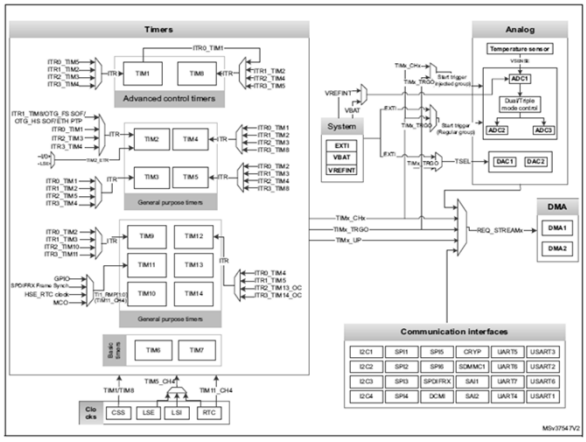
Hello and welcome to this presentation of the STM32 Interconnect Matrix. It covers the main features of this matrix, which is widely used to connect various internal peripherals between each other.

Overview

- The Interconnect Matrix provides direct connections between peripherals.



Application benefits

- Time-predictable operations
- Decreased power consumption
- Reduced GPIO use

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The Interconnect Matrix integrated inside STM32 microcontrollers provides direct connections between peripherals.
Applications benefit from these interconnections to ensure time-predictable operations and decrease power consumption. This matrix avoids complex management of peripheral communications through reading/writing registers using CPU instructions. In some cases, it reduces the need to loop a signal from a source to a destination through a dedicated GPIO.

Key features

- Direct, autonomous connections between peripherals
  - Remove latency in comparison to software event handling
  - Save CPU resources
  - Remove the need for looping signals through dedicated GPIOs
  - Allow automating various processes and regulation loops
  - Improve security of MCU-controlled applications
- Can operate during low-power modes (peripheral dependent)

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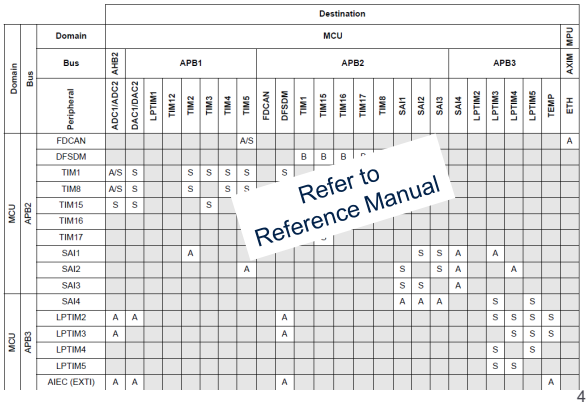
The Interconnect Matrix offers two main features. First, it ensures direct and autonomous connections between peripherals, allowing to remove latency in regards to software handling, , thus saving GPIO and CPU resources. Second, the interconnection between certain peripherals can operate during low-power modes.

Interconnect sources and destinations

Plenty of interconnect possibilities available

- Source peripherals
  - Timers: TIMx and RTC
  - Analog IPs: ADCx, DACx, VrefInt, VBAT, and temperature sensor
  - Clocks: HSE, LSE, LSI, and HSI
  - EXTI, DFSDM, USB, and ETH
  - System errors (CSS, parity, ECC, and Lock-up)
- Destination peripherals
  - Timers: TIMx and LPTIM
  - Analog IPs: ADCx, and DACx
  - DFSDM, DMA, etc...



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The main peripherals having direct, autonomous interconnections are:

- Connection sources: timers, analog IPs, clocks, extended interrupt/event controllers, digital filters for sigma-delta modulators, USB interfaces and system errors.
- Connection destinations: timers, analog IPs, digital filters for sigma-delta modulators and direct memory access controllers.

