Crypto libraries OpenSSL (cont.)

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OpenSSL – www.openssl.org

- opensource cryptography toolkit
- OpenSSL3 ~ released 2021, many API improvements
- Apache-style license
- hash, symmetric/asymmetric encryption, PKI, CA, ...
- ASN.1, PKCS-5,7,8,12, X509, OCSP, PEM, SSL, TLS
- command line tool
- C/C++ library bindings (+many other library wrappers)
  - on Linux compile with **-lcrypto –lssl**
  - #include <openssl/...>

Today’s goals

- **Symmetric encryption**
- **Encryption modes**

  ~~ECB~~, CBC, CTR, XTS

  IV – initialization vector, tweak
- **OpenSSL I/O abstraction (BIO)**
- **Demonstration of failures/mistakes**

  ECB use,

  CBC mangled IV, CBC mangled ciphertext,

  XTS patterns

  CTR stream reuse

Example 4: Symmetric encryption

OpenSSL (3.x)

Encryption with EVP interface. Cipher mode is for example **”AES-256-CBC”.**

```
cipher = EVP_CIPHER_fetch(cipher_mode, ...)
EVP_CIPHER_CTX_new()
EVP_EncryptInit_ex2(context, cipher, key, iv, PARAMS)
EVP_EncryptUpdate(context, ciphertext, &clen, plaintext, plen)
EVP_EncryptFinal_ex(context, ciphertext + clen, &len)
EVP_CIPHER_CTX_free(context)
EVP_CIPHER_free(cipher)
```

*See **4_encryption_openssl3** directory.*

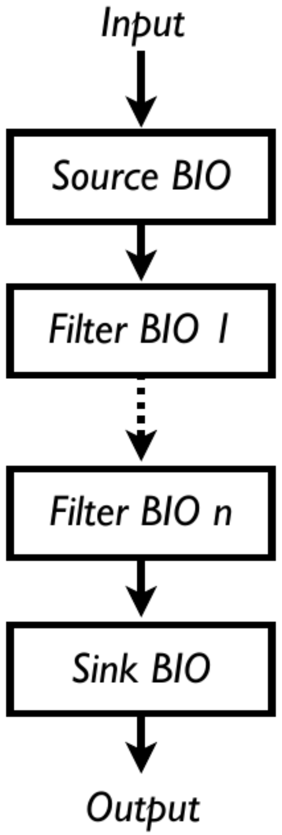
Example 7:
OpenSSL BIO (I/O abstraction)

Source/sink BIOs:

BIO_s_mem() - memory I/O
BIO_s_file() - file I/O
BIO_s_fd() - file descriptor IO
BIO_s_socket() - sockets
BIO_s_accept()
BIO_s_connect()
BIO_s_null() - discard (like /dev/null)

Filters

BIO_f_base64() - Base64 encoding
BIO_f_buffer() - buffering I/O
BIO_f_cipher() - encryption/decryption
BIO_f_md() - message digest
BIO_f_ssl() - SSL support for BIO



Example 7: the same encryption as in Example 4 using BIO interface.
*See **7_bio_openssl** directory.*

Symmetric Encryption common mistakes or failures

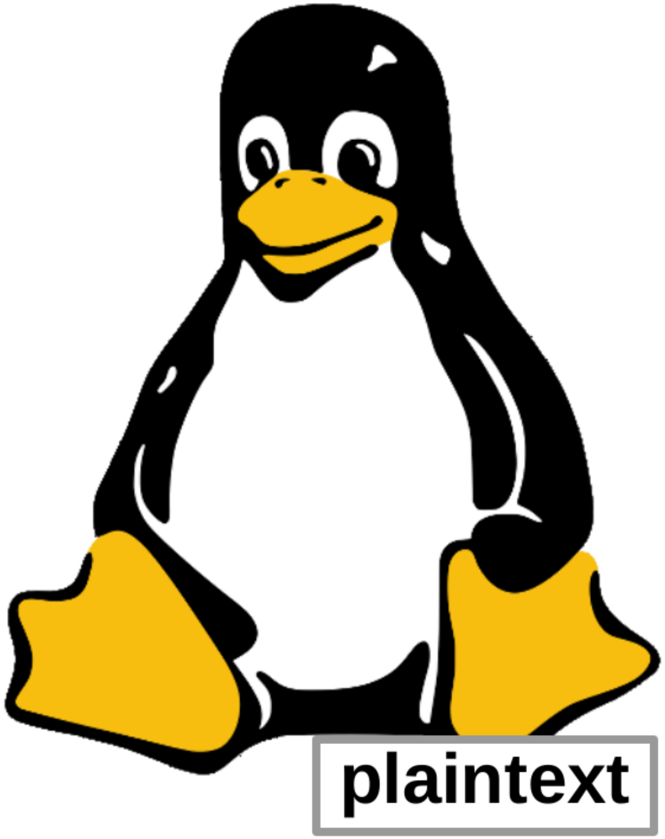
See **6_encryption_fails_openssl** example in git.

