Data Encryption Standard (DES)

History, method, application and strength

Data Encryption Standard (DES)

- Published 1977 NBS
- Original IBM design
- 64 bit input → 64 bit encrypted output
- 56 bit key with odd parity (total 64 bits)
- Suitable for hardware not software
- 56 bits no longer secure

KEY TRANSFORMS IN BLOCK CIPHERS

For a k-bit block cipher

- Substitution

For every k-bit i/p specify a k-bit o/p

This requires $k.2^k$ bits

- Permutation

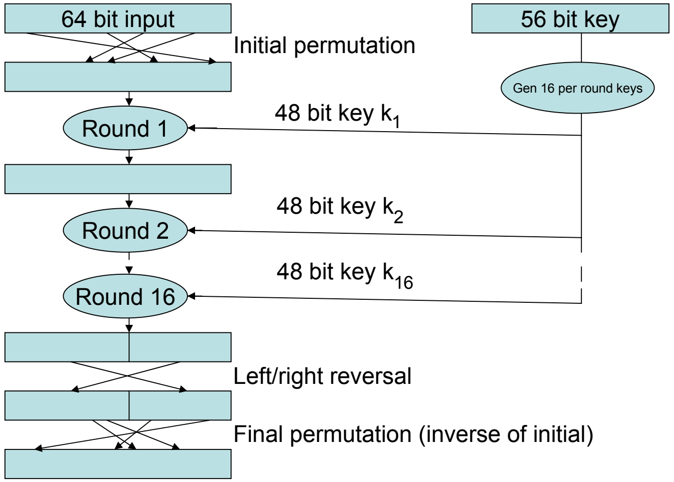
For every bit specify new position in block

This requires $k.\log_2 k$ bits

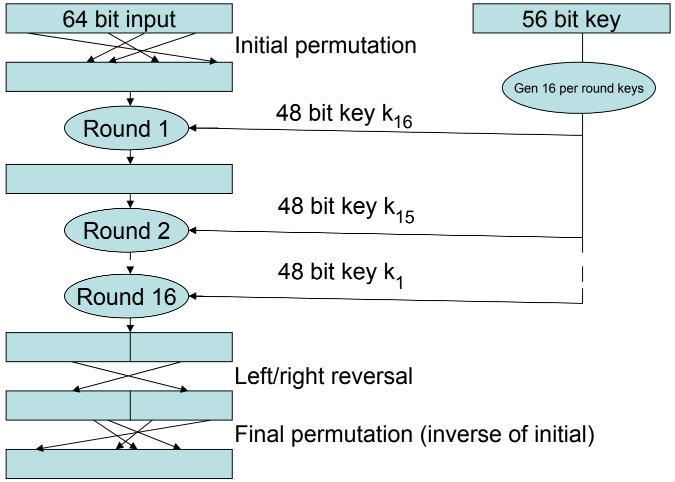
Round Structure for Block Encryption

- Take 64-bit i/p
- Break into 8x8-bit blocks
- Perform substitution and reassemble into 64 bits
- Perform permutation and repeat
- After several rounds single i/p bit affects every o/p bit
- Optimum number of rounds
- Can be run in reverse for decryption

DES Overview (Encryption)



DES Overview (Decryption)



DES Overview (decryption)

Encryption run in reverse

i.e. Initial permutation

Round 1 with k_{16}

Round 2 with k_{15}

¦

Round 16 with k_1

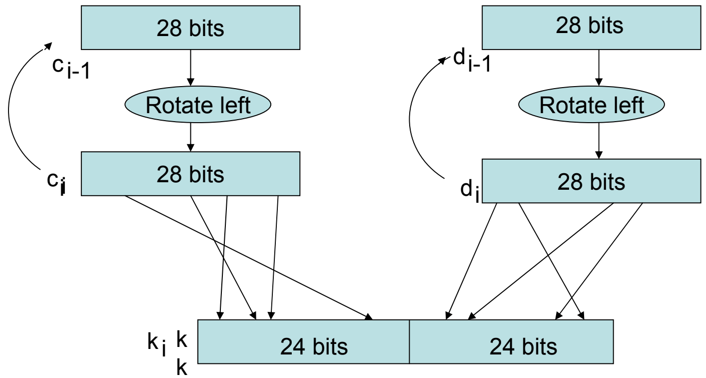
Same keys as for Encryption but in Reverse order

