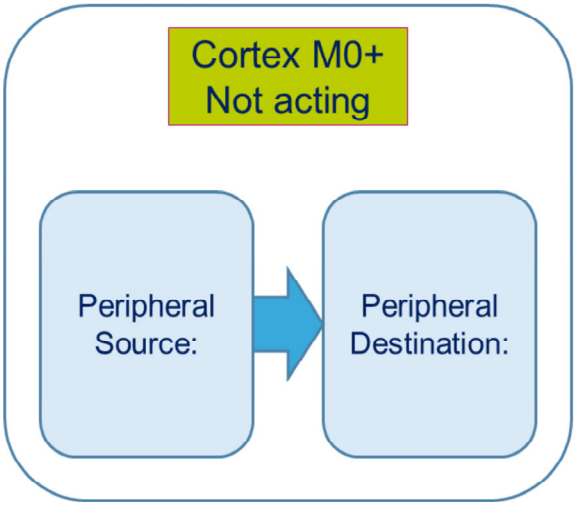
Hello and welcome to this presentation of the STM32 Interconnect Matrix. It covers the main features of this matrix, which is widely used to connect various internal peripherals between each other.

Overview



- Provides direct connections between peripherals

Application benefits

- Time-predictable operations
- Decreased power consumption
- Reduced GPIO usage
- Optimized computation time

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

Key features

- Direct, autonomous connections between peripherals
  - Removes latency in regards to software handling
  - Saves CPU resources
  - Removes the need for looping signals through a dedicated GPIO
- Can operate during Low-power modes (depending on peripheral)

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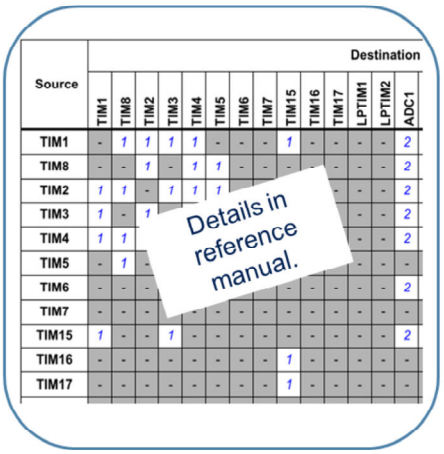
The Interconnect Matrix offers two main features. First, it ensures direct and autonomous connections between peripherals, allowing to remove latency in regards to software handling, thus saving GPIO and CPU resources.
Second, the interconnection between certain peripherals can even operate during low-power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

Sources and destinations

- **Plenty of interconnect possibilities available**

Source peripherals	
Interrupts	EXTI
Timers	TIM1, TIM2, TIM3, TIM14, TIM15, TIM16, TIM17, TIM6, TIM7 LPTIM1, LPTIM2
Connectivity IPs	USART1, USART4
Analog IPs	ADC, Temperature Sensor, VBAT, VREFINT, COMP1, COMP2
Clocks	HSE, LSE, LSI, MCO
RTC	RTC and Tampers
SoC event	System error
Destination peripherals	
Timers	TIM1, TIM2, TIM3, TIM14, TIM15, TIM16, TIM17 LPTIM1, LPTIM2
Connectivity IPs	IRTIM
Analog IPs	ADC, DAC, COMP1, COMP2
DMA	DMAMUX



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This slide indicates the list of source and destination peripherals.
Source peripherals are the EXTI, timers, USARTs, analog IPs, clocks, RTC and System Error.
Destination peripherals are the timers, Infrared Interface, analog IPs and DMAMUX.
The interconnect matrix is further described in the STM32G0 Reference Manual.