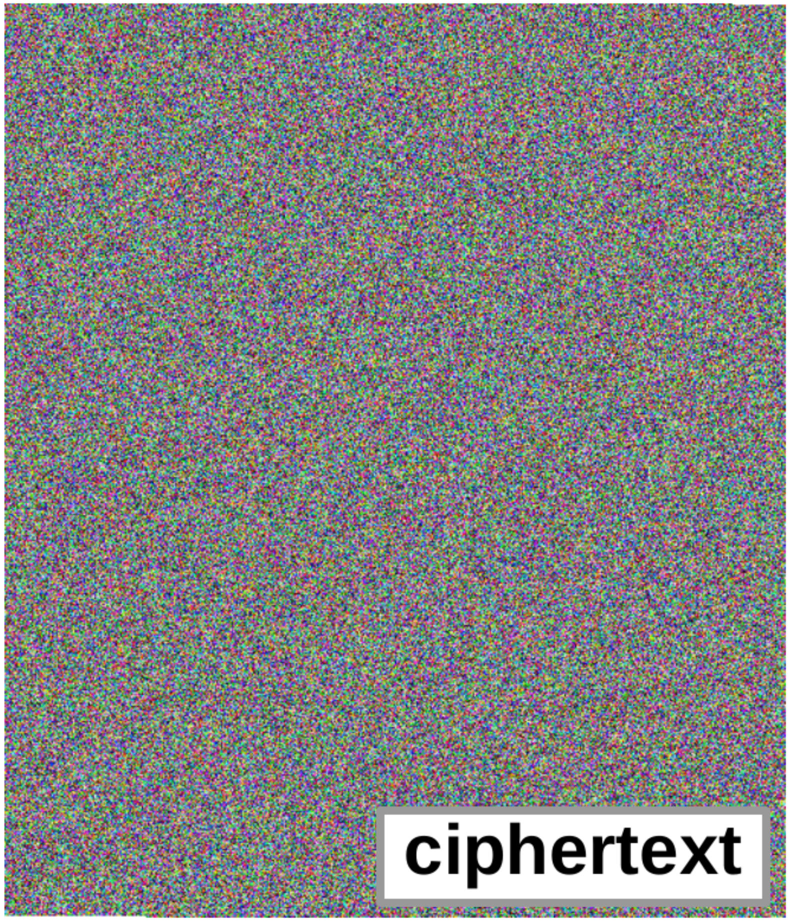
Comment out various sections a play with demos.

Note there is no data integrity protection in these modes.

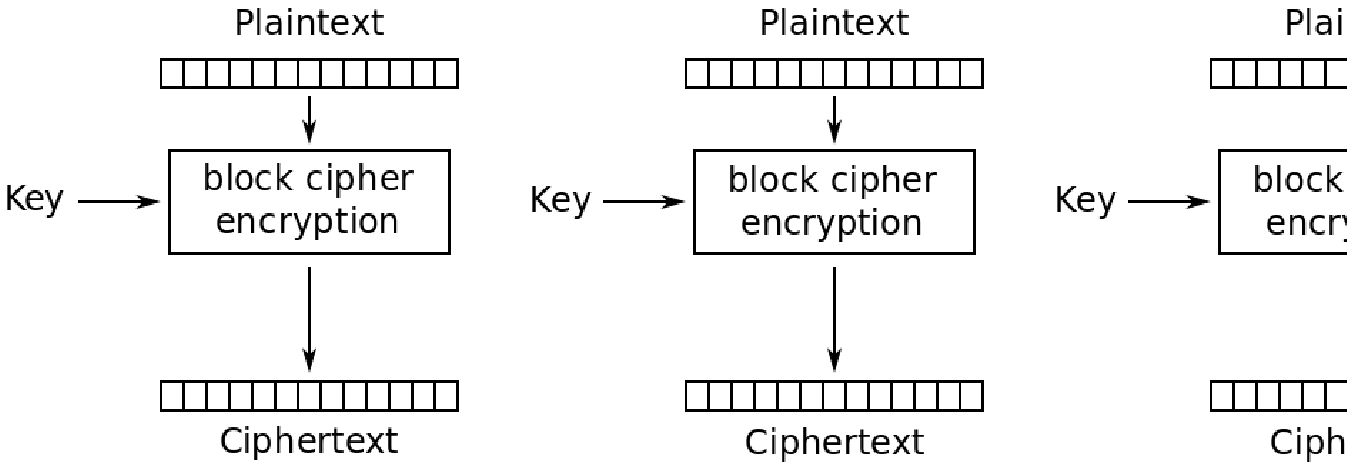
- Example 1: **ECB patterns**
- Example 2: **CBC IV bit flips**
- Example 3: **CBC bit flips in a consecutive block**
- Example 4: **XTS constant IV block patterns**
- Example 5: **CTR stream reuse**

