Key size differs

AES → Encryption Standard

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Advanced Encryption Standard:

→ Symmetric, block ciper

↳ same key is used for both encryption and decryption

↳ Take a group of bits as input and produce a group of bits as the output

↳ Take 128 bits as the input - plaintext size, 128 bits as the output - ciphertext size

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Input State array

Final State array

Round 1 Transformations

↳ Substitute Bytes,
Shift Rows,
Mix Columns,
Add round Key

There is some relationship beth the Key size & the number of rounds to be performed in AES.

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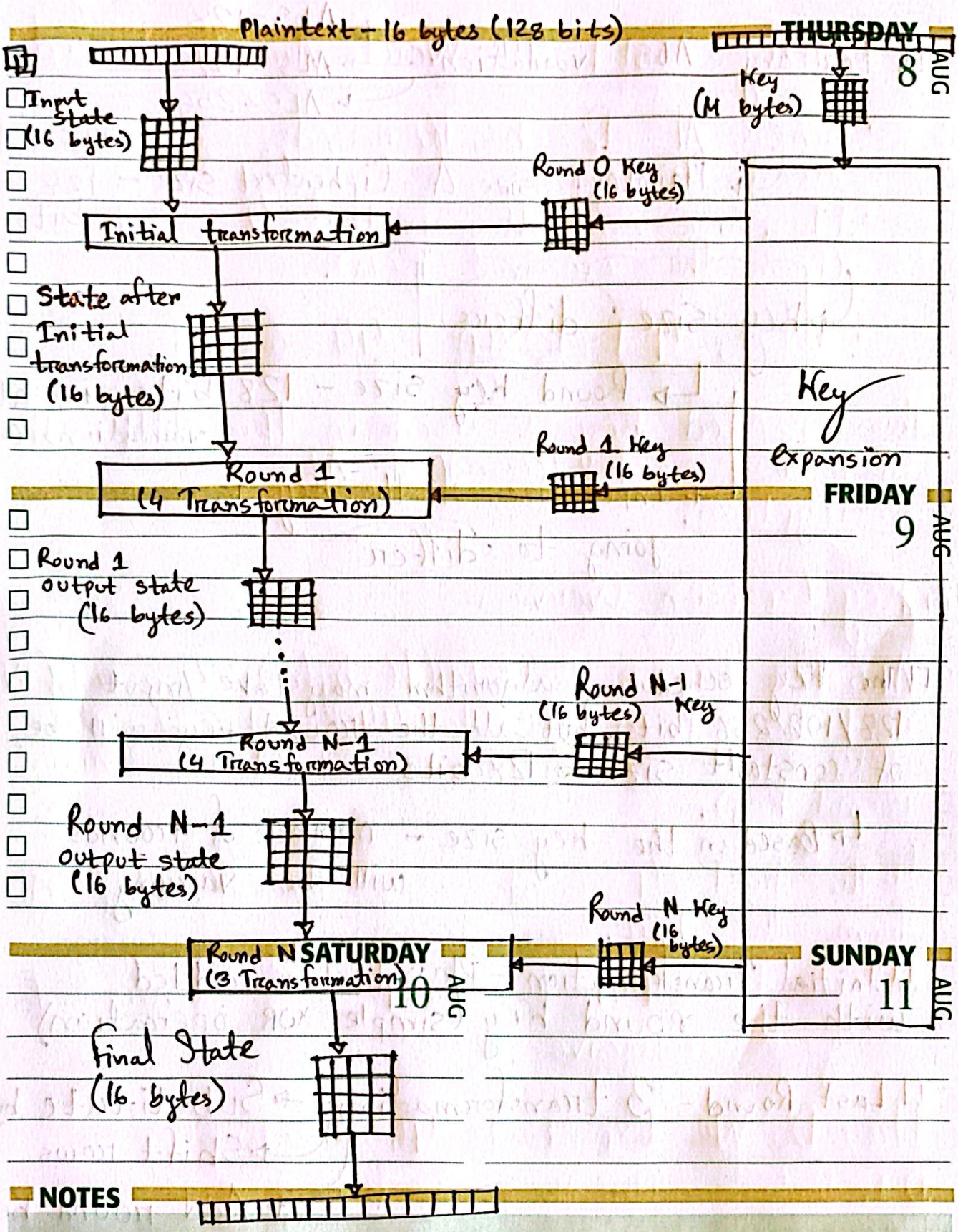
This Key is used by the Key scheduling algorithm to generate the round keys that are required for every round.

