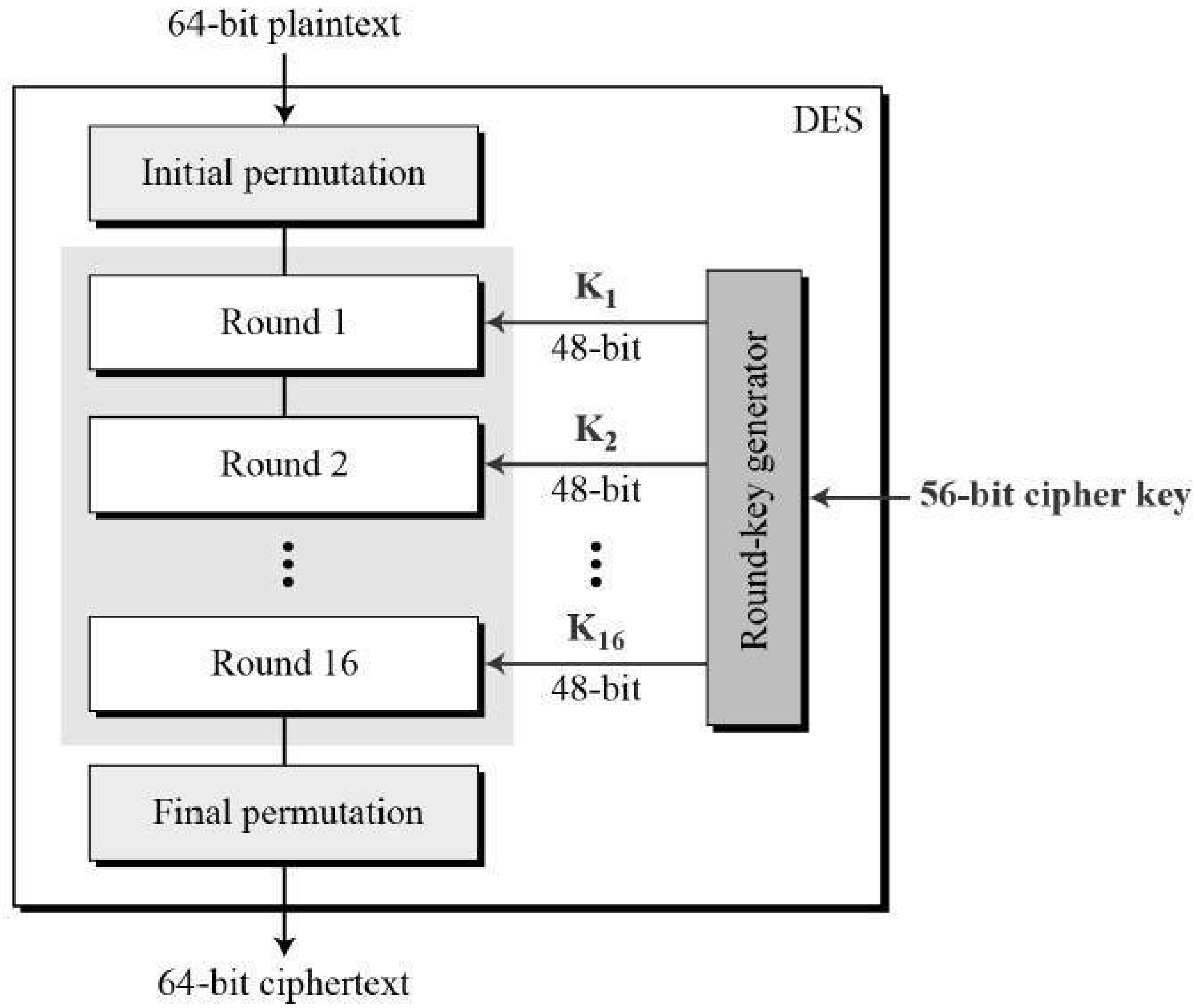
CRYPTO M2 (p-2)

techworldthink • March 19, 2022

Data Encryption Standard

The Data Encryption Standard (DES) is a symmetric-key block cipher published by the National Institute of Standards and Technology (NIST).