Symmetric encryption: ciphertext





ECB mode
…should be never used



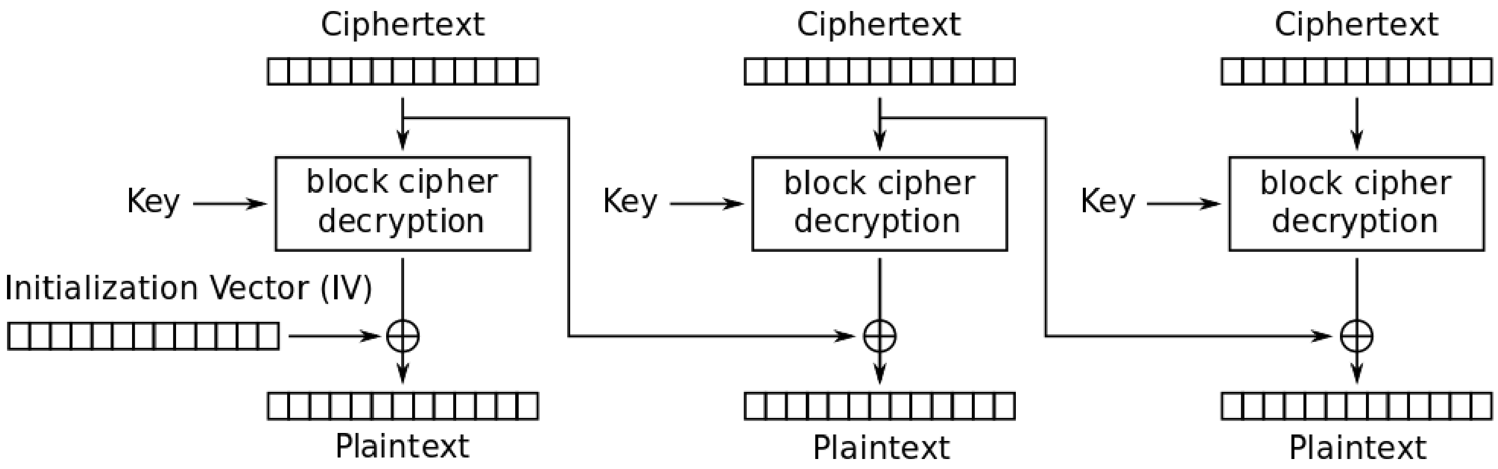
Electronic Codebook (ECB) mode encryption

Wrong use demo: ciphertext patterns, block relocation.