Left/right reversal

Final permutation

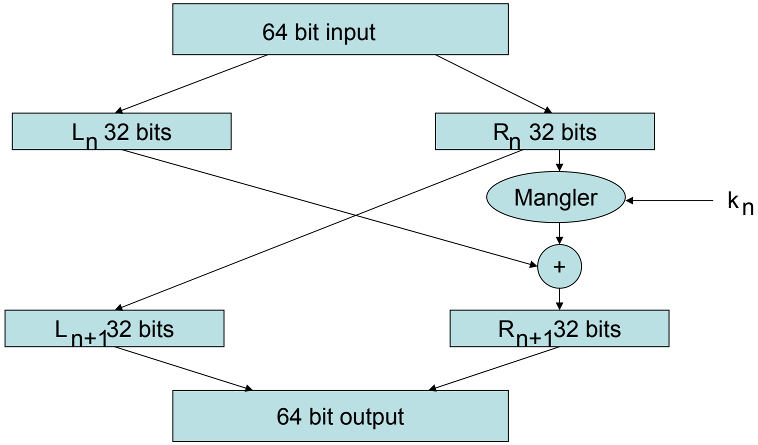
NB Initial and final permutations are inverses of each other and have no security value

The 16 Per Round Keys

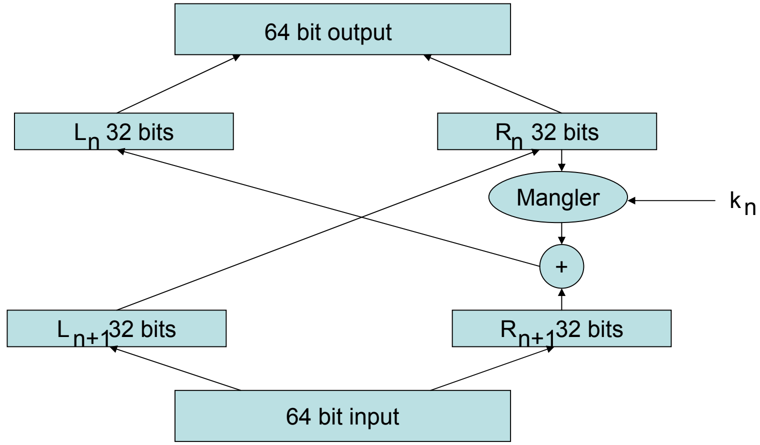


NB Initial permutation to produce c_0 and d_0 is not random and has no security value

A DES Round (encryption)



A DES Round (decryption)



