Using STM32 cache to optimize performance and power efficiency

Introduction

This application note describes the instruction cache (ICACHE) and the data cache (DCACHE), the first caches developed by STMicroelectronics.

The ICACHE and DCACHE introduced on the AHB bus of the Arm® Cortex®-M33 processor are embedded in the STM32 microcontroller (MCUs) listed in the table below. These caches allow users to improve their application performance and reduce the consumption when fetching instruction and data from both internal and external memories, or for data traffic from external memories.

This document gives typical examples to highlight the ICACHE and DCACHE features and facilitate their configuration.

Table 1. Applicable products

Type	Product series
Microcontrollers	STM32H5 series, STM32L5 series, STM32U5 series

1 General information

This application note applies to the STM32 series microcontrollers that are Arm® Cortex® core-based devices.

Note: Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

2 ICACHE and DCACHE overview

This section provides an overview of the ICACHE and DCACHE interfaces embedded in the STM32 Arm® Cortex® core-based microcontrollers.

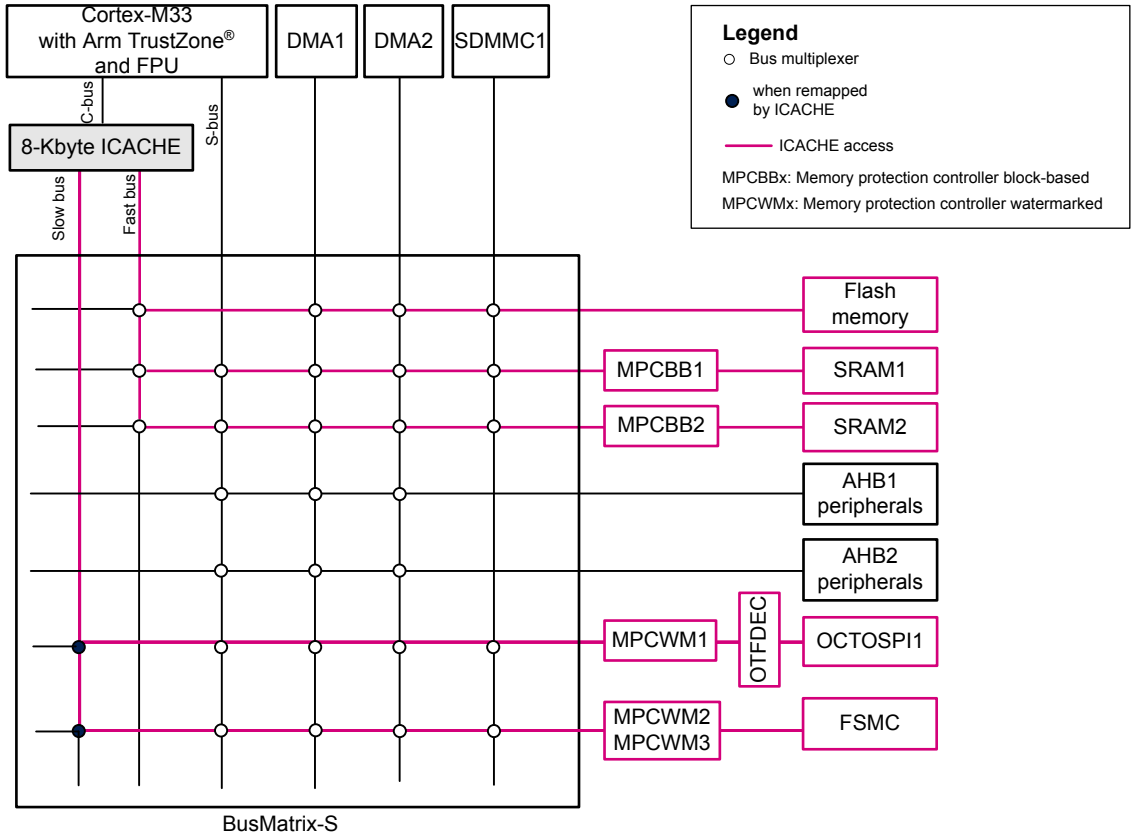
This section details the ICACHE and DCACHE diagram and integration in the system architecture.

2.1 STM32L5 series smart architecture

This architecture is based on a bus matrix allowing multiple masters (Cortex-M33, ICACHE, DMA1/2, and SDMMC1) to access multiple slaves (such as flash memory, SRAM1/2, OCTOSPI1, or FSMC).

The figure below describes the STM32L5 series smart architecture.