*See **6_encryption_fails_openssl** directory.*

picture: Wikipedia

CBC mode



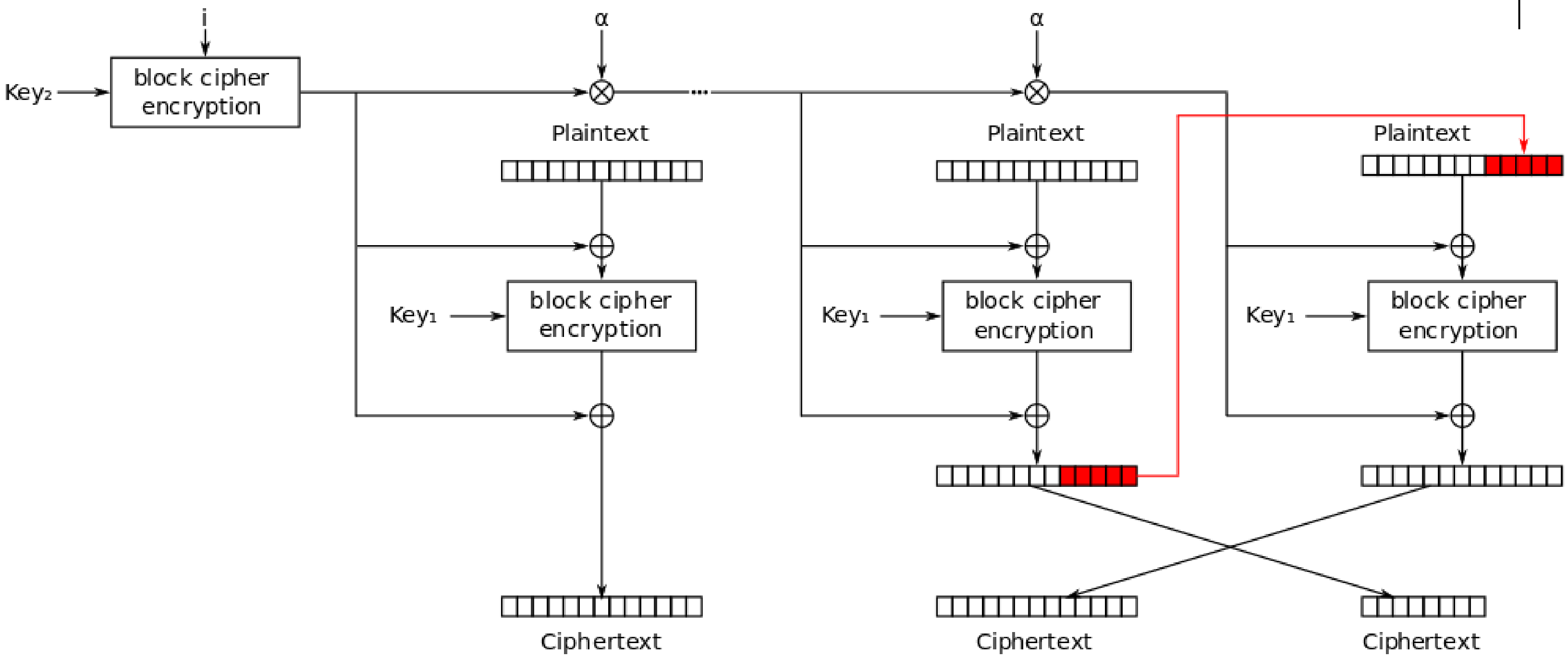
Cipher Block Chaining (CBC) mode decryption

Wrong use demo: first block bit flips (IV) and consecutive block change.

*See **6_encryption_fails_openssl** directory.*

picture: Wikipedia

XTS mode storage (file, disk) encryption



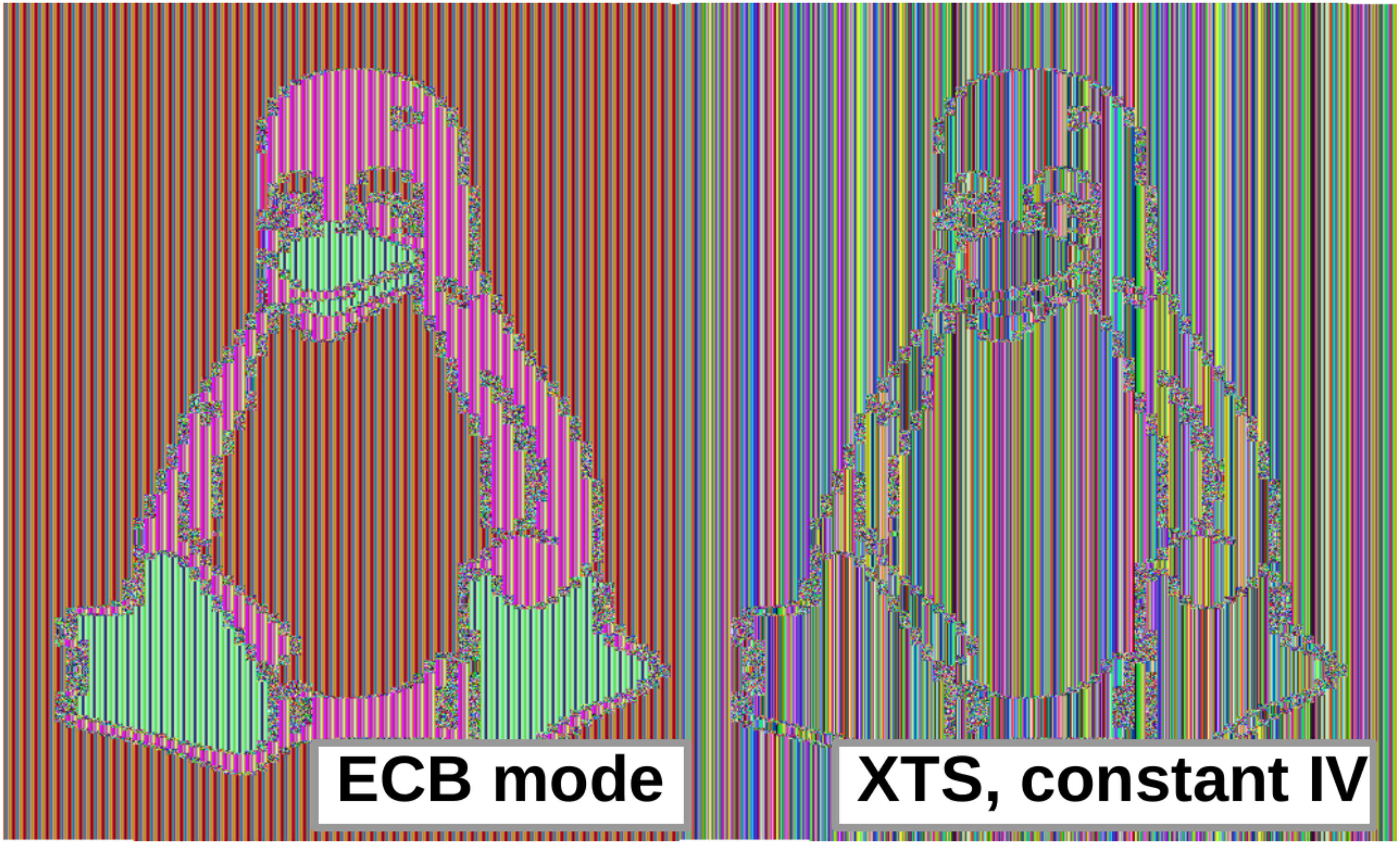
XEX with tweak and ciphertext stealing (XTS) mode encryption

