CS 3002 Information Security

Fall 2023

1. Explain key concepts of information security such as design principles, cryptography, risk management,(1)

2. Discuss legal, ethical, and professional issues in information security (6)
3. Analyze real world scenarios, model them using security measures, and apply various security and risk management tools for achieving information security and privacy (2)
4. Identify appropriate techniques to tackle and solve problems of real life in the discipline of information security (3)
5. Understand issues related to ethics in the field of information security(8)

ISO/IEC 27001: 2013

Week # 3

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Possible Coverage before Midterm # 1

2.1 **Confidentiality with Symmetric Encryption**
- Symmetric Encryption
- Symmetric Block Encryption Algorithms
- Stream Ciphers

2.2 **Message Authentication and Hash Functions**
- Authentication Using Symmetric Encryption
- Message Authentication without Message Encryption
- Secure Hash Functions
- Other Applications of Hash Functions

2.3 **Public-Key Encryption**
- Public-Key Encryption Structure
- Applications for Public-Key Cryptosystems
- Requirements for Public-Key Cryptography
- Asymmetric Encryption Algorithms

2.4 **Digital Signatures and Key Management**
- Digital Signature
- Public-Key Certificates
- Symmetric Key Exchange Using Public-Key Encryption
- Digital Envelopes

21.4 **The RSA Public-Key Encryption Algorithm**
- Description of the Algorithm
- The Security of RSA

CHAPTER 2

Cryptographic Tools

2.1 Confidentiality with Symmetric Encryption

Symmetric Encryption
Symmetric Block Encryption Algorithms
Stream Ciphers

Data Encryption Standard (DES)

Coverage from slides provided by Course Coordinator

DES is a block cipher, as shown in Figure 6.1.