Figure 1. STM32L5 series smart architecture



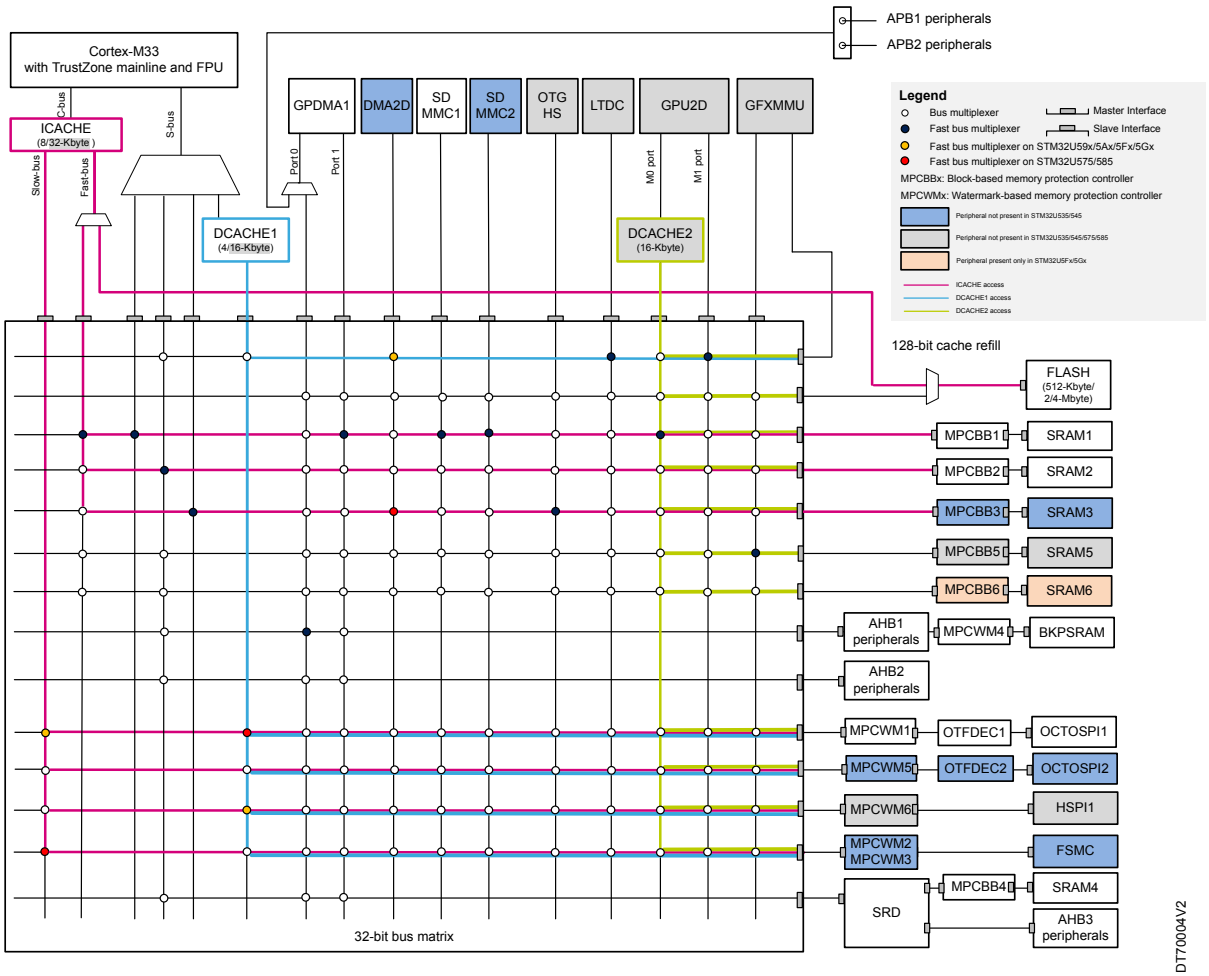
The Cortex-M33 performance is improved by using the 8-Kbyte ICACHE interface introduced to its C-AHB bus, when fetching code or data from the internal memories (flash memory, SRAM1, or SRAM2) through the fast bus, and also from the external memories (OCTOSPI1 or FSMC) through the slow bus.

2.2 STM32U5 series smart architecture

This architecture is based on a bus matrix allowing multiple masters (Cortex-M33, ICACHE, DCACHE, GPDMA, DMA2D and SDMMCs, OTG_HS, LTDC, GPU2D, GFXMMU) to access multiple slaves (such as flash memory, SRAMs, BKPSRAM, HSPI/OCTOSPI, or FSMC).

The figure below describes the STM32U5 series smart architecture.

Figure 2. STM32U5 series smart architecture



The Cortex-M33 and the GPU2D interfaces both benefit from using CACHE.

- ICACHE improves the performance of Cortex-M33 when fetching code or data from the internal memories through fast bus (flash memory, SRAMs) and from external memories through slow bus (OCTOSPI1/2 and HSPI1, or FSMC). DCACHE1 improves the performance when fetching data from internal or external memories through the s-bus (GFXMMU, OCTOSPI1/2 and HSPI1, or FSMC).
- DCACHE2 improves the performance of GPU2D when fetching data from internal and external memories (GFXMMU, flash memory, SRAMs, OCTOSPI1/2 and HSPI1, or FSMC) through the M0 port bus.

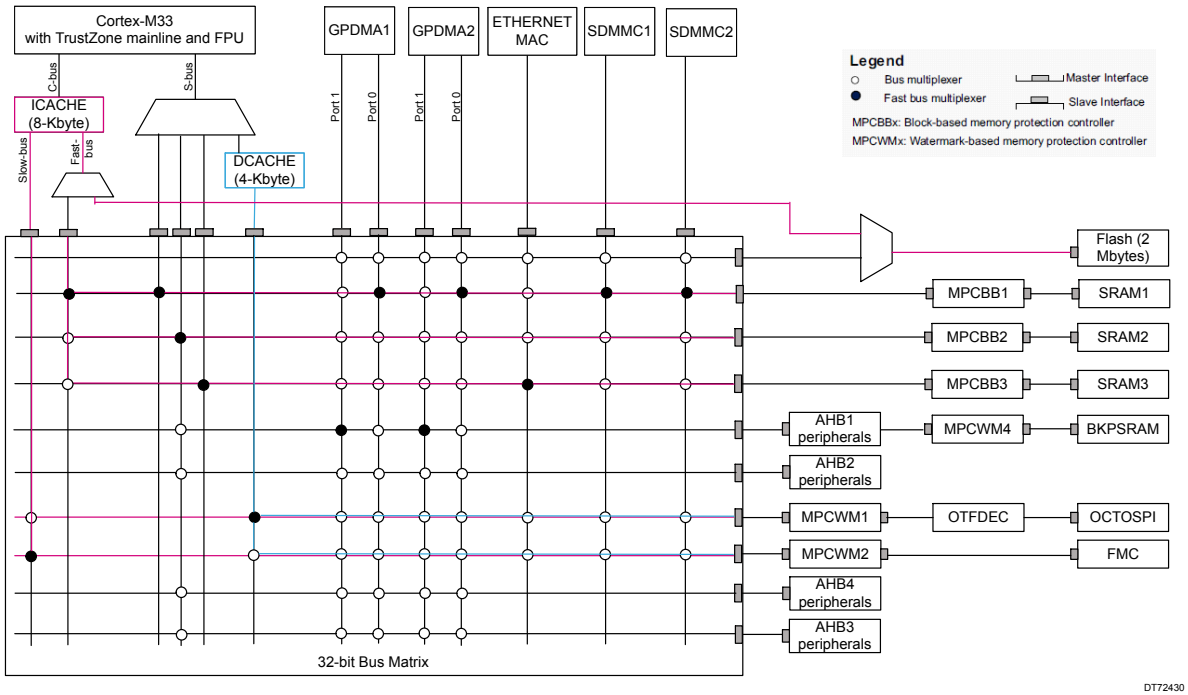
2.3 STM32H5 series smart architecture

STM32H563/H573 and STM32H562 smart architecture

This architecture is based on a bus matrix allowing multiple masters (Cortex-M33, ICACHE, DCACHE, GPDMAs,Ethernet and SDMMCs) to access multiple slaves (such as flash memory, SRAMs, BKPSRAM, OCTOSPI and FMC).