Wrong use demo: block patterns with constant IV.

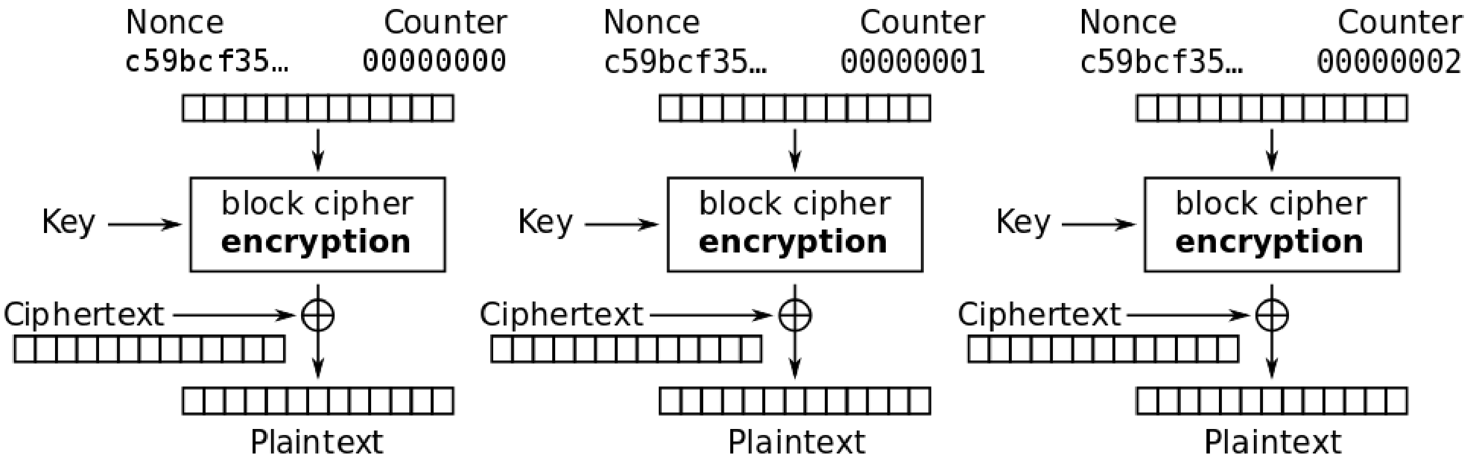
*See **6_encryption_fails_openssl** directory.*

picture: Wikipedia

Symmetric encryption fails: patterns in ciphertext



CTR (counter) mode



Counter (CTR) mode decryption

Wrong use demo: re-use key from known ciphertext/plaintext pair.

*See **6_encryption_fails_openssl** directory.*

picture: Wikipedia