Low-power modes

Several interconnections are able to work in low-power modes

- All interconnections work in the following power modes:
  - Run
  - Sleep
- Some interconnections work in Stop mode:
  - Ethernet MAC, USB, LPTIM, MDIOS, RTC and PVD connection to EXTI
  - Connections from RTC, GPIO to low-power timer (LPTIM1)

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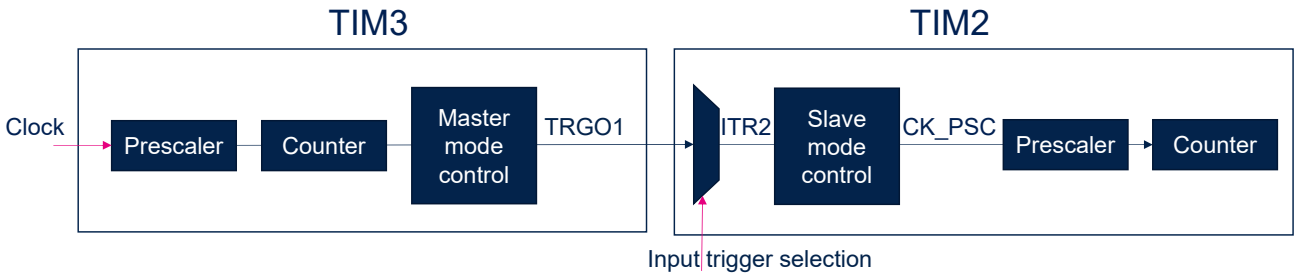
Peripherals can be interconnected using the Interconnect Matrix even when the circuit is in a low-power mode.
The fully supported power modes are Run and Sleep.
The connections from the real-time clock or GPIO to low-power timers can also be used in Stop modes, as well as Ethernet MAC, USB, low-power timers, management data input/output (MDIO) slaves, real-time clocks and the programmable voltage detector (PVD) connection to the external interrupt/event controller.

Application examples (1)

- Timer synchronization or chaining:
  - TIM2 can be started with TIM3 without delay (precise synchronization)
  - TIM3 can work as prescaler for TIM2 (clock mode)
  - TIM2 can be reset on request from TIM3 (slave reset mode)



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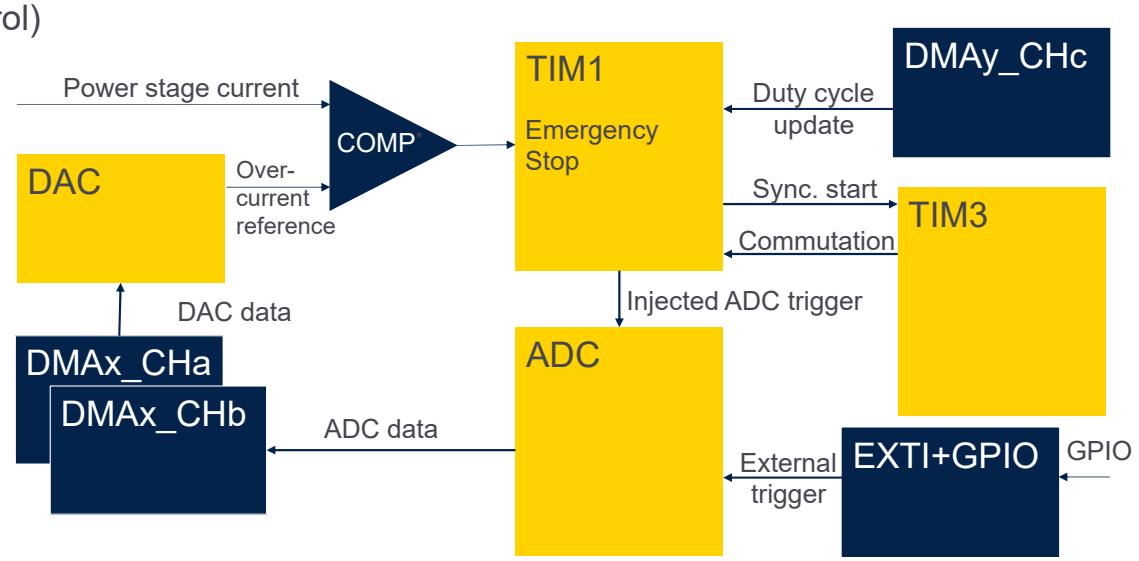
The Interconnect Matrix can be used for synchronizing or chaining timers allowing, for example, a master timer to reset or trigger a second slave timer.