The figure below describes the STM32H5 series smart architecture.

Figure 3. STM32H563/H573 and STM32H562 series smart architecture



The Cortex-M33 benefits from using CACHE.

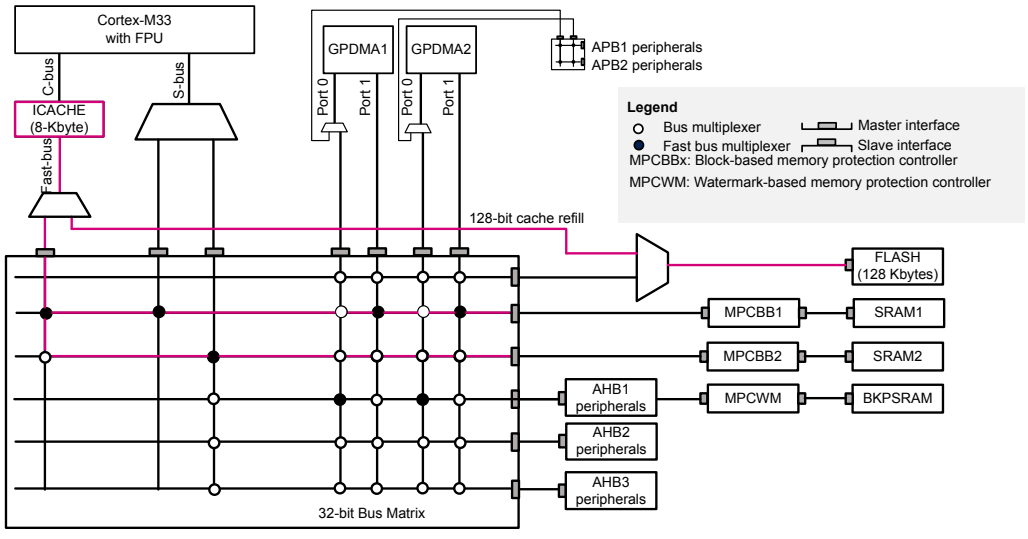
- ICACHE improves the performance of Cortex-M33 when fetching code or data from the internal memories through fast bus (flash memory, SRAMs) and from external memories through slow bus (OCTOSPI and FMC).
- DCACHE improves the performance when fetching data from external memories through the slow bus (OCTOSPI and FMC).

STM32H503 smart architecture

This architecture is based on a bus matrix allowing multiple masters (Cortex-M33, ICACHE and GPDMAs) to access multiple slaves (such as flash memory, SRAMs and BKPSRAM).

The figure below describes the STM32H5 series smart architecture.

Figure 4. STM32H503 series smart architecture



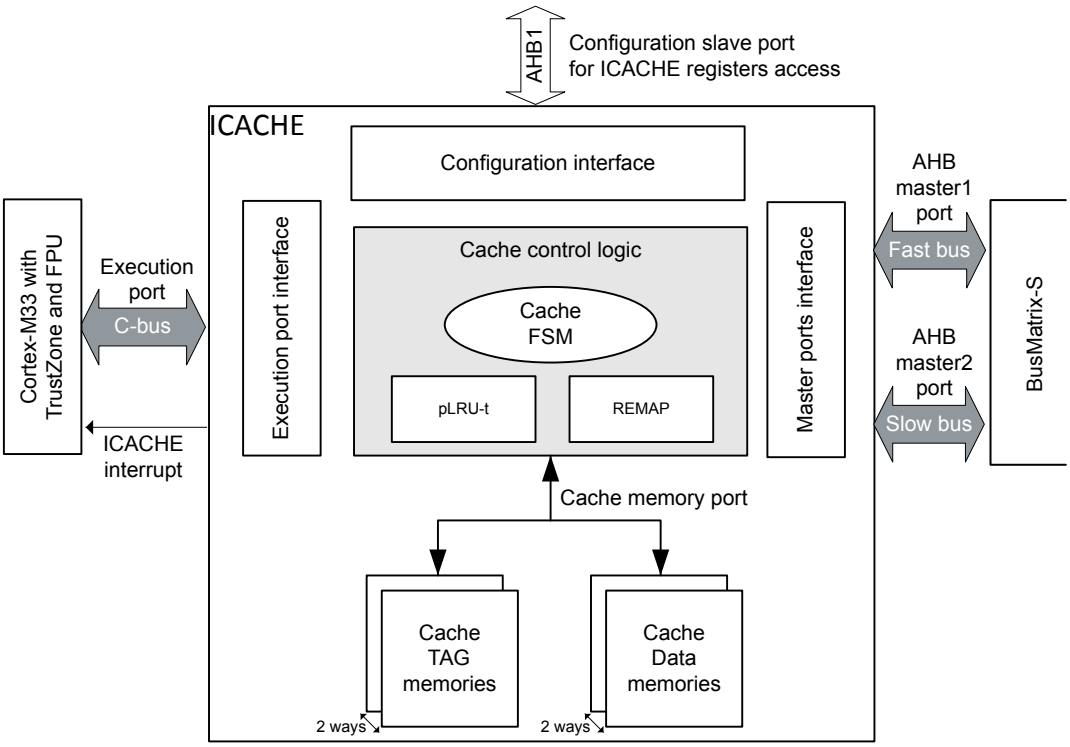
The Cortex-M33 benefits from using CACHE.

