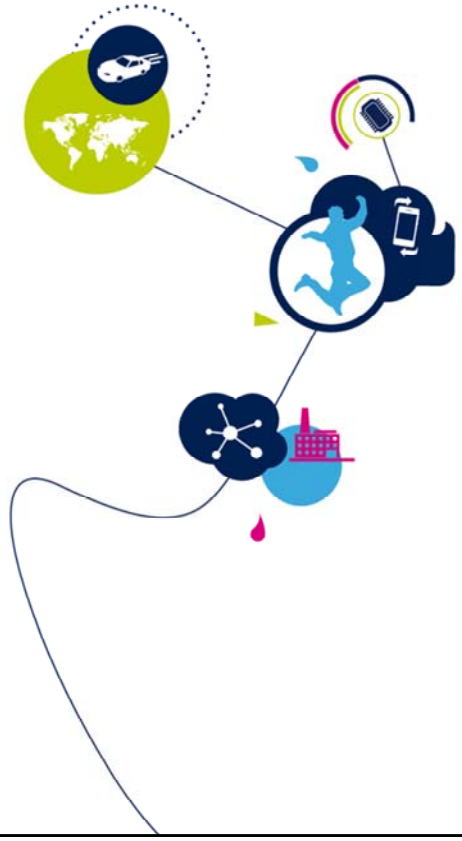
STM32G4 – IMX

Interconnect Matrix
Revision 1.0



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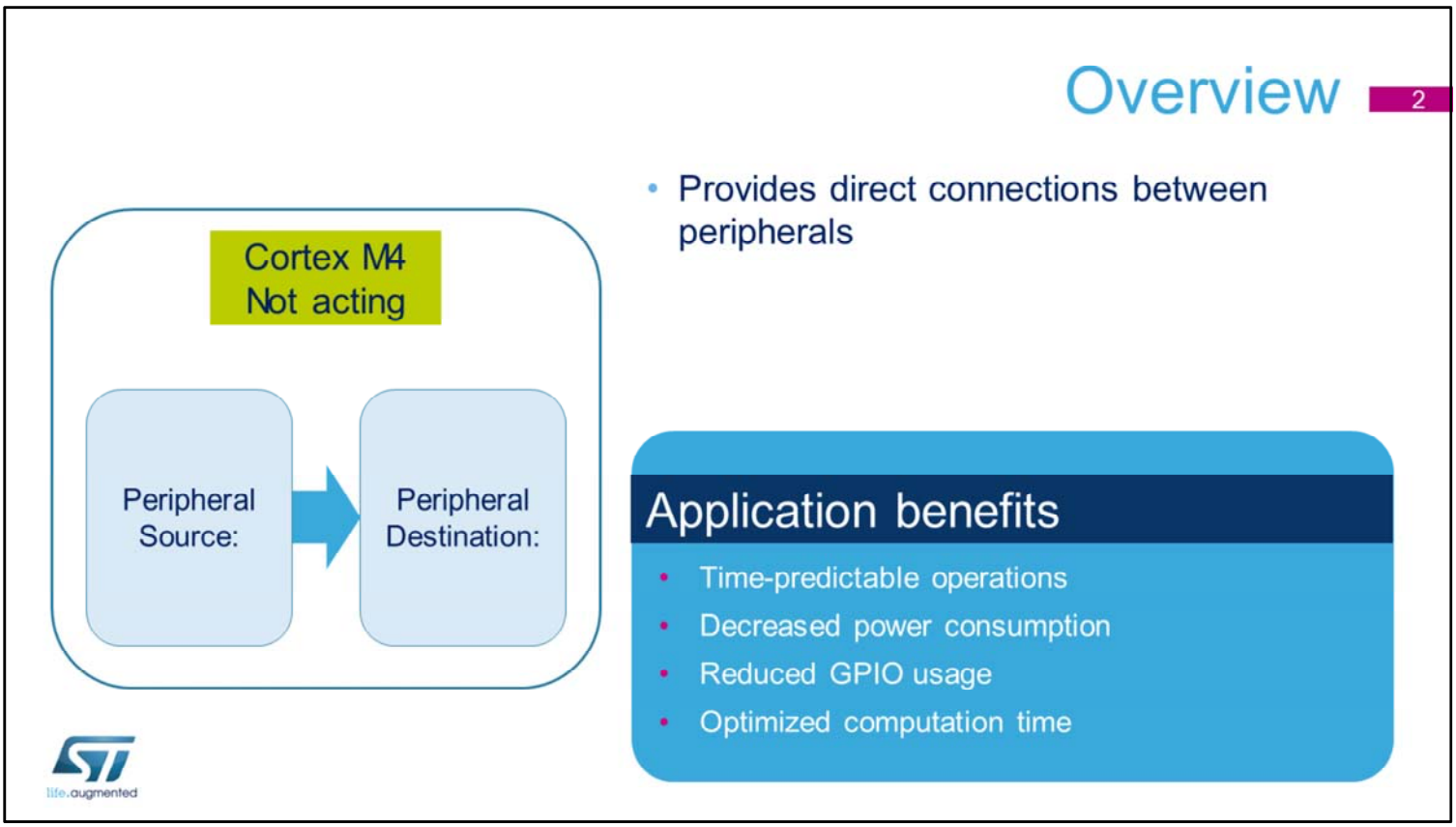
Hello and welcome to this presentation of the STM32 Interconnect Matrix. It covers the main features of this matrix, which is widely used to connect various internal peripherals between each other.