Figure 6.1 ***Encryption and decryption with DES***

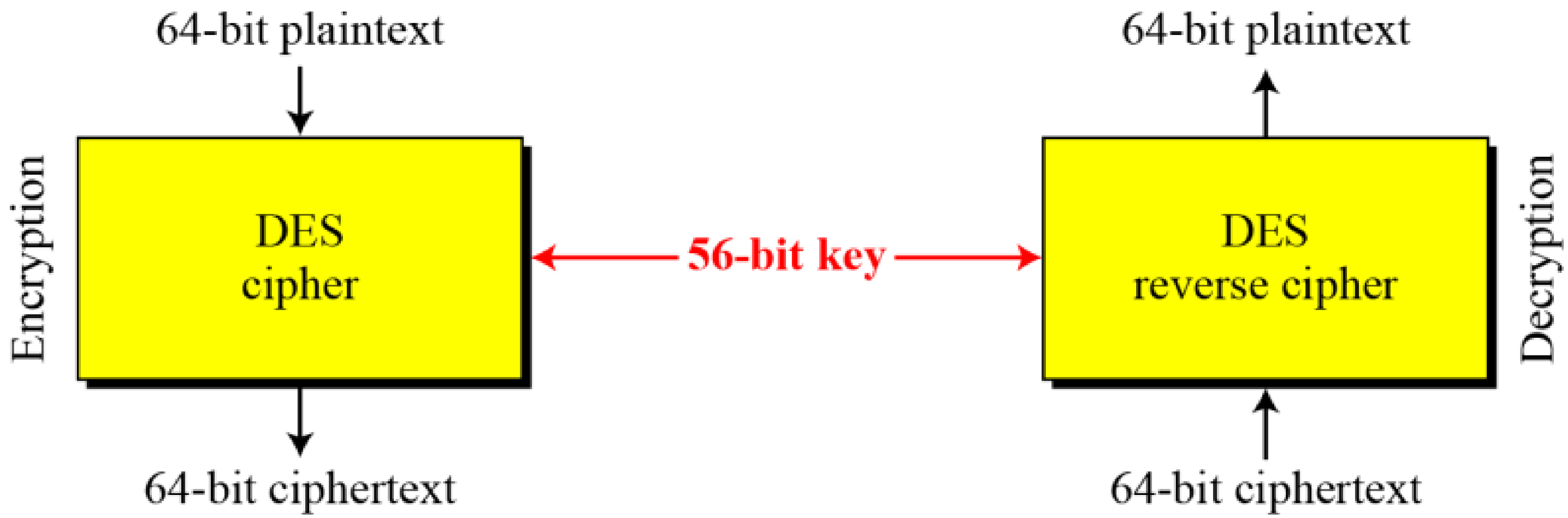


Figure 6.2 ***General structure of DES***

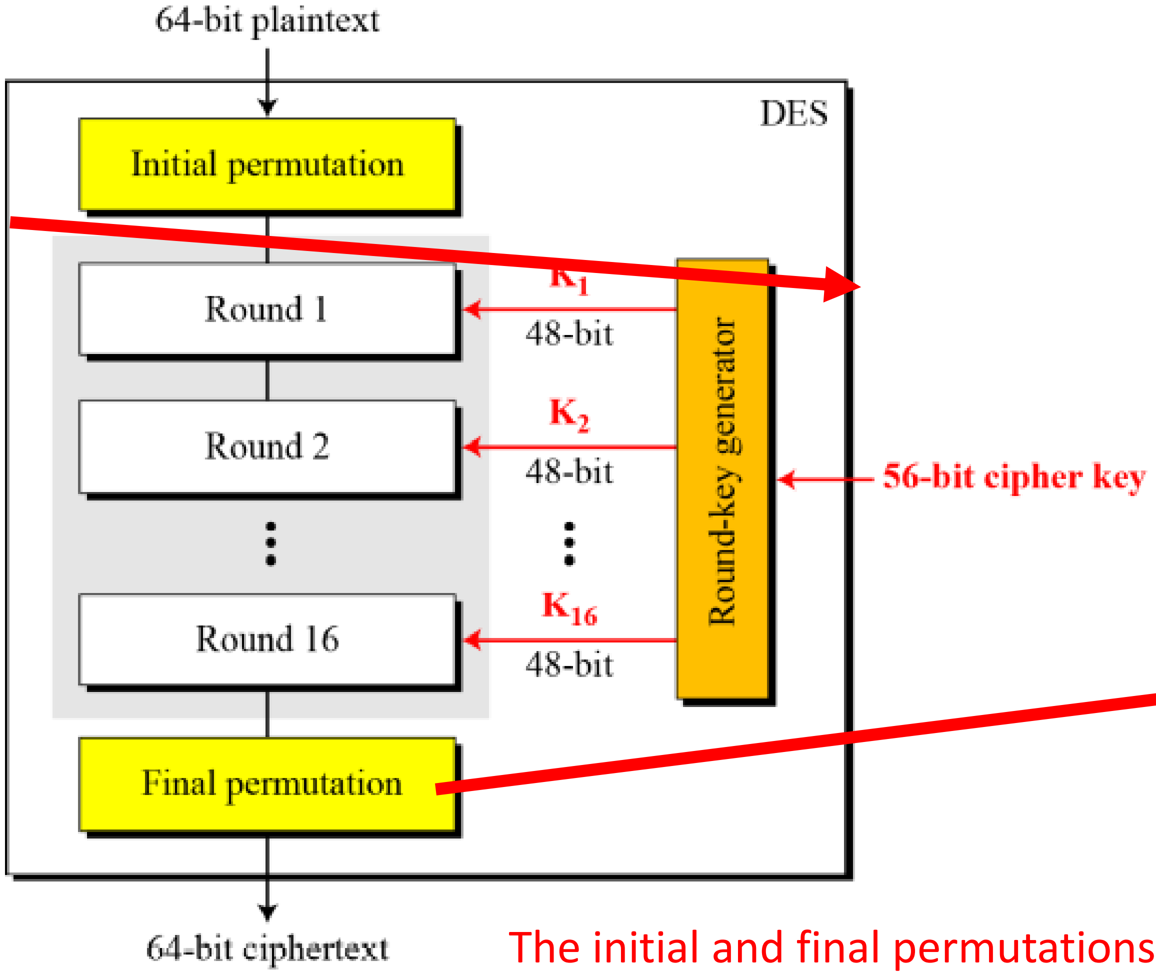
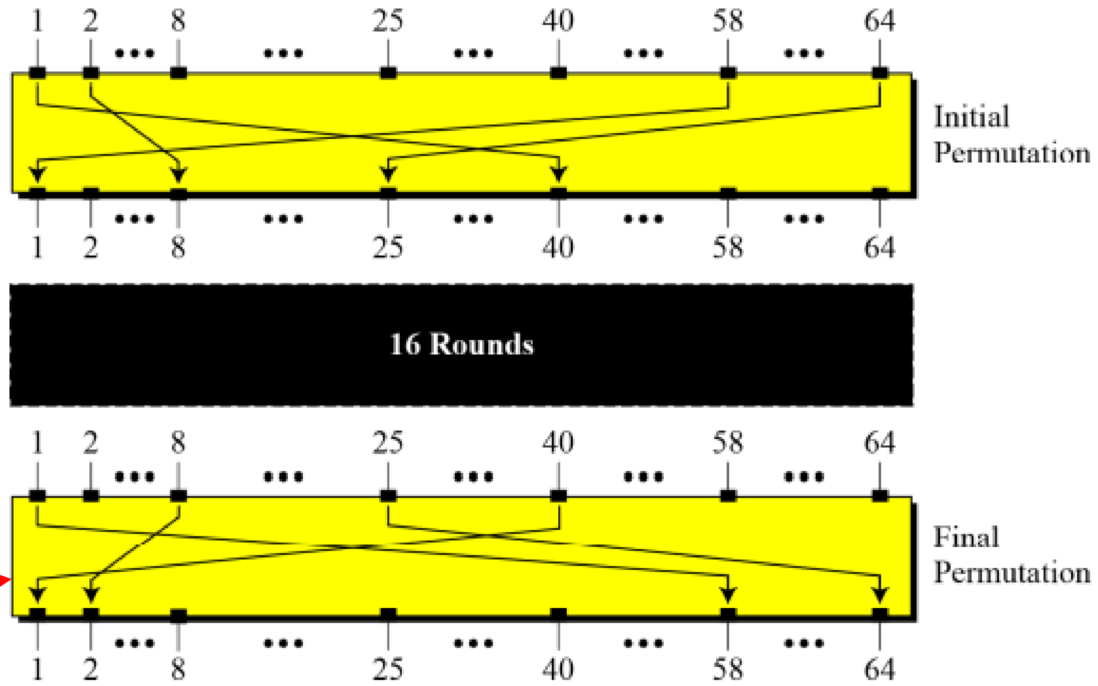