- ICACHE improves the performance of Cortex-M33 when fetching code or data from the internal memories through fast bus (flash memory, SRAMs).

2.4 ICACHE block diagram

The ICACHE block diagram is given in the figure below.

Figure 5. ICACHE block diagram



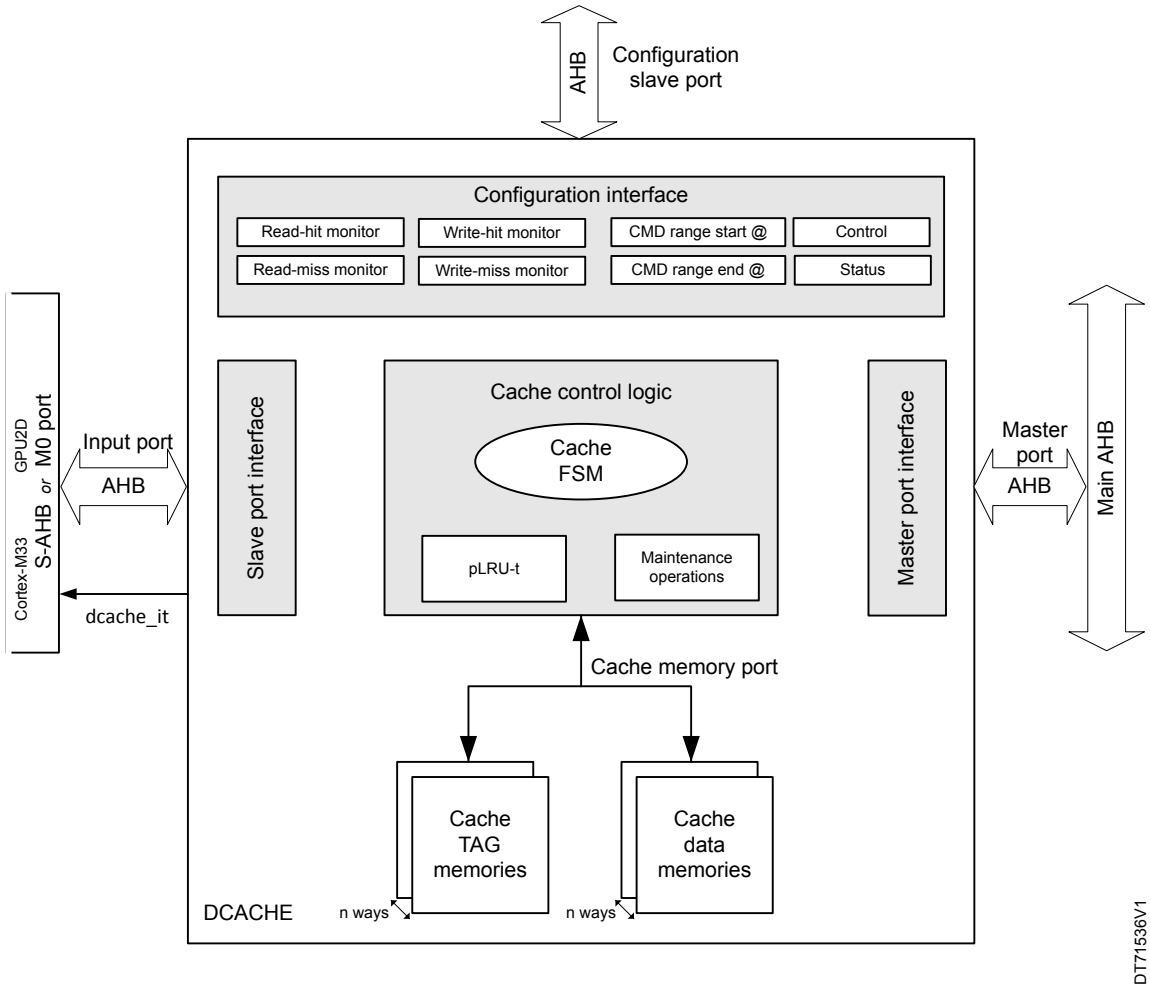
The ICACHE memory includes:

- the TAG memory with:
  - the address tags that indicate which data are contained in the cache data memory
  - the validity bits
- the data memory, that contains the cached data

2.5 DCACHE block diagram

The DCACHE block diagram is given in the figure below.

Figure 6. DCACHE block diagram



The DCACHE memory includes:

- the TAG memory with:
  - the address tags that indicate which data are contained in the cache data memory
  - the validity bits
  - the privilege bits
  - the dirty bits
- the data memory, that contains the cached data

3 ICACHE and DCACHE features

3.1 ICACHE features

3.1.1 Dual masters

The ICACHE accesses the AHB bus matrix either over:

- One AHB master port: master1 (fast bus)
- Two AHB master ports: master1 (fast bus) and master2 (slow bus)

This feature allows the traffic to be decoupled when accessing different memory regions (such as internal flash memory, internal SRAM and external memories), in order to reduce the CPU stalls on cache misses.

The following table summarizes memory regions and their addresses.