No. of rounds	Key size (in bits)
10	128
12	192
14	256

AES Structure

Key - M bytes



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NOTES

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For any AES variation → AES-128, AES-192, AES-256

↳ Plaintext size & Ciphertext size - 128 bits

↳ Key size differs

↳ Round key size - 128 bits in all variations (same)

↳ Input size of the key is going to differ

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The key scheduling algorithm may take input of 128/192/256 bits, but all the round keys will be of constant size - 128 bits

↳ Based on the key size - number of rounds will be varying

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Initial Transformation - Plaintext is added with the round key (simple XOR operation)

Last Round - 3 transformations → Substitute bytes, Shift rows, Add round key

NO mix column transformation

1 word = 4 bytes

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Understanding Words in AES

- AES works with 4-byte (32-bit) words.
- AES-128 Key is 128 bits = $\frac{128}{8}$ = 16 bytes.
- Since 1 word = 4 bytes, the AES-128 Key consists of (4) words. → 4 words = 4 × 4 bytes = 16 bytes = 16 × 8 bits = 128 bits

Key Expansion Process:

- The goal is to generate 44 words for 11 round Keys (including the initial key). The Key schedule follows these steps:

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① Initialize with the Cipher Key

- The first four words (w[0] to w[3]) come directly from the original 128-bit key.

② Expand to 44 Words (w[4] to w[43])

- The expansion follows this formula:

$w[i] = w[i-4] \oplus g(w[i-1])$ (for words that are multiples of 4)

$w[i] = w[i-1] \oplus w[i-4]$ (otherwise)

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- The g() function is applied every 4th word (w[i] where i is a multiple of 4). It includes:
  - Byte rotation (left circular shift by 1 byte)
  - Substitution (using the AES S-box)
  - XOR with Round Constant (Rcon)

NOTES

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③ Continue until 44 Words Are Generated

- Since AES-128 has 10 rounds, each round needs 4 words.
- Plus, we need the initial 4 words (from the original key).
- Total: 4 + (10X4) = 44 words

This expanded key is used in the AddRoundKey step for each round of AES encryption.

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Key Expansion Overview

AES-128 key is 128 bits (16 bytes) = 4 words. We need to expand this to 44 words to use across 10 encryption rounds (+ the initial round key).

↳ The first 4 words are directly taken from the key. The remaining 40 words (w[4] to w[43]) are generated using a recursive process.

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How Do We Expand to 44 words:

① Initialize with the original key

w[0] = first 4 bytes of the key
w[1] = next 4 bytes
w[2] = next 4 bytes
w[3] = last 4 bytes

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② Generate words w[4] to w[43]
- For each new word w[i]:

→ If i is a multiple of 4, we apply a special transformation g(), which involves

Rotating bytes,
Substituting bytes using the S-box
XOR-ing with the round constant (Rcon)

→ Otherwise, we apply a simple XOR operation with w[i-4].

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③ Continue expanding until 44 words are generated