Figure 6.3 ***Initial and final permutation steps in DES***



The initial and final permutations are straight P-boxes that are inverses of each other. They have no cryptography significance in DES.

DES uses 16 rounds. Each round of DES is a Feistel cipher.

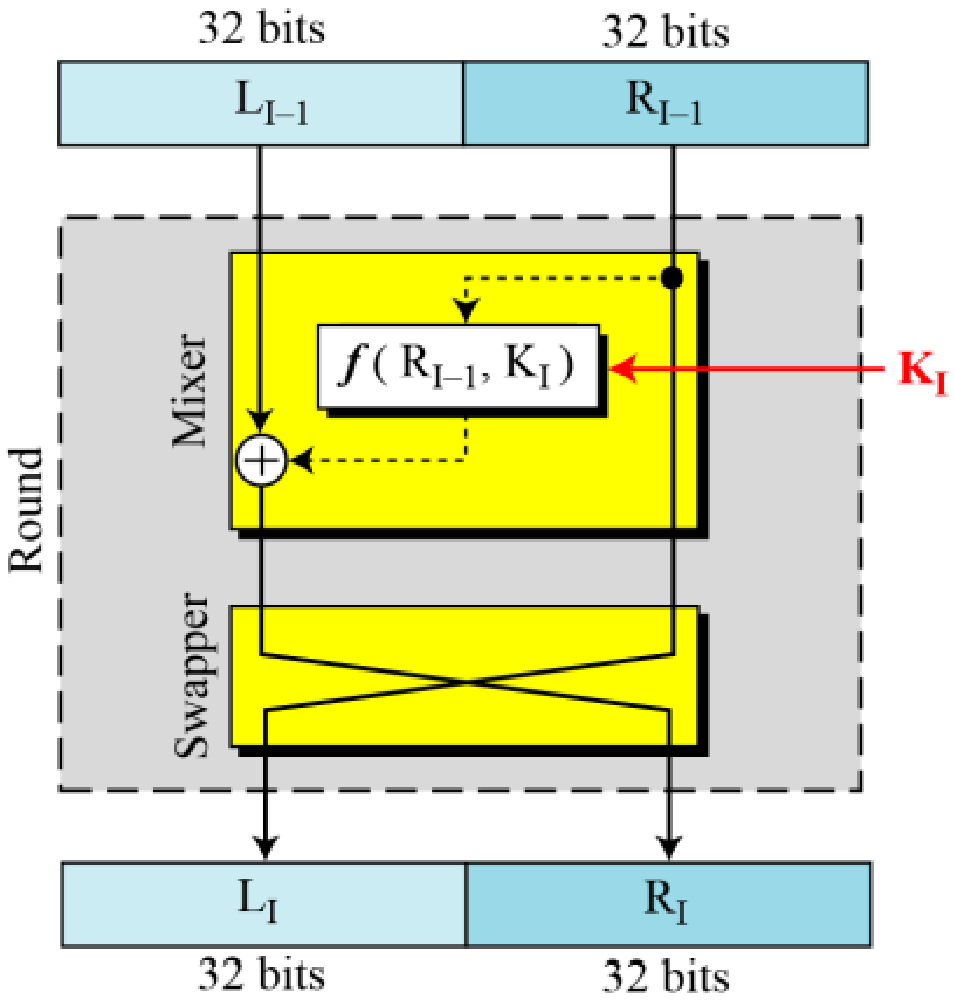
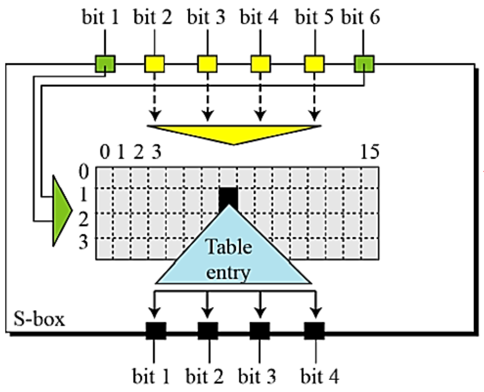