Table 2. Memory regions and their addresses

Peripheral				Cacheable memory access			Not cacheable memory access		
Type	Name	Product name and region size		Bus name	Nonsecure region starting address	Secure, nonsecure callable region starting address	Bus name	Nonsecure region starting address	Secure, nonsecure callable region starting address
Internal	FLASH	STM32H503	128 KB	ICACHE fast bus	0x0800 0000	N/A	N/A	N/A	N/A
		STM32L5 series/ STM32U535/ 545	512 KB			0x0C00 0000			
		STM32U575/ 585 STM32H563/ 573/562	2 MB						
		STM32U59x/ 5Ax/5Fx/5Gx	4 MB						
	SRAM1	STM32H503	16 KB		0x0A00 0000	N/A	S-bus	0x2000 0000	0x3000 0000
		STM32L5 series/ STM32U535/ 545/575/585	192 KB			0x0E00 0000			
		STM32H563/ 573/562	256 KB						
		STM32U59x/ 5Ax/5Fx/5Gx	768 KB						
	SRAM2	STM32H503 series	16 KB		0x0A00 4000	N/A		0x2000 4000	N/A
		STM32L5 series/ STM32U535/ 545/575/585	64 KB		0x0A03 0000	0x0E03 0000		0x2003 0000	0x3003 0000
		STM32H563/ 573/562			0x0A04 0000	0x0E04 0000		0x2004 0000	0x3004 0000
		STM32U59x/ 5Ax/5Fx/5Gx			0x0A0C 0000	0x0E0C 0000		0x200C 0000	0x300C 0000
	SRAM3	STM32U575/ 585	512 KB		0x0A04 0000	0x0E04 0000		0x2004 0000	0x3004 0000

Peripheral				Cacheable memory access			Not cacheable memory access		
Internal	SRAM3	STM32H563/573/562	64 KB	ICACHE fast bus	0x0A05 0000	0x0E05 0000	S-bus	0x2005 0000	0x3005 0000
		STM32U59x/5Ax/5Fx/5Gx	832 KB		0x0A0D 0000	0x0E0D 0000		0x200D 0000	0x300D 0000
	SRAM5	STM32U59x/5Ax/5Fx/5Gx	832 KB		0x0A1A 0000	0x0E1A 0000		0x201A 0000	0x301A 0000
	SRAM6	STM32U5Fx/5Gx	512 KB		0x0A27 0000	0x0E27 0000		0x2027 0000	N/A
External	HSPI1	STM32U59x/5Ax/5Fx/5Gx	256 MB	ICACHE slow bus (1)	Alias address in the range of [0x0000 0000 to 0x07FF FFFF] or [0x1000 0000:0x1FFF FFFF] defined by means of remapping feature	N/A		0xA000 0000	
	FMC SDRAM	STM32H563/573/562						0xC000 0000	
	OCTOSPI1 bank nonsecure	STM32L5/U5 series STM32H563/573/562						0x9000 0000	
	FMC bank 3 nonsecure	STM32L5/U5 series STM32H563/573/562						0x8000 0000	
	OCTOSPI2 bank nonsecure	STM32U575/585/59x/5Ax/5Fx/5Gx						0x7000 0000	
	FMC bank 1 nonsecure	STM32L5/U5 series STM32H563/573/562						0x6000 0000	

1. *To be selected when remapping such regions.*

3.1.2 1-way versus 2-way ICACHE

By default, the ICACHE is configured in associative operating mode (two ways enabled), but it is possible to configure the ICACHE in direct mapped mode (one way enabled), for applications requiring a very-low power consumption. The ICACHE configuration is done with the WAYSEL bit in ICACHE_CR as follows:

- WAYSEL = 0: direct mapped operating mode (1-way)
- WAYSEL = 1 (default): associative operating mode (2-way)

Table 3. 1-way versus 2-way ICACHE

Parameter	1-way ICACHE	2-way ICACHE
Cache size (Kbytes)	8(1)/32(2)	
Cache number of ways	1	2
Cache line size	128 bits (16 bytes)	
Number of cache lines	512(1)/2048(2)	256(1)/1024(2) per way

1. *For STM32L5 series /STM32H5 series /STM32U535/545/575/585*
2. *For STM32U59x/5Ax/5Fx/5Gx*

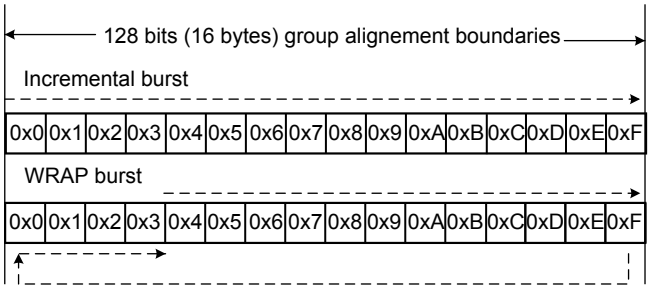
3.1.3 Burst type

Some Octo-SPI memories support the WRAP burst, that provides the benefit of critical-word-first feature performance. The ICACHE burst type of the AHB memory transaction for remapped regions is configurable. It implements incremental burst or WRAP burst, selected with the HBURST bit in the ICACHE_CRRx register.

The differences between the WRAP and the incremental bursts are given below (see also the figure):

- WRAP burst:
  - cache line size = 128 bits
  - burst starting address = word address of the first data requested by the CPU
- Incremental burst:
  - cache line size = 128 bits
  - burst starting address = address aligned on the boundary of the cache line containing the requested word

Figure 7. Incremental versus WRAP burst



3.1.4 Cacheable regions and remapping feature

The ICACHE is connected to the Cortex-M33 through the C-AHB bus, and caches the code region from addresses [0x0000 0000 to 0x1FFF FFFF].

Since the external memories are mapped at an address in the range [0x6000 0000 to 0xAFFF FFFF], the ICACHE supports a remap feature that allows any external memory region to be remapped at an address in the range of [0x0000 0000 to 0x07FF FFFF] or [0x1000 0000 to 0x1FFF FFFF], and to become accessible through the C-AHB bus.

Up to four external memory regions can be remapped with this feature.

Once a region is remapped, the remap operation occurs even if the ICACHE is disabled or if the transaction is not cacheable.

The cacheable memory regions can be defined and programmed by the user in the memory protection unit (MPU). The table below summarizes the configurations of the STM32L5 and STM32U5 series memories.

