

# AES

## AES Encrypt/Decrypt Engine

The AES encryption IP core implements hardware Rijndael encoding and decoding in compliance with the NIST Advanced Encryption Standard. It processes 128-bit blocks, and is programmable for 128-, 192-, and 256-bit key lengths.

Two architectural versions are available to suit system requirements. The **Standard** version (AES-S) is more compact, using a 32-bit datapath and requiring 44/52/60 clock cycles for each data block (128/192/256-bit cipher key, respectively). The **Fast** version (AES-F) achieves higher throughput, using a 128-bit datapath and requiring 11/13/15 clock cycles for each data block.

Various cipher modes can be supported (CBC, CFB, CTR, ECB, LRW, and OFB). The core works with a pre-expanded key, or with optional key expansion logic.

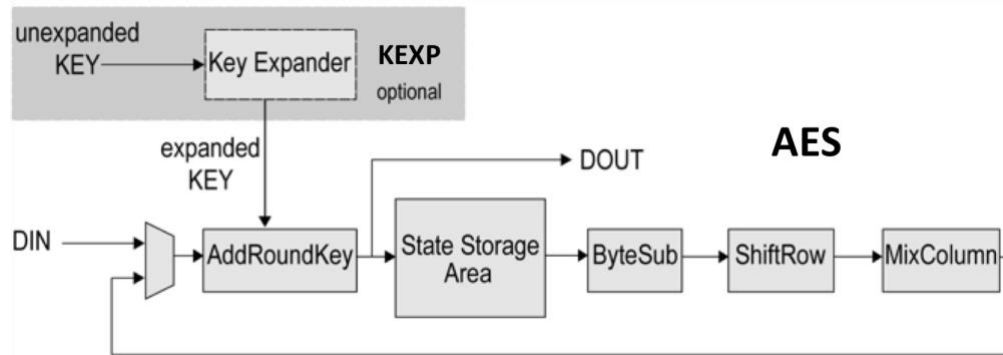
The AES cores are fully synchronous designs, have been evaluated in a variety of technologies, and are available optimized for ASICs or FPGAs.

### Applications

The AES can be utilized for a variety of encryption applications including:

- Protected network routers
- Electronic financial transactions
- Secure wireless communications
- Secure video surveillance systems
- Encrypted data storage

### Block Diagram



### Functional Description

An AES encryption operation transforms a 128-bit block into a block of the same size. The encryption key can be chosen among three different sizes: 128-, 192- or 256-bit. The key is expanded during cryptographic operations.

The AES algorithm consists of a series of steps repeated a number of times (rounds). The number of rounds depends on the size of the key and the data block. The intermediate cipher result is known as state.

	KSIZE = 00	KSIZE = 01	KSIZE = 10
Rounds	10	12	14

Number of rounds as a function of key size

Initially, the incoming data and the key are added together in the AddRoundKey module. The result is stored in the State Storage area.

### FEATURES

- Encrypts and decrypts using the AES Rijndael Block Cipher Algorithm
- Implemented according to the Federal Information Processing Standard (FIPS) Publication 197 from the US National Institute of Standards and Technology (NIST)
- NIST Certified
- Processes 128-bit data in 32-bit blocks
- Employs user-programmable key size of 128, 192, or 256 bits
- Smallest version supports a single block cipher mode. Modes available:
  - Cipher Block Chaining (CBC)
  - Cipher Feedback (CFB)
  - Electronic Codebook (ECB)
  - Counter (CTR)
  - Liskov-Rivest-Wagner (LRW)
  - Output Feedback (OFB)
- Two architectural versions:
  - Standard is more compact: 32-bit data path size  
Processes each 128-bit data block in 44/52/60 clock cycles for 128/192/256-bit cipher keys, respectively
  - Fast yields higher transmission rates: 128-bit data path  
Processes each 128-bit block in 11/13/15 clock cycles for 128/192/256-bit cipher keys, respectively
- Works with a pre-expanded key or can integrate the optional key expansion function
- Simple, fully synchronous, reusable design
- Available as fully functional and synthesizable VHDL or Verilog, or as a netlist for popular programmable devices
- Complete deliverables include test benches, C model and test vector generator

## Functional Description (cont.)

The state information is then retrieved and the ByteSub, Shiftrow, MixColumn, and AddRoundKey functions are performed on it in the specified order. At the end of each round, the new state is stored in the State Storage area. These operations are repeated according to the number of rounds.

The final round is anomalous as the MixColumn step is skipped. The cipher is output after the final round.

### Key Expansion

The AES algorithm requires an expanded key for encryption or decryption. The CAST KEXP AES key expander core is available as an AES core option.

During encryption, the key expander can produce the expanded key on the fly while the AES core is consuming it. For decryption, though, the key must be pre-expanded and stored in an appropriate memory before being used by the AES core. This is because the core uses the expanded key backwards during decryption.

In some cases a key expander is not required. This might be the case when the key does not need to be changed (and so it can be stored in its expanded form) or when the key does not change very often (and thus it can be expanded more slowly in software).

## Implementation Results

The AES can be mapped to any ASIC technology or FPGA device (provided sufficient silicon resources are available). The following are sample ASIC pre-layout results reported from synthesis with a silicon vendor design kit under typical conditions, with all core I/Os assumed to be routed on-chip and throughput for a 128-bit key size for CBC mode.

### AES Standard Core ASIC Implementation Results

ASIC Technology	Number of eq. gates	Memory bits	Freq. (MHz)	Throughput (Gbps)
TSMC 7nm	12,426	0	1,600	4.65
TSMC 16nm	12,968	0	1,200	3.49
TSMC 28nm HPC	14,180	0	1,100	3.20

### AES Fast Core ASIC Implementation Results

ASIC Technology	Number of eq. gates	Memory bits	Freq. (MHz)	Throughput (Gbps)
TSMC 7nm	45,924	0	1,700	19.78
TSMC 16nm	46,643	0	1,300	15.13
TSMC 28nm HPC	54,388	0	1,100	12.80

The provided figures do not represent the higher speed or smaller area for the core. Please contact CAST to get characterization data for your target configuration and technology.

## Available Versions

The AES core is available in ECB, CFB, CBC, OFB, and CTR modes, and for different datapath sizes. The related KEXP key expander core is available as a standalone core.

## Related Products

A smaller and faster AES-E core is also available for encoding-only applications.

AES in CCM, GCM and XTS modes are available as standalone cores.

AES-P is a run-time programmable AES core supporting ECB, CBC, CFB, OFB, and CTR modes.

## Export Permits

This core implements encryption functions and as such it is subject to export control regulations. Export to your country may or may not require a special export license. Please contact CAST to determine what applies in your specific case.

## Support

The core as delivered is warranted against defects for ninety days from purchase. Thirty days of phone and email technical support are included, starting with the first interaction. Additional maintenance and support options are available.

## Verification

The core has been verified through extensive synthesis, place and route and simulation runs. It has also been embedded in several products, and is proven in both ASIC and FPGA technologies.

## Deliverables

The core is available in ASIC (RTL) or FPGA (netlist) formats, and includes everything required for successful implementation. The ASIC version includes

- HDL RTL source
- Sophisticated HDL Testbench (self-checking)
- C Model & test vector generator
- Simulation script, vectors & expected results
- Synthesis script
- User documentation