Figure 6.4

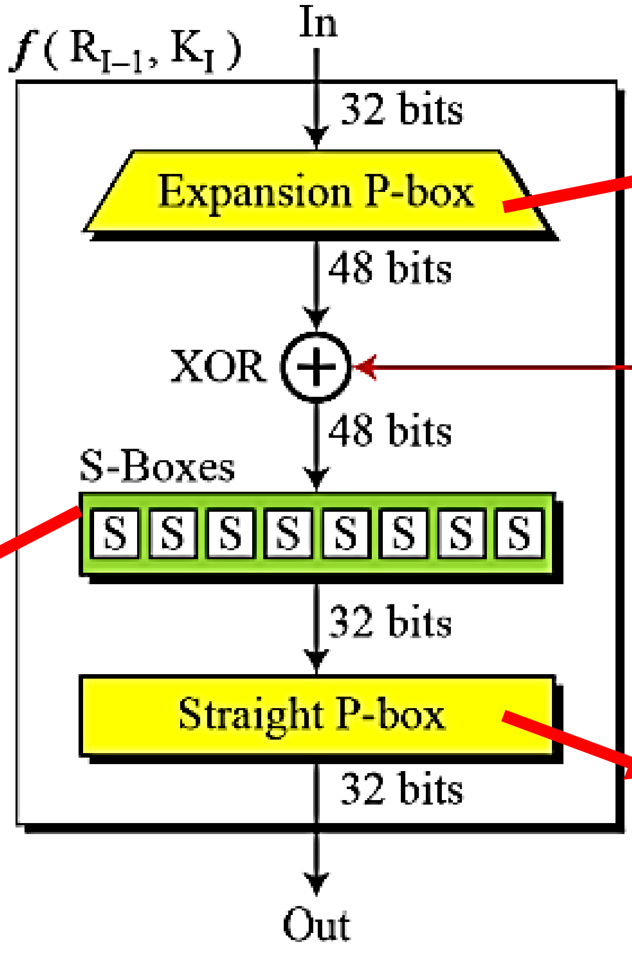
A round in DES (encryption site)

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

Figure 6.5
DES function



Details on next slide



By duplicating bits

K_I (48 bits)

Table 6.6 *Expansion P-box table*

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	[illegible]	29
[illegible]	29	31	31	32	01

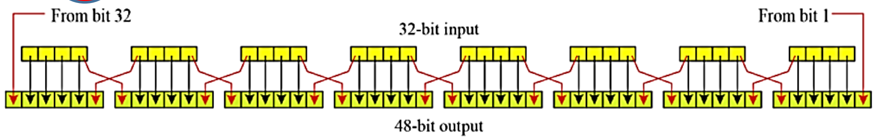


Table 6.11 *Straight permutation table*

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

S-Boxes (Substitution Boxes)

The S-boxes do the real mixing (confusion). DES uses 8 S-boxes, each with a 6-bit input and a 4-bit output. See Figure 6.7.