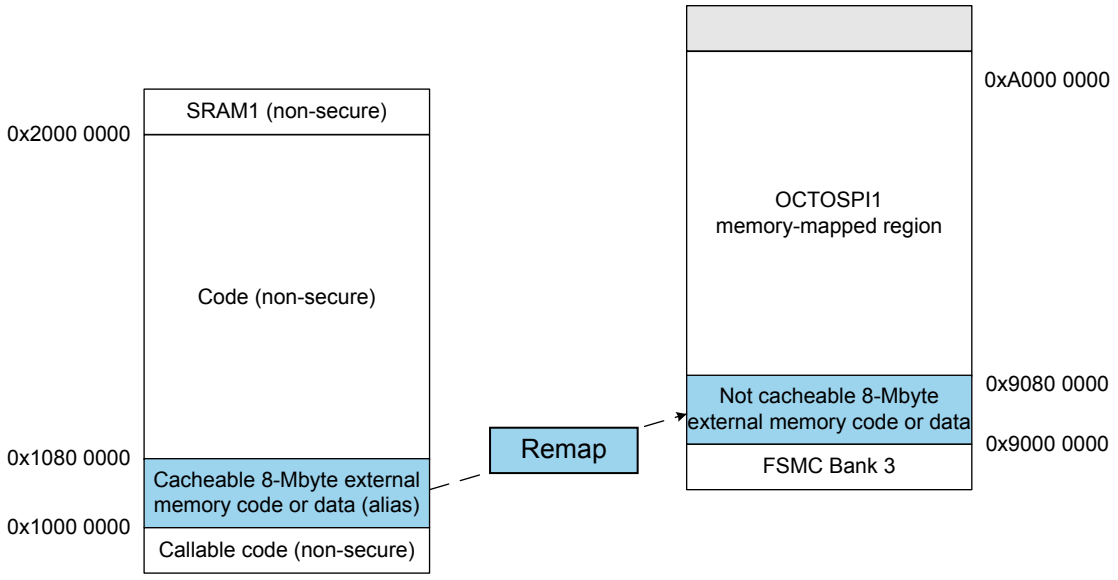
Table 4. Configuration of STM32L5 and STM32U5 series memories

Product memory	Cacheable (MPU programming)	Remapped in ICACHE (ICACHE_CRRx programming)
Flash memory	Yes or No	Not required
SRAM	Not recommended	
External memories (HSPI/ OCTOSPI or FSMC)	Yes or No	Required if the user wants external code fetching on C-AHB bus (else on S-AHB bus)

3.1.5 Benefit of ICACHE external memory remapping

The example in the figure below shows how to benefit from the ICACHE enhanced performance during code execution or data read when accessing an external 8-Mbyte external Octo-SPI memory (such as external flash memory or RAM).

Figure 8. Octo-SPI memory remap example



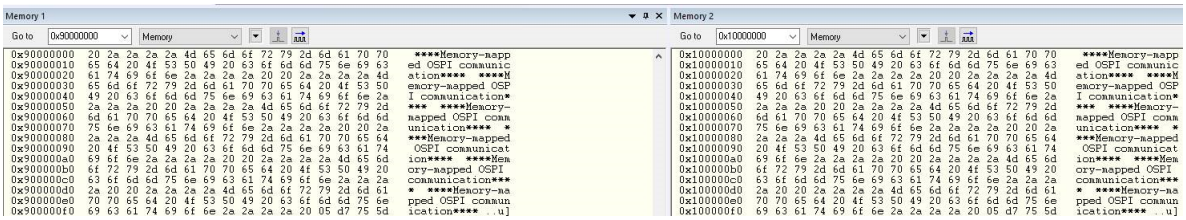
The following steps are needed to remap this external memory:

1. OCTOSPI configuration for the external memory
   Configure the OCTOSPI interface in order to access the external memory in Memory mapped mode (the external memory is seen as an internal memory mapped in the [0x9000 0000 to 0x9FFF FFFF] region). Since the external memory size is 8 Mbytes, it is seen at the region [0x9000 0000 to 0x907F FFFF]. The external memory at this region is accessed through the S-bus and is not cacheable. The next step shows the ICACHE configuration in order to remap this region.

Note: For the OCTOSPI configuration in memory-mapped mode, refer to the application note Octo-SPI interface on STM32 microcontrollers (AN5050).

2. ICACHE configuration to remap the external memory mapped region
The 8 Mbytes placed in the [0x9000 0000 to 0x907F FFFF] region are remapped to the [0x1000 0000 to 0x107F FFFF] region. They can then be accessed through the slow bus (ICACHE master2 bus).
   – ICACHE_CR register configuration
     a. Disable ICACHE with EN = 0.
     b. Select 1-way or 2-ways (depending on the application needs) with WAYSEL = 0 or 1, respectively.
   – ICACHE_CRRx register configuration (up to four regions, x = 0 to 3)
     a. Select the 0x1000 0000 base address (remap address) with BASEADDR [28:21] = 0x80.
     b. Select the 8-Mbyte region size to remap with RSIZE[2:0] = 0x3.
     c. Select the 0x9000 0000 remapped address REMAPADDR[31:21] = 0x480.
     d. Select the ICACHE AHB master2 port for external memories with MSTSEL = 1.
     e. Select the WRAP burst type with HBURST = 0.
     f. Enable the remapping for region x with REN = 1.
   The following figure shows how the memory regions are seen with IAR after enabling the remap.

Figure 9. Memory regions remapping example



The 8-Mbyte external memory is now remapped and can be accessed over the [0x1000 0000 to 0x107F FFFF] region.

3. ICACHE enable
   – ICACHE_CR register configuration
   Enable the ICACHE with EN = 1.

3.1.6 Hit and miss monitors

ICACHE provides two monitors for performance analysis: a 32-bit hit monitor and a 16-bit miss monitor.

- The hit monitor counts the cacheable AHB-transactions on slave cache port that hit ICACHE content (fetched data already available in the cache). The hit monitor counter is available in the ICACHE_HMONR register.
- The miss monitor counts the cacheable AHB-transactions on slave cache port that miss ICACHE content (fetched data not already available in the cache).
  The miss monitor counter is available in the ICACHE_MMONR register.

Note: These two monitors do not wrap over when reaching their maximum values.

These monitors are managed from the following bits in the ICACHE_CR register:

- HITMEN bit (respectively MISSMEN bit) to enable/stop the hit (respectively miss) monitor
- HITMRST bit (respectively MISSMRST bit) to reset the hit (respectively miss) monitor

By default, theses monitors are disabled in order to reduce power consumption.