Encrypt/Decrypt in a DES Round

From encryption $L_{n+1} = R_n$ and

$R_{n+1} = L_n \oplus M_{K_n}(R_n)$

Therefore

$R_{n+1} \oplus M_{k_n}(R_n) = L_n$ and hence decryption

NB Mangler function does not require an inverse

Mangler Overview

R = 32 bits = 8 x 4 bits → 8 x 6 bits by copying last 2 bits in every 4

Take 48 bit key k and add mod 2 to expanded 48 bit R

Result is 48 bits = 8 x 6 bits

Compress each 6 bits to 4 bits through S box giving 32 bits

Permute 32 bit result

NB Importance of permutation to influence next round

International Data Encryption Algorithm

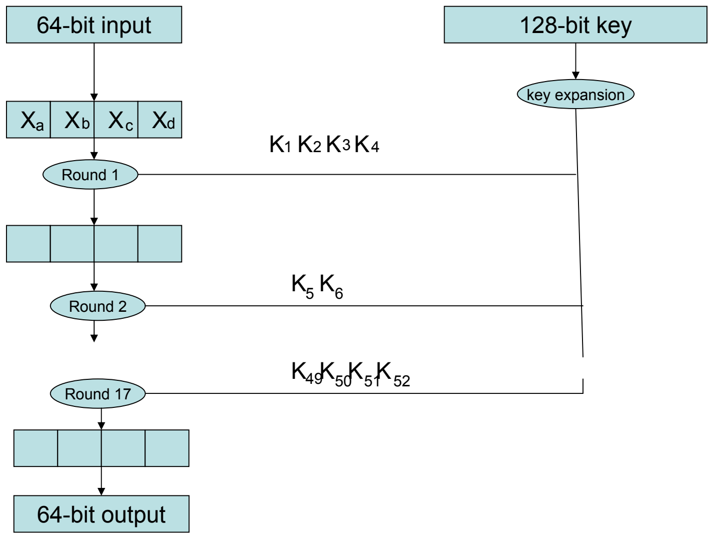
International Data Encryption Algorithm (IDEA)

- Established 1991
- 64-bit plaintext → 64-bit ciphertext
- 128-bit key
- Round structure and Mangler similar to DES

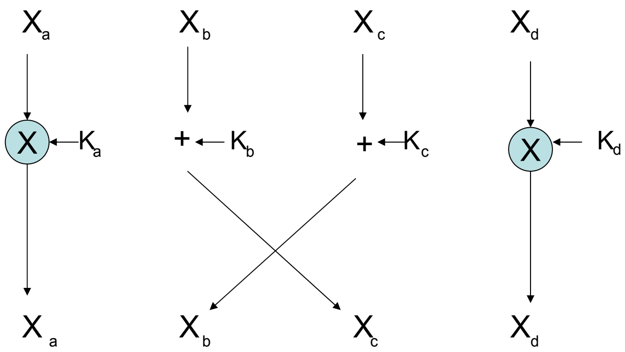
IDEA Primitive Operations

- Two 16-bit numbers → one 16 bit number
- Bitwise exclusive or ⊕
- Addition + modulo 2^{16}
- Multiplication ⊗ modulo $2^{16}+1$
- All operations are "reversible"

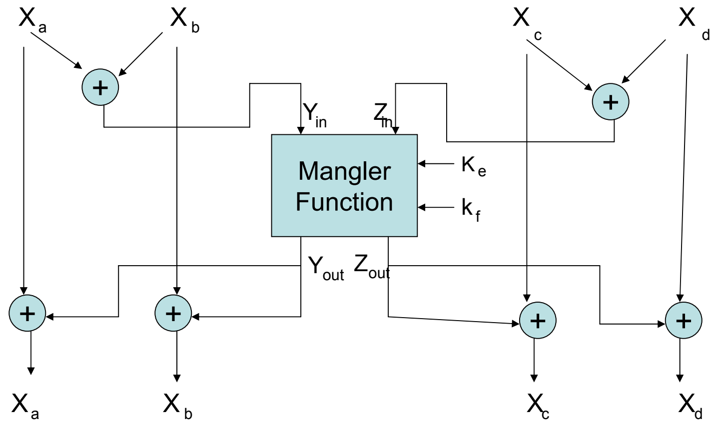
IDEA Overview



IDEA Odd Round



IDEA Even Round



IDEA Decryption

- All processes the same
- Even round is its own inverse (use same keys)
- Odd rounds use inverse keys

Advanced Encryption Standard

Advanced Encryption Standard

- Uses Rijndael system
- In a pure Rijndael system block and key sizes may be chosen independently(128, 160, 192, 224 and 256 bits) but AES specifies 128-bit block size
- Number of rounds = 6 + max (block, key size expressed in 32-bit words}