DES is an implementation of a Feistel Cipher. It uses 16 round Feistel structure. The block size is 64-bit. Though, key length is 64-bit, DES has an effective key length of 56 bits, since 8 of the 64 bits of the key are not used by the encryption algorithm (function as check bits only). General Structure of DES is depicted in the following illustration –



DES Structure

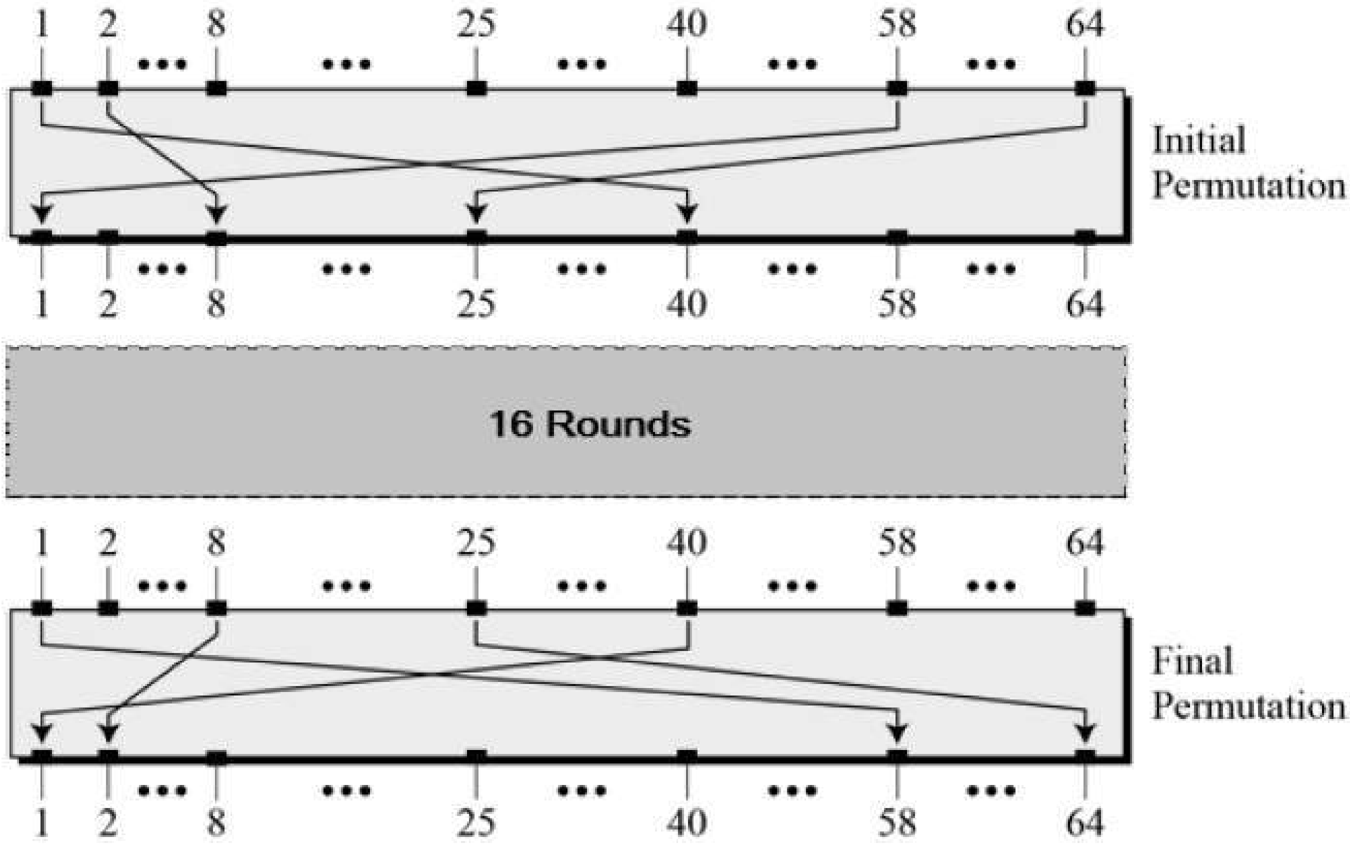
- DES is a symmetric block cipher.
- DES encrypts 64-bit plain text to 64-bit cipher text.
- DES uses a 56-bit key for encryption.
- Encryption and decryption algorithm is the same in DES. But, the procedure of encryption is reversed while decryption.
- 16 rounds in DES strengthens the algorithm.
- Each round has the same function which involves key transformation, expansion permutation, s-box substitution, p-box permutation and XOR and swapping.