3.1.7 ICACHE maintenance

The software can invalidate the ICACHE by setting the CACHEINV bit in the ICACHE_CR register. This action invalidates the whole cache, making it empty. Meanwhile, if some remapped regions are enabled, the remap feature is still active, even when the ICACHE is disabled.

As the ICACHE only manages read transactions and does not manage write transactions, it does not ensure coherency in case of writes. Consequently, the software must invalidate the ICACHE after programming a region.

3.1.8 ICACHE security

ICACHE is a securable peripheral that can be configured as secure through the GTZC TZSC secure configuration register. When it is configured as secure, only secure accesses are allowed to the ICACHE registers. ICACHE can also be configured as privileged through the GTZC TZSC privilege configuration register. When ICACHE is configured as privileged, only privileged accesses are allowed to the ICACHE registers.

By default, the ICACHE is nonsecure and non-privileged through the GTZC TZSC.

3.1.9 Event and interrupt management

The ICACHE manages the functional errors when detected, by setting the ERRF flag in ICACHE_SR. An interrupt can also be generated if the ERRIE bit is set in ICACHE_IER.

In case of ICACHE invalidation, when the cache busy state finished, the BSYENDF flag is set in ICACHE_SR. An interrupt can also be generated if the BSYENDIE bit is set in ICACHE_IER.

The table below lists the ICACHE interrupt and event flags.

Table 5. ICACHE interrupt and event management bits

Register	Bit name	Bit description	Bit access type
ICACHE_SR	BUSYF	Cache executing a full invalidate operation	Read-only
	BSYENDF	Cache invalidation operation finished	
	ERRF	An error occurred during caching operation	
ICACHE_IER	ERRIE	Enable interrupt for cache error	Read/write
	BSYENDIE	Enable interrupt in case of invalidation operation finished	
ICACHE_FCR	CERRF	Clears ERRF in ICACHE_SR	Write-only
	CBSYENDF	Clears BSYENDF in ICACHE_SR	

3.2 DCACHE features

The purpose of the data cache is to cache external memories data loads and data stores coming from the processor or from another bus master peripheral. DCACHE manages both read and write transactions.

3.2.1 DCACHE cacheability traffic

The DCACHE caches the external memories from the master port interface through the AHB bus. The incoming memory requests are defined cacheable according to its AHB transaction memory lockup attribute.

The DCACHE write policy is defined as write-through or write-back depending to the memory attribute configured by the MPU. When a region is configured as non-cacheable , the DCACHE is bypassed.

Table 6. DCACHE cacheability for AHB transaction

AHB lookup attribute	AHB bufferable attribute	Cacheability
0	X	Read and write: non cacheable
1	0	Read: cacheable Write: (cacheable) write-through
1	1	Read: cacheable Write: (cacheable) write-back

3.2.2 DCACHE cacheable regions

For STM32U5 series, the DCACHE1 slave interface is connected to the Cortex-M33 through the S-AHB bus, and caches the GFXMMU, FMC, and HSPI/OCTOSPIs. The DCACHE2 slave interface is connected to the DMA2D through the M0 port bus, and caches all the internal and external memories (except SRAM4 and BRKPSRAM).

For STM32H5 series, the DCACHE slave interface is connected to the Cortex-M33 through the S-AHB external memories through FMC and OCTOSPI.

Table 7. **DCACHE cacheable regions and interfaces**

Cacheable memory address region	DCACHE1 cacheable interfaces	DCACHE2 cacheable interfaces
GFXMMU	X	X
SRAM1	N/A	X
SRAM2		X
SRAM3		X
SRAM5		X
SRAM6		X
HSPI1	X	X
OCTOSPI1	X	X
FMC BANKs	X	X
OCTOSPI2	X	X

Note: Some interfaces are not supported in certain products. Refer to Figure 1 or the specific product reference manual.

3.2.3 Burst type

Same as ICACHE, the DCACHE supports incremental and wrapped bursts (see Section 3.1.3).

For DCACHE, the burst type is configured through the HBURST bit in DCACHE_CR.

3.2.4 DCACHE configuration

During boot , DCACHE is disabled by default making the slave memory requests forwarded directly to master port. To enable DCACHE, EN bit must be set in the DCACHE_CR register.

3.2.5 Hit and miss monitors

The DCACHE implements four monitors for cache performance analysis:

- Two 32-bit (R/W) hit monitor: counts the number of times the CPU read or write data in the cache memory without generating a transaction on DCACHE master ports (data already available in the cache). The (R/W) hit monitors counters are available respectively in the DCACHE_RHMONR and DCACHE_WHMONR registers.
- Two 16-bit (R/W) miss monitor: counts the number of times the CPU read or write data in the cache memory and generates a transaction on DCACHE master ports, in order to load the data from the memory region (fetched data not already available in the cache). The (R/W) miss monitors counters are available respectively in the DCACHE_RMMONR and DCACHE_WMMONR registers.

Note: These four monitors do not wrap over when reaching their maximum values. These monitors are managed from the following bits in the DCACHE_CR register:

- WHITMEN bit (respectively WMISSMEN bit) to enable/stop the write hit (respectively miss) monitor
- RHITMEN bit (respectively RMISSMEN bit) to enable/stop the read hit (respectively miss) monitor
- WHITMRST bit (respectively WMISSMRST bit) to reset the write hit (respectively miss) monitor
- RHITMRST bit (respectively RMISSMRST bit) to reset the read hit (respectively miss) monitor

By default, theses monitors are disabled in order to reduce power consumption.

3.2.6 DCACHE maintenance

The DCACHE offers multiple maintenance operations that can be configured through CACHECMD[2:0] in DCACHE_CR.

000: no operation (default)

001: clean range. Clean a certain range in the cache

010: invalidate range. Invalidate a certain range in the cache

010: clean and invalidate range. Clean and invalidate a certain range in the cache

The selected range is configured through:

- CMDSTARTADDR register: command starting address
- CMDENDADDR register: command ending address

Note: This register must be set before CACHECMD is written.