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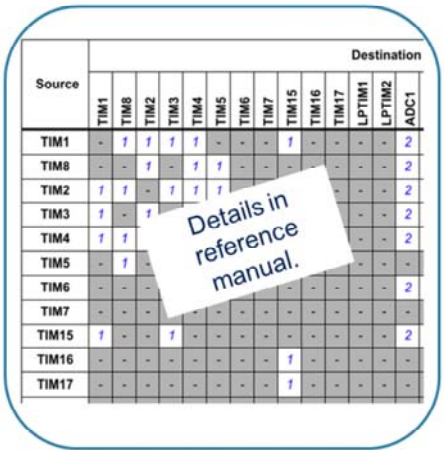
The Interconnect Matrix offers two main features. First, it ensures direct and autonomous connections between peripherals, allowing to remove latency in regards to software handling, thus saving GPIO and CPU resources.
Second, the interconnection between certain peripherals can even operate during low-power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

Sources and destinations

- Plenty of interconnect possibilities available

Source peripherals	
Interrupts	EXTI
Timers	TIM1-8, TIM15-17, TIM20, LPTIM, HRTIM
Analog IPs	ADC1-5, Temperature Sensor, VBAT, VREFINT, OPAMP1-6, DAC1-4, COMP1-7
Clocks	HSE, LSE, HSI16, LSI, MCO
RTC	Real-Time Clock and Tampers
SoC event	System error
Destination peripherals	
Timers	TIM1-5, TIM8, TIM15-17, TIM20, LPTIM, HRTIM
Connectivity IPs	IRTIM
Analog IPs	ADC1-5, DAC, OPAMP1-6, DAC1-4, COMP1-7



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This slide indicates the list of source and destination peripherals.
Source peripherals are the EXTI, the timers, analog IPs, clocks, RTC and System Error.
Destination peripherals are the timers, Infrared Interface, and analog IPs
The interconnect matrix is further described in the STM32G4 Reference Manual.

Application examples

From	To	Purpose
TIM1-8, TIM15-17, TIM20, LPTIM1, HRTIM	TIM1-5, TIM8, TIM15-17, TIM20	Some of the 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.
TIM7, TIM16, TIM17	HRTIM	The HRTIM burst operation, and update, can be triggered by on chip event coming from a general purpose timer.
TIM1-4, TIM6-8, TIM15-16, TIM20, HRTIM, LPTIM, and EXTI	ADC	Timers and EXTI can be used to generate an ADC triggering event.
ADC	TIM1, TIM3, TIM20, HRTIM	ADC Analog watchdogs are connected to timers for digital power applications (cycle-by-cycle current regulation with ADC)
TIM1-4, TIM6-8,1 TIM5, HRTIM, EXTI	DAC	Timers and EXTI can trigger a DAC conversion.
HSE, LSE, LSI, HSI16, MCO, RTC	TIM2, TIM14, TIM16 and TIM17	External clocks (HSE, LSE), internal clocks (LSI, HSI16), Microcontroller Output Clock (MCO), GPIO and RTC wakeup interrupt can be used as input to timers. This allows to calibrate the HSI16 and precisely measure the LSI oscillator frequency.

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This slide and the two next ones 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 the transition to burst mode and also the configuration update of the HRTIM through a general-purpose 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.

Application examples

From	To	Purpose
RTC, COMP1-7	LPTIM	RTC alarm A/B, RTC_TAMP1/2/3 input detection, comparators output can be used as trigger to start LPTIM counter.
TIM1-4, TIM8, TIM15, TIM20	COMP1-7	Timers can be used as blanking window input to comparators.
Internal analog sources (Temperature Sensor, VREFINT, VBAT), ADC input channels, OPAMP1-5 output and DAC outputs	ADC1-5, COMP1-7, OPAMP1-6	Analog interconnect: ➢ Internal temperature sensor output voltage, internal reference voltage VREFINT, VBAT monitoring channel, ADC input channels and the output of OPAMP and DAC are connected to ADC, COMP, and OPAMP input channels.
COMP1-7	TIM1-5, TIM8, TIM20, HRTIM	Comparators output values can be connected to TIMx input capture, trigger and OCxREF clear signal Comparators output values can also generate break input signals for timers. Comparators output values can be connected to HRTIM external events and fault inputs.

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Other use cases:

- Starting low-power timers from an RTC alarm