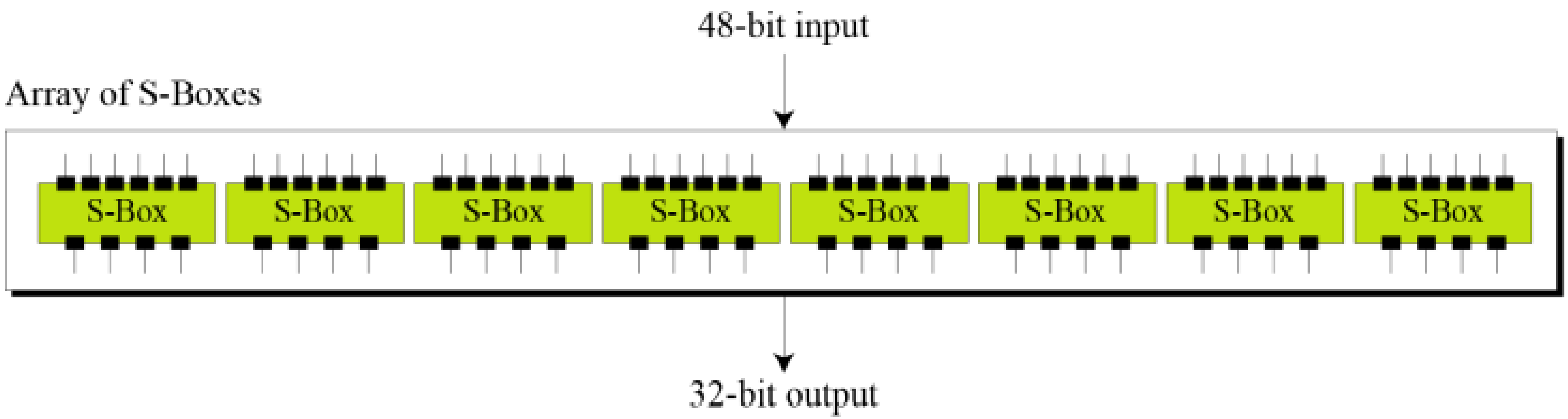
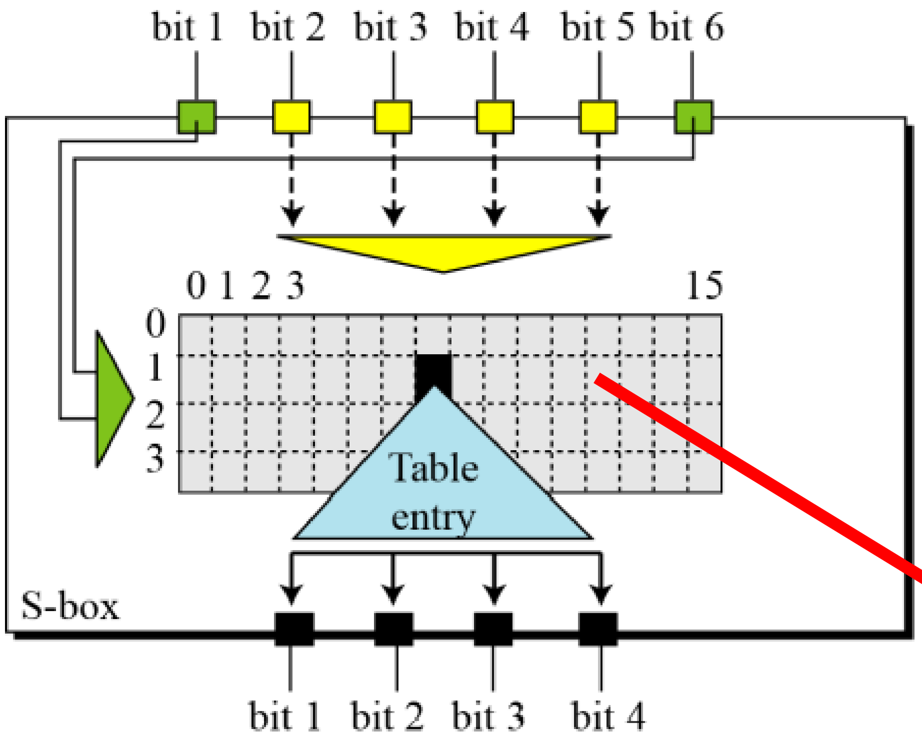


Figure 6.7 ***S-boxes***

* There are 8 S-Boxes. Each one has its own table.