Since DES is based on the Feistel Cipher, all that is required to specify DES is −

- Round function
- Key schedule
- Any additional processing − Initial and final permutation

Initial and Final Permutation

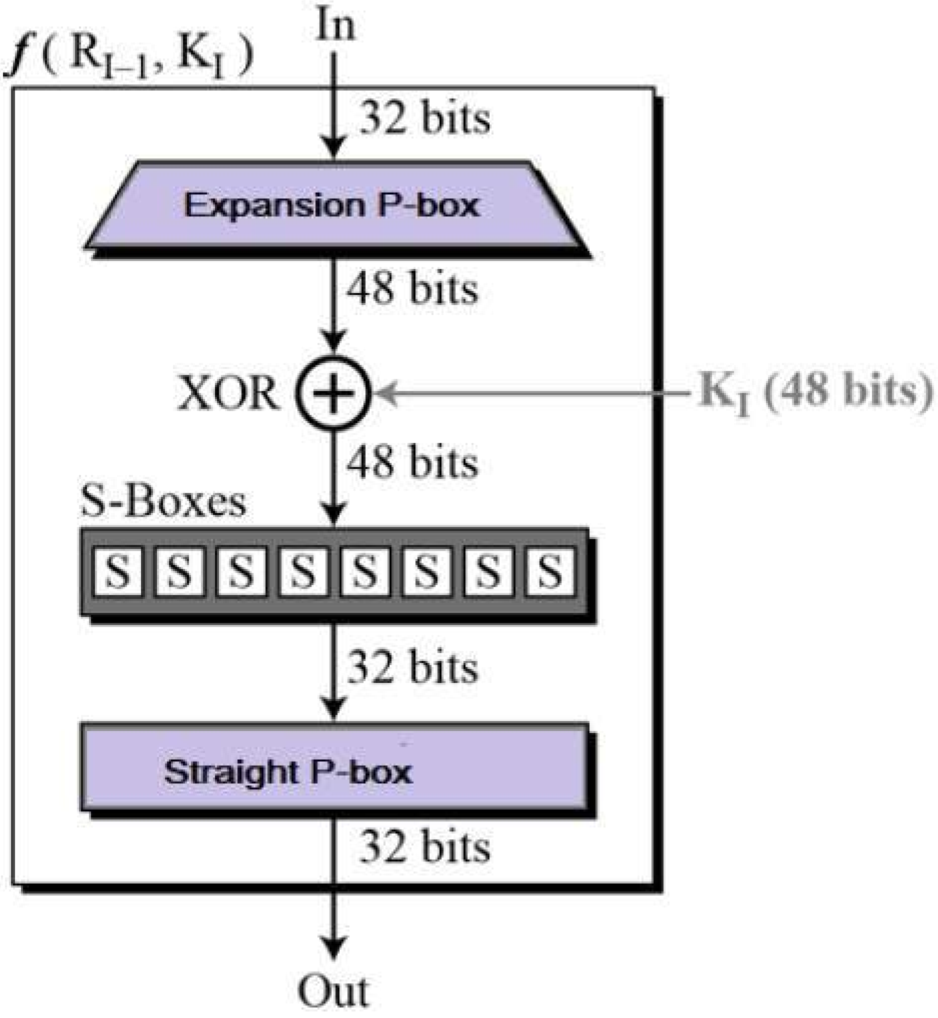
The initial and final permutations are straight Permutation boxes (P-boxes) that are inverses of each other. They have no cryptography significance in DES. The initial and final permutations are shown as follows −



Initial and Final Permutation

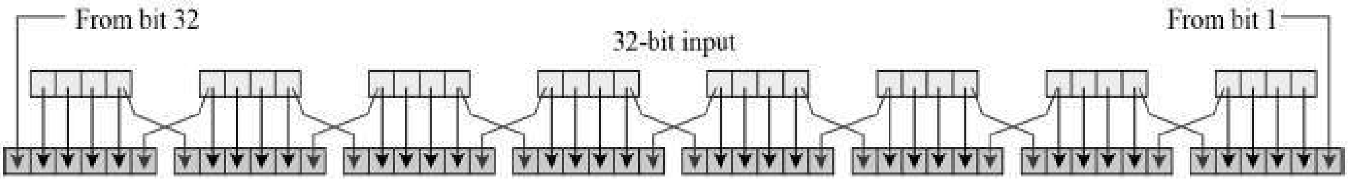
Round Function

The heart of this cipher is the DES function, *f*. The DES function applies a 48-bit key to the rightmost 32 bits to produce a 32-bit output.