Application examples

From	To	Purpose
TIM1, TIM2, TIM3, TIM15, TIM16, and TIM17	TIM1, TIM2, TIM3, and TIM15	Some of the TIMx timers are linked together internally for timer synchronization or chaining When one timer is configured in Master mode, it can reset, start, stop or clock the counter of another timer configured in Slave mode
TIM1, TIM2, TIM3, TIM6, TIM15, and EXTI	ADC	Timers and EXTI can be used to generate an ADC triggering event
ADC	TIM1	ADC can provide trigger event through watchdog signals to TIM1
TIM1, TIM2, TIM3, TIM6, TIM7, TIM15, LPTIM1, LPTIM2, and EXTI	DAC	Timers and EXTI can trigger a DAC conversion
HSE, LSE, LSI, MCO, RTC and TAMP	TIM2, TIM14, TIM16, and TIM17	External clocks (HSE, LSE), internal clock (LSI), Microcontroller Output Clock (MCO), RTC clock, RTC wakeup interrupt, and Tamper inputs can be selected as inputs to capture channel 1 of some of timers The timers allow calibrating or precisely measuring internal clocks such as HSI16 or LSI, using accurate clocks such as LSE or HSE/32 for timing reference
RTC, TAMP, COMP1, and COMP2	LPTIM1 and LPTIM2	RTC alarm A/B, TAMP1/2 input detection, COMP1/2_OUT can be used as trigger to start LPTIM counters LPTIM1/2

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This slide and the next one describe the various possible uses for the interconnect matrix:

- Synchronizing or chaining timers, for example allowing a master timer to reset or trigger a second slave timer
- Triggering an ADC through a timer or EXTI event
- Triggering a timer through an ADC watchdog signal when a predefined threshold value is crossed by the analog input
- Triggering a DAC through a timer or EXTI event
- Calibrating HSI16 and LSI clocks, for example measuring the external oscillator LSE frequency by a timer clocked by the calibrated internal oscillator
- Starting low-power timers from an RTC alarm, a tamper event or comparator event.

Application examples

From	To	Purpose
TIM1, TIM2, TIM3, and TIM15	COMP1 and COMP2	Advanced-control timer TIM1 and general-purpose timers TIM2, TIM3, and TIM15 can be used as blanking window input to COMP1 and COMP2
Internal analog sources (Temperature Sensor, VREFINT, VBAT)	ADC	Internal temperature sensor output voltage VTS, internal reference voltage VREFINT and VBAT monitoring channel are connected to ADC input channels
COMP1 and COMP2	TIM1, TIM2, TIM3, TIM15, TIM16, and TIM17	COMP1 and COMP2 comparator outputs can be connected to input capture or TIMx_ETR inputs of TIM1, TIM2, TIM3 COMP1 and COMP2 comparator outputs can also act as TIMx_BKIN or TIMx_BKIN2 break input signals for TIM1, TIM15, TIM16, and TIM17
System errors	TIM1, TIM2, TIM3, TIM15, TIM16, and TIM17	CSS, CPU hardfault, RAM parity error, FLASH ECC double error detection, PVD can generate system errors in the form of timer break toward TIM1, TIM2, TIM3, TIM15, TIM16, and TIM1 Protection of timer-driven power switches
TIM16, TIM17, USART1, and USART4	IRTIM	TIMx_OC1 output channel of TIM16 or TIM17 timers, associated with USART1 or USART4 transmission signal, can generate the infrared output waveform
TIM14, LPTIM1, LPTIM2 and EXTI	DMAMUX	TIM14 general-purpose timer, LPTIM1 and LPTIM2 low-power timers, and EXTI, can be used as triggering event to DMAMUX

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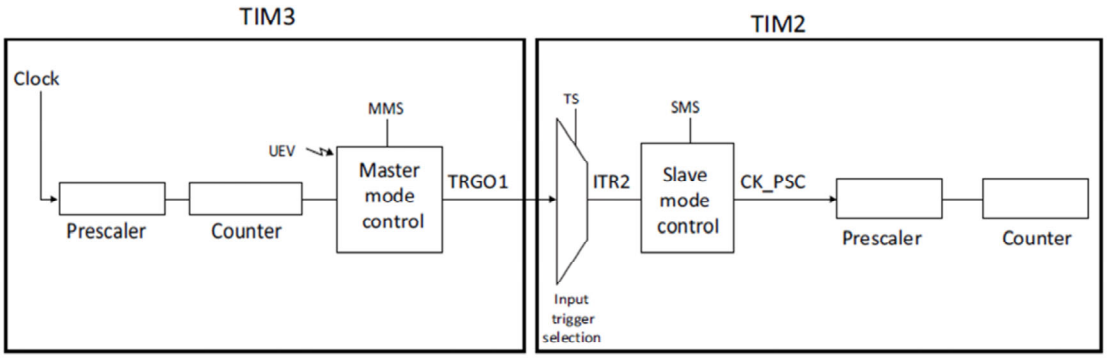
Other use cases:

- Implementing blanking windows in COMP modules
- Monitoring the temperature of a connected internal temperature sensor or VBAT or VREFINT
- Using the COMP outputs as timer external triggers or break inputs
- Protecting timer-driven power switches through the direct connection of System Error signals to the timer break input
- Infrared pulse modulation signal waveform generation using 2 timers
- Triggering a DMA data transfer by a timer.

Timer synchronization example

- Timer 3 can act as a prescaler for Timer 2



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

Low-power modes

From	To	Run	Sleep	Low-power run	Low-power sleep	Stop0	Stop1
TIM1, TIM2, TIM3, TIM15, TIM16, and TIM17	TIM1, TIM2, TIM3, and TIM15	✓	✓	✓	✓		
TIM1, TIM2, TIM3, TIM6, TIM15, and EXTI	ADC	✓	✓	✓	✓		
ADC	TIM1	✓	✓	✓	✓		
TIM1, TIM2, TIM3, TIM6, TIM7, TIM15, LPTIM1, LPTIM2, and EXTI	DAC	✓	✓	✓	✓		
HSE, LSE, LSI, MCO, RTC and TAMP	TIM2, TIM14, TIM16, and TIM17	✓	✓	✓	✓		
RTC, TAMP, COMP1, and COMP2	LPTIM1 and LPTIM2	✓	✓	✓	✓	✓	✓
TIM1, TIM2, TIM3, and TIM15	COMP1 and COMP2	✓	✓	✓	✓		
Internal analog sources (Temperature Sensor, VREFINT, VBAT)	ADC	✓	✓	✓	✓		
COMP1 and COMP2	TIM1, TIM2, TIM3, TIM15, TIM16, and TIM17	✓	✓	✓	✓		
System errors	TIM1, TIM2, TIM3, TIM15, TIM16, and TIM17	✓	✓	✓	✓		
TIM16, TIM17, USART1, and USART4	IRTIM	✓	✓	✓	✓		
TIM14, LPTIM1, and LPTIM2	DMAMUX	✓	✓	✓	✓		

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Peripherals can be interconnected using the Interconnect Matrix even when the circuit is in a low-power mode. This table indicates in which low-power modes, the interconnection between peripherals remains active.

Low-power modes

- **Most interconnections are able to work in low-power modes**

- All interconnections work in the following power modes:
  - Run, Sleep, Low-power run and Low-power sleep modes
- Connections from RTC, COMP1, COMP2 to low-power timer (LPTIM1/LPTIM2) also works in Stop0 and Stop1 modes

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The low-power modes that can be used are: Run, Sleep and Low-power sleep modes for all interconnections. The connections from the real-time clock or comparators to low-power timers can also be used in Stop0 and Stop1 modes.

References

- For more details, please refer to:
  - Reference manuals for STM32G0 microcontrollers
  - Peripherals trainings linked to this peripheral
    - Timers (TIM)
    - Low Power Timers (LPTIM)
    - Analog-to-Digital Converter (ADC)
    - Digital-to-Analog Converter (DAC)
    - Comparators (COMP)
    - Extended interrupts and event Controller (EXTI)
    - DMA Request Multiplexer (DMAMUX)
    - Infrared Interface (IRTIM)
    - Reset and Clock Control (RCC)
    - Real-Time Clock (RTC)
    - Tamper & backup registers

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For more details about the Interconnect Matrix, refer to the reference manual for STM32G0 microcontrollers. Refer also to these trainings for more information if needed:

- Timers (TIM)
- Low-Power Timers (LPTIM)
- Analog-to-Digital Converter (ADC)
- Digital-to-Analog Converter (DAC)
- Comparators (COMP)
- Extended interrupts and event Controller (EXTI)
- DMA Request Multiplexer (DMAMUX)
- Infrared Interface (IRTIM)
- Reset and Clock Control (RCC)
- Real-Time Clock (RTC)
- Tamper & backup registers