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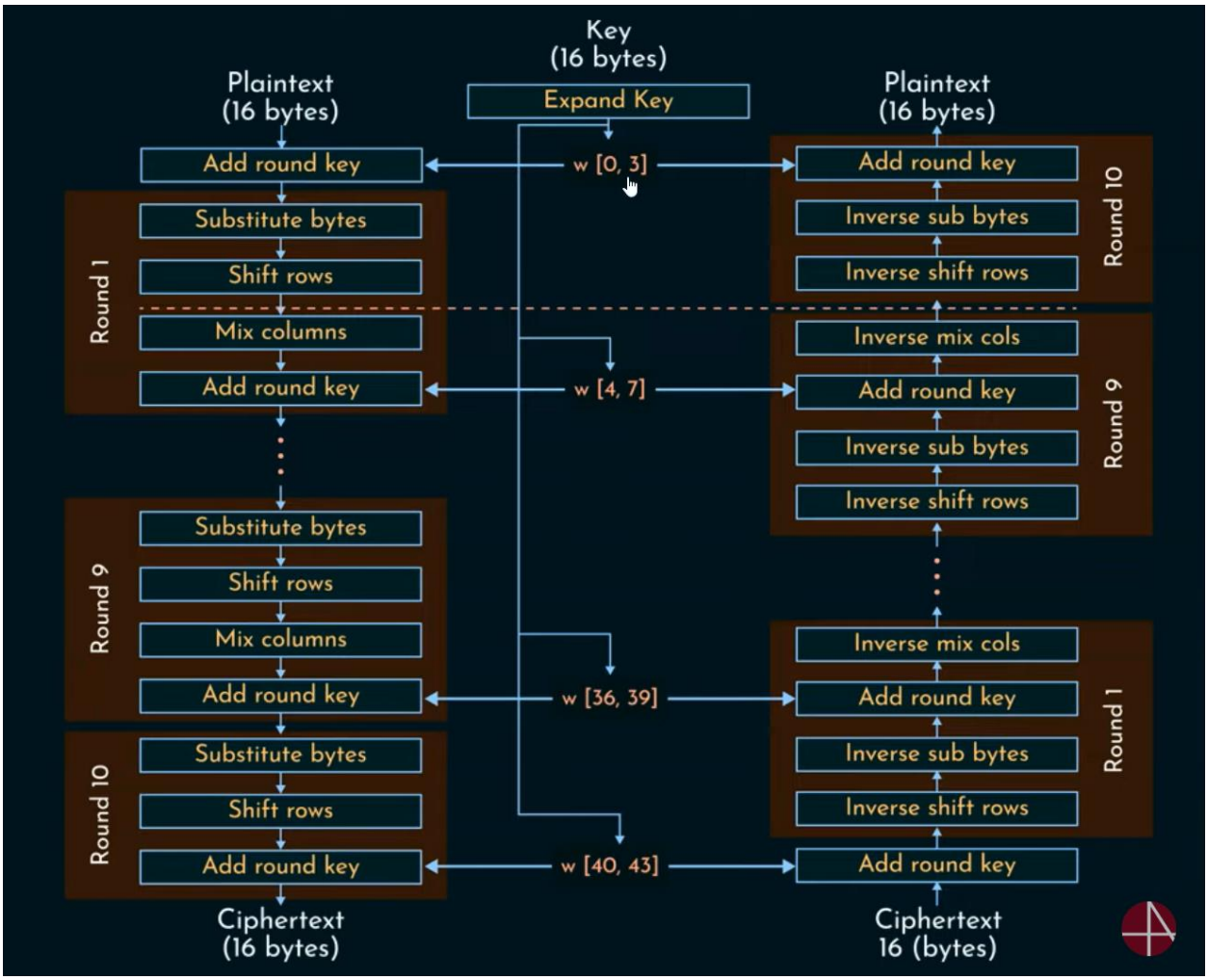
NOTES


Key
(16 bytes)
Plaintext
(16 bytes)
Expand Key
Plaintext
(16 bytes)
Add round key
w [0, 3]
Add round key
Round 10
Substitute bytes
Inverse sub bytes
Shift rows
Inverse shift rows
Round 1
Mix columns
Inverse mix cols
Add round key
w [4, 7]
Add round key
Round 9
Inverse sub bytes
Inverse shift rows
Substitute bytes
Shift rows
Mix columns
Inverse mix cols
Round 9
Add round key
w [36, 39]
Add round key
Substitute bytes
Inverse sub bytes
Round 10
Shift rows
Inverse shift rows
Round 1
Add round key
w [40, 43]
Add round key
Ciphertext
(16 bytes)
Ciphertext
16 (bytes)