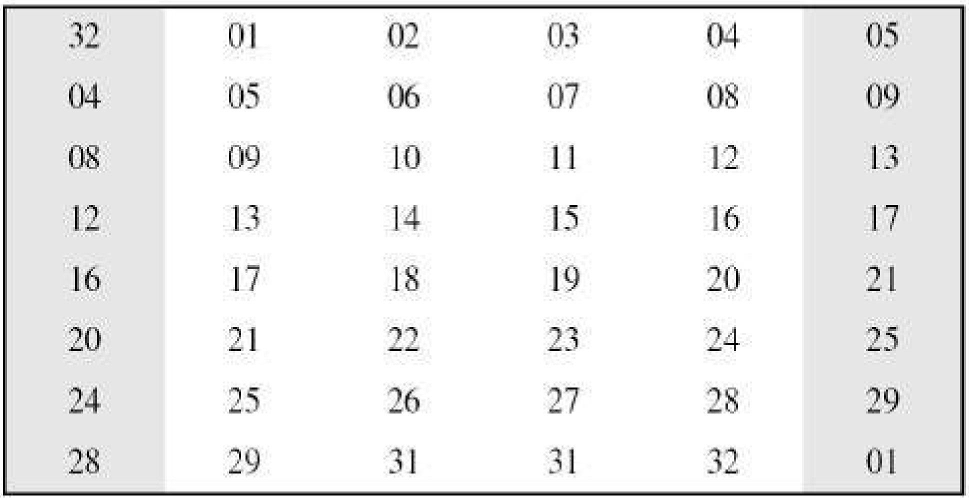
Round Function

- Expansion Permutation Box − Since right input is 32-bit and round key is a 48-bit, we first need to expand right input to 48 bits. Permutation logic is graphically depicted in the following illustration −



Permutation Logic

- The graphically depicted permutation logic is generally described as table in DES specification illustrated as shown −

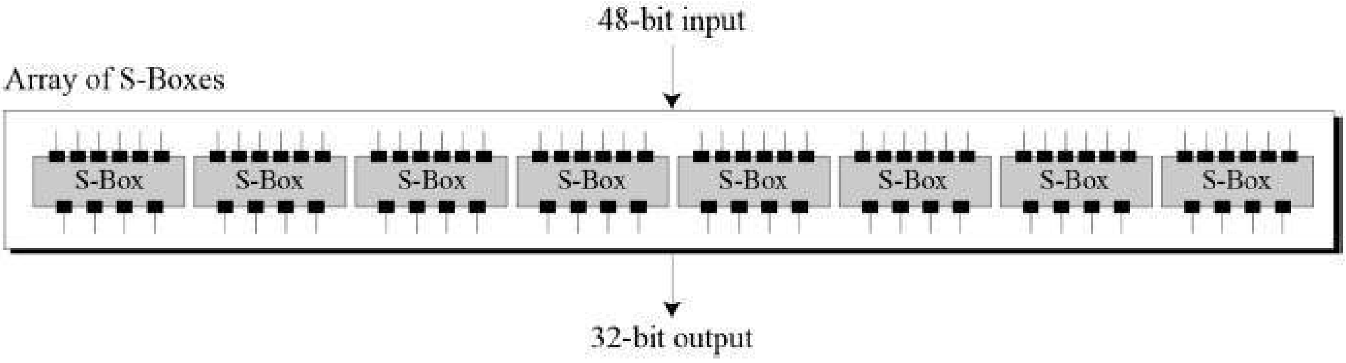


32	01	02	03	04	05
04	05	06	07	08	09
08	09	10	11	12	13
12	13	14	15	16	17
16	17	18	19	20	21
20	21	22	23	24	25
24	25	26	27	28	29
28	29	31	31	32	01