Figure 6.8 *S-box rule*



* Each S-box has its own table.

Table 6.3 *S-box 1*

	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
0	14	04	13	01	02	15	11	08	03	10	06	12	05	09	00	07
1	00	15	07	04	14	02	13	10	03	06	12	11	09	05	03	08
2	04	01	14	08	13	06	02	11	15	12	09	07	03	10	05	00
3	15	12	08	02	04	09	01	07	05	11	03	14	10	00	06	13

Key Generation

The round-key generator creates sixteen 48-bit keys out of a 56-bit cipher key.

Shifting

Rounds	Shift
1, 2, 9, 16	one bit
Others	two bits

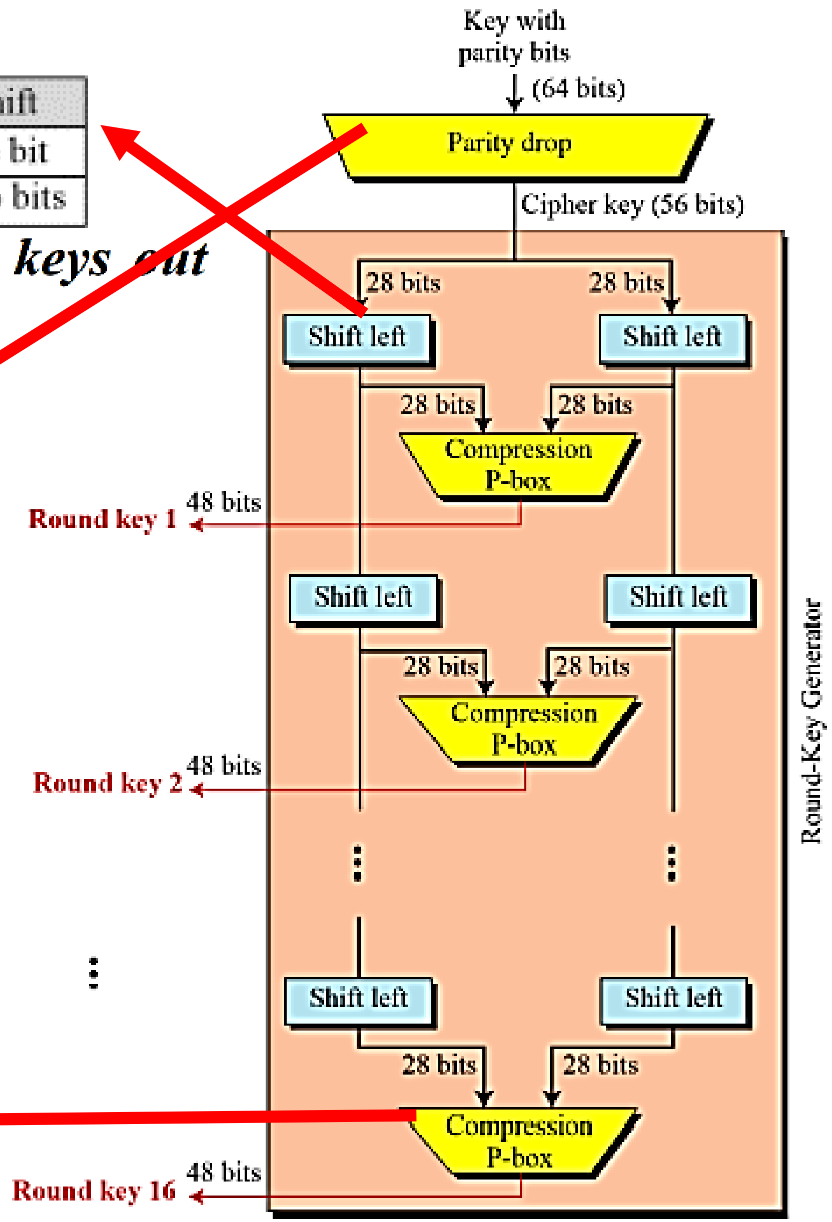


Figure 6.10 *Key generation*

Table 6.12 *Parity-bit drop table*

57	49	41	33	25	17	09	01
58	50	42	34	26	18	10	02
59	51	43	35	27	19	11	03
60	52	44	36	63	55	47	39
31	23	15	07	62	54	46	38
30	22	14	06	61	53	45	37
29	21	13	05	28	20	12	04