This slide shows a simple example of timer synchronization. Timer 3 is used as the Master Timer and can reset, start, stop or clock Timer 2 configured in Slave mode.
Timer 3 is clocking Timer 2 so that it acts as a prescaler for Timer 2.

Timers can also be triggered by a short-circuit detection on a digital filter for sigma-delta modulators, when a USB Start Of Frame is detected, or by a real-time clock interrupt at a given time or at a regular interval. All these use cases are enabled thanks to the propagation of these triggering signals through the Interconnect Matrix.

Application examples (2)

- Timers with ADC, DMA and emergency shutdown (voltage inverters or motor control)



* COMP: The operational amplifier present on other STM32 families, is here implemented externally

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This example generates 3-phase PWM signals in Timer 1. The commutation and duty cycle update are generated via the DMA engines, respectively Timer 3.
The overcurrent is guarded by a comparator (external to the STM32MP1 Series), whose reference is driven by the digital-to-analog converter (DAC) and changed via the DMA engine.
Phase voltage and currents are measured by an analog-to-digital converter (ADC), which samples the channel 4 synchronously with the events generated by Timer 1. Other voltage sources are measured on external events, detected by the GPIO and routed via the EXTI unit to the ADC regular trigger.
The whole mechanism runs autonomously just after proper setup, so the CPU can safely execute speed or voltage regulation algorithms without the need for low-level control.

Other application examples

- Triggering of ADC, DAC or DFSDM (by Timers or EXTI)
- Triggering of timers (by DFSDM, RTC or USB)
- Triggering of DMA data transfer from memory to DAC (by Timer)
- Calibration of HSI/LSI clocks by Timer
- Dual-ADC mode (synchronization and load balancing)
- Temperature and supply + battery voltage monitoring
- Analog IP interconnect (DAC, op amp to ADC, COMP)
- Protection of timer-driven power switches (System Error to Timer)

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The Interconnect Matrix is mostly used for:

- Triggering an ADC, DAC, digital filter for sigma-delta modulator through a timer event or an external interrupt,
- Triggering a timer through an ADC or DFSDM watchdog signal when a predefined threshold value is crossed by the analog input,
- Triggering a DMA data transfer from memory to the DAC by a timer to allow a frequency-controlled conversion,
- Calibrating HSI and LSI clocks, for example measuring the external oscillator LSE frequency by a timer clocked by the calibrated internal oscillator,
- Dual-ADC mode, using ADC1 as the master to trigger a start of conversion for the ADC2 slave,
- Monitoring the temperature of a connected internal temperature sensor or the VBAT to ADC voltage,
- Analog IP interconnect, for example, DAC to an ADC,
- Protecting timer-driven power switches through the direct connection of System Error signals to the timer break

input.

Interconnection in details

- Both peripherals need to be active and configured
- Their inputs and outputs need to be active and the input multiplexer configured (e.g. TIM1 TRGO enabled, TIM3 slave mode enabled and its TRGI configured as input ITR0).
  - There is no specific interconnection peripheral to configure, details for each peripheral can be found in the reference manual separately!
- Some peripheral inputs share connections with other peripherals and the associated GPIO pin (e.g. Comparator and Timer CHx inputs). In such cases, the GPIO Alternate Function must be deactivated to avoid interference.
- ADCx inputs can be shared, but two ADCs must not sample the same input at the same time.
- Peripherals with analogue outputs, when active, override the associated GPIO functionality (e.g. DAC)

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These recommendations should be followed to ensure a proper interconnection in between the peripherals and avoid unexpected behaviors:

- Both peripherals need to be active and their inputs and outputs configured.
- When peripheral inputs share connections with other peripherals, associated GPIO alternate functions must be deactivated to avoid interference.
- Peripherals with active analogue outputs override the associated GPIO functionality.

References

- For more details, please refer to:
  - STM32MP1 Series Reference manuals
  - STM32MP1 Series Datasheets

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Specific details can be found in the specific sections for each peripheral in the Reference Manual as well as in the Datasheet.

Thank you

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