The cache command maintenance starts when STARTCMD bit is set in DCACHE_CR register. The DCACHE also support a full CACHE invalidation by setting the CACHEINV bit in DCACHE_CR register.

3.2.7 DCACHE security

The DCACHE is a securable peripheral that can be configured as secure through the GTZC TZSC secure configuration register. When it is configured as secure, only secure accesses are allowed to the DCACHE registers.

DCACHE can also be configured as privileged through the GTZC TZSC privilege configuration register. When DCACHE is configured as privileged, only privileged accesses are allowed to the DCACHE registers.

By default, the DCACHE is nonsecure and non- privileged through the GTZC TZSC.

3.2.8 Event and interrupt management

The DCACHE manages the functional errors when detected, by setting the ERRF flag in DCACHE_SR. An interrupt can also be generated if the ERRIE bit is set in DCACHE_IER. In case of DCACHE invalidation, when the cache busy state finished, the BSYENDF flag is set in DCACHE_SR.

An interrupt can also be generated if the BSYENDIE bit is set in DCACHE_IER. The DCACHE command status can be checked through CMDENF and BUSYCMDF through the DCACHE_SR

An interrupt can also be generated if the CMDENDIE bit is set in DCACHE_IER. The table below lists the DCACHE interrupts and events flags.

Table 8. DCACHE Interrupt and events management bits

Register	Register	Bit description	Bit access type
DCACHE_SR	BUSYF	Cache executing a full invalidate operation	Read-only
	BSYENDF	Cache full invalidate operation ended	
	BUSYCMDF	Cache executing a range command	
	CMDENDF	A range command end	
	ERRF	An error occurred during caching operation	
DCACHE_IER	ERRIE	Enable interrupt for cache error	Read/write
	CMDENDIE	Enable interrupt on range command end	
	BSYENDIE	Enable interrupt on full invalidate operation end	
DCACHE_FCR	CERRF	Clears ERRF in DCACHE_SR	Write-only
	CCMDENDF	Clears CMDENDF in DCACHE_SR	
	CBSYENDF	Clears BSYENDF in DCACHE_SR	

4 ICACHE and DCACHE performance and power consumption

Using ICACHE and DCACHE improve the application performance when accessing external memories. The following table shows the impact of ICACHE and DCACHE on CoreMark® execution when accessing external memories.

Table 9. ICACHE and DCACHE performance on CoreMark execution with external memories

(1)

CoreMark code	CoreMark Data	ICACHE configuration	DCACHE configuration	CoreMark score/Mhz
Internal Flash memory	Internal SRAM	Enabled (2-ways)	Disabled	3.89
Internal Flash memory	External Octo-SPI PSRAM (S-bus)	Enabled (2-ways)	Enabled	3.89
Internal Flash memory	External Octo-SPI PSRAM (S-bus)	Enabled (2-ways)	Disabled	0.48
External Octo-SPI Flash (C-bus)	Internal SRAM	Enabled (2-ways)	Disabled	3.86
External Octo-SPI Flash (C-bus)	Internal SRAM	Disabled	Disabled	0.24
Internal Flash memory	Internal SRAM	Disabled	Disabled	2.69

1. *Test Conditions:*
   - *Applicable product: STM32U575/585*
   - *System frequency: 160 MHz.*
   - *External Octo-SPI PSRAM memory: 80 MHz (DTR mode).*
   - *External Octo-SPI flash memory: 80 MHz (STR mode).*
   - *Compiler: IAR V8.50.4.*
   - *Internal Flash PREFETCH: ON.*

Using ICACHE and DCACHE reduce the power consumption when accessing internal and external memories. The following table shows the impact of ICACHE on power consumption during CoreMark execution.

Table 10. CoreMark execution ICACHE impact on power consumption

(1)

ICACHE configuration	MCU power consumption (mA)
Enabled (2-ways)	7.60
Enabled (1-way)	7.13
Disabled	8.89

1. *Test Conditions:*
   - *Applicable product: STM32U575/585*
   - *CoreMark code: internal Flash memory.*
   - *CoreMark data: internal SRAM.*
   - *Internal Flash memory PREFETCH: ON.*
   - *System frequency: 160 MHz.*
   - *Compiler: IAR V8.32.2.*
   - *Voltage range: 1.*
   - *SMPS: ON.*

Note: 2-way set associative configuration is more performing than 1-way set associative configuration for code that cannot be fully loaded in cache. Meanwhile, 1-way set associative cache is almost always more power efficient than 2-way set associative cache. Each code has to be evaluated in both associativity configurations, in order to select the best trade-off between performance and power consumption. The selection depends on the user priority.

5 Conclusion

The first caches developed by STMicroelectronics, ICACHE and DCACHE, are able to cache internal and external memories, offering performance enhancement for data traffic and instruction fetches. This document shows the different features supported by the ICACHE and DCACHE, their configuration simplicity and flexibility allow lower development cost and faster time to market.

Revision history

Table 11. **Document revision history**

Date	Version	Changes
10-Oct-2019	1	Initial release.
27-Feb-2020	2	Updated: • Table 2. Memory regions and their addresses • Section 2.1.7 ICACHE maintenance • Section 2.1.8 ICACHE security
7-Dec-2021	3	Updated: • Document title • Introduction • Section 1 ICACHE and DCACHE overview • Section 4 Conclusion Added: • Section 2 ICACHE and DCACHE features • Section 3 ICACHE and DCACHE performance and power consumption
15-Feb-2023	4	Updated: • Section 2.2 STM32U5 series smart architecture • Section 2.5 DCACHE block diagram • Section 3.1.1 Dual masters • Section 3.1.2 1-way versus 2-way ICACHE • Section 3.1.4 Cacheable regions and remapping feature • Section 3.2 DCACHE features • Section 3.2.2 DCACHE cacheable regions • Section 4 ICACHE and DCACHE performance and power consumption Added: • Section 1 General information

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