Table 6.14 *Key-compression table*

14	17	11	24	01	05	03	28
15	06	21	10	23	19	12	04
26	08	16	07	27	20	13	02
41	52	31	37	47	55	30	40
51	45	33	48	44	49	39	56
34	53	46	42	50	36	29	32

Concerns about the strength of DES Algorithm (1)

Concerns about the strength of DES fall into two categories: concerns about the algorithm itself, and concerns about the use of a 56-bit key. The first concern refers to the possibility that cryptanalysis is possible by exploiting the characteristics of the DES algorithm. Over the years, there have been numerous attempts to find and exploit weaknesses in the algorithm, making DES the most-studied encryption algorithm in existence. Despite numerous approaches, no one has so far reported a fatal weakness in DES.

A more serious concern is key length. With a key length of 56 bits, there are 2^{56} possible keys, which is approximately 7.2×10^{16} keys. Given the speed of commercial off-the-shelf processors, this key length is woefully inadequate. A paper from Seagate Technology [SEAG08] suggests that a rate of one billion (10^9) key combinations per second is reasonable for today's multicore computers. Recent offerings confirm this.

Concerns about the strength of DES Algorithm (2)

Both Intel and AMD now offer hardware-based instructions to accelerate the use of AES. Tests run on a contemporary multicore Intel machine resulted in an encryption rate of about half a billion encryptions per second [BASU12]. Another recent analysis suggests that with contemporary supercomputer technology, a rate of 10^{13} encryptions/s is reasonable [AROR12].

Table 2.2 Average Time Required for Exhaustive Key Search

Key Size (bits)	Cipher	Number of Alternative Keys	Time Required at 10^9 decryptions/μs	Time Required at 10^{13} decryptions/μs
56	DES	$2^{56} \approx 7.2 \times 10^{16}$	$2^{55}\ \mu s = 1.125$ years	1 hour
128	AES	$2^{128} \approx 3.4 \times 10^{38}$	$2^{127}\ \mu s = 5.3 \times 10^{21}$ years	5.3×10^{17} years
168	Triple DES	$2^{168} \approx 3.7 \times 10^{50}$	$2^{167}\ \mu s = 5.8 \times 10^{33}$ years	5.8×10^{29} years
192	AES	$2^{192} \approx 6.3 \times 10^{57}$	$2^{191}\ \mu s = 9.8 \times 10^{40}$ years	9.8×10^{36} years
256	AES	$2^{256} \approx 1.2 \times 10^{77}$	$2^{255}\ \mu s = 1.8 \times 10^{60}$ years	1.8×10^{56} years

Addressing the small key size of DES Algorithm

TRIPLE DES The life of DES was extended by the use of triple DES (3DES), which involves repeating the basic DES algorithm three times, using either two or three unique keys, for a key size of 112 or 168 bits.

3DES has two attractions that assure its widespread use over the next few years. First, with its 168-bit key length, it overcomes the vulnerability to brute-force attack of DES. Second, the underlying encryption algorithm in 3DES is the same as in DES. This algorithm has been subjected to more scrutiny than any other encryption algorithm over a longer period of time, and no effective cryptanalytic attack based on the algorithm rather than brute force has been found. Accordingly, there is a high level of confidence that 3DES is very resistant to cryptanalysis. If security were the only consideration, then 3DES would be an appropriate choice for a standardized encryption algorithm for decades to come.

Drawback of DES Algorithm

The principal drawback of 3DES is that the algorithm is relatively sluggish in software. The original DES was designed for mid-1970s hardware implementation and does not produce efficient software code. 3DES, which requires three times as many calculations as DES, is correspondingly slower. A secondary drawback is that both DES and 3DES use a 64-bit block size. For reasons of both efficiency and security, a larger block size is desirable.

Advanced Encryption Standard Because of its drawbacks, 3DES is not a reasonable candidate for long-term use. As a replacement, NIST in 1997 issued a call for proposals for a new Advanced Encryption Standard (AES), which should have a security strength equal to or better than 3DES and significantly improved efficiency. In addition to these general requirements, NIST specified that AES must be a symmetric block cipher with a block length of 128 bits and support for key lengths of 128, 192, and 256 bits. Evaluation criteria included security, computational efficiency, memory requirements, hardware and software suitability, and flexibility.