DES Specification

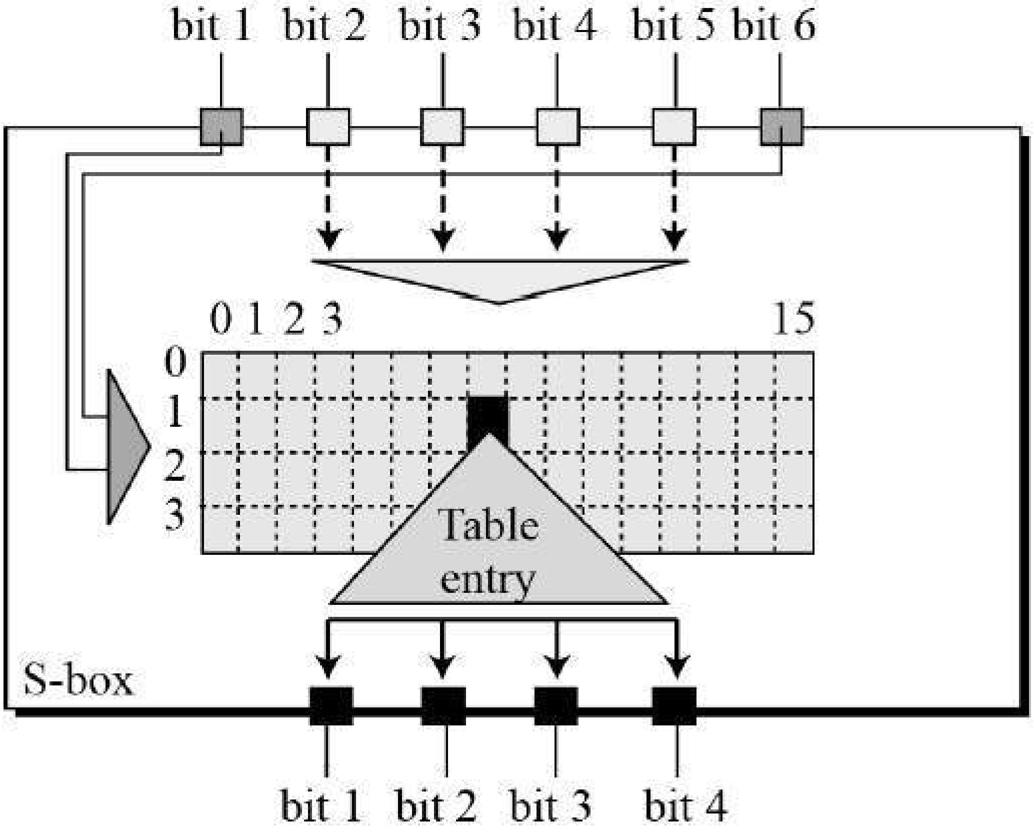
- XOR (Whitener). − After the expansion permutation, DES does XOR operation on the expanded right section and the round key. The round key is used only in this operation.

- Substitution Boxes. − The S-boxes carry out the real mixing (confusion). DES uses 8 S-boxes, each with a 6-bit input and a 4-bit output. Refer the following illustration −



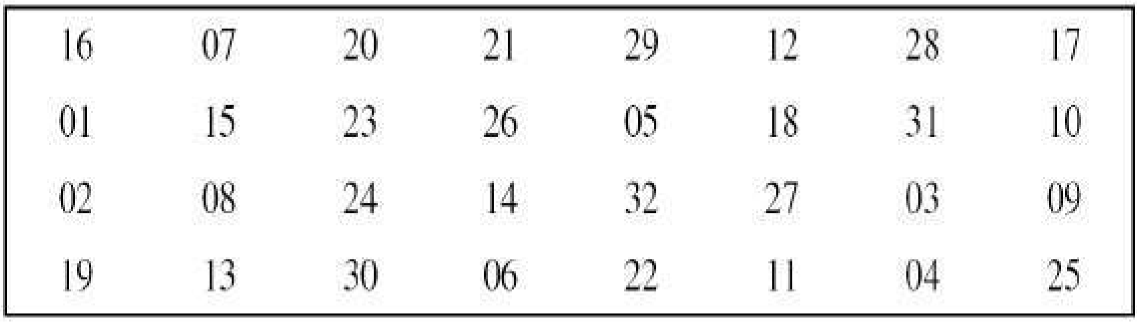
S-boxes

- The S-box rule is illustrated below −



S-box Rule

- There are a total of eight S-box tables. The output of all eight s-boxes is then combined in to 32 bit section.
- Straight Permutation – The 32 bit output of S-boxes is then subjected to the straight permutation with rule shown in the following illustration:

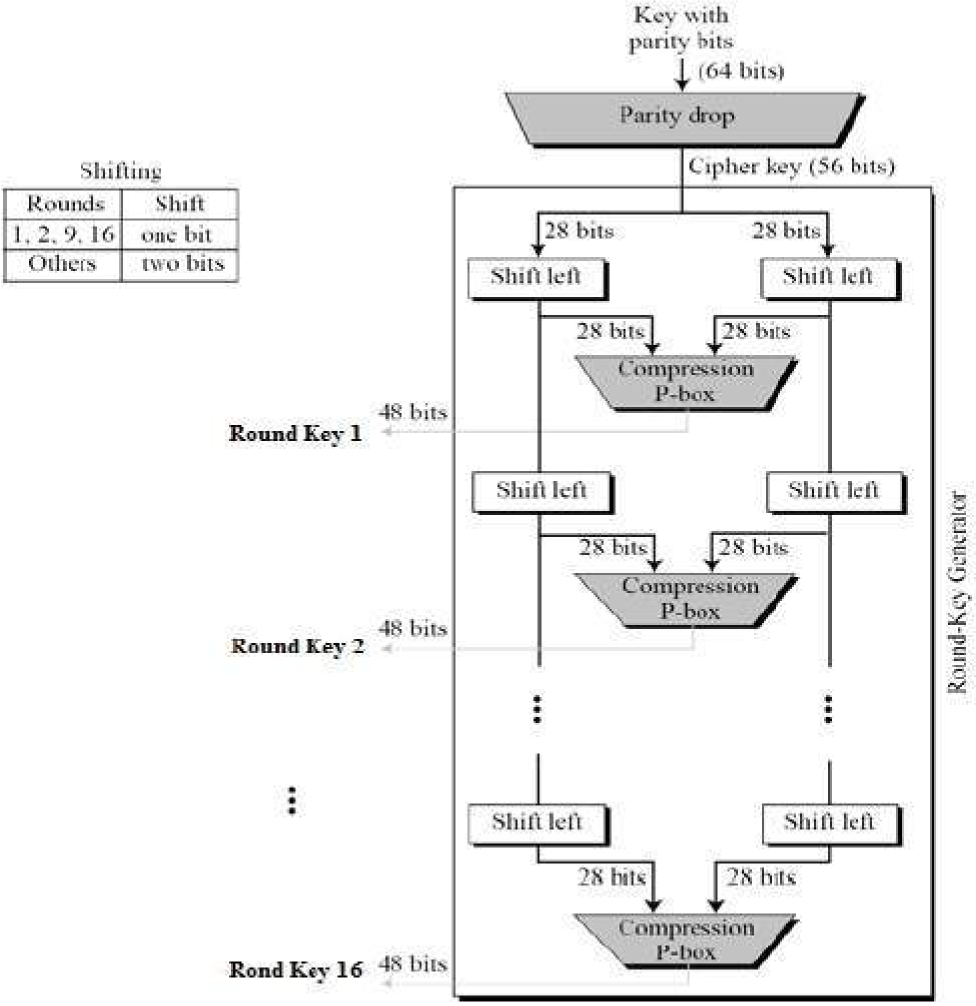


16	07	20	21	29	12	28	17
01	15	23	26	05	18	31	10
02	08	24	14	32	27	03	09
19	13	30	06	22	11	04	25

Straight Permutation

Key Generation

The round-key generator creates sixteen 48-bit keys out of a 56-bit cipher key. The process of key generation is depicted in the following illustration –



Key Generation

The logic for Parity drop, shifting, and Compression P-box is given in the DES description.

DES Analysis

The DES satisfies both the desired properties of block cipher. These two properties make cipher very strong.

- Avalanche effect − A small change in plaintext results in the very great change in the ciphertext.
- Completeness − Each bit of ciphertext depends on many bits of plaintext.

During the last few years, cryptanalysis have found some weaknesses in DES when key selected are weak keys. These keys shall be avoided.

DES has proved to be a very well designed block cipher. There have been no significant cryptanalytic attacks on DES other than exhaustive key search.

Advantages and Disadvantages of DES

1. DES has a 56-bit key which raises the possibility of 256 possible keys which make brute force impossible.
2. The 8 S-boxes used in each round were not made public and even it impossible for any to discover the design of the s-boxes which makes the attack more impossible.
3. The number of rounds in DES increases the complexity of the algorithm.
4. However, the cryptanalysis attack is easier than the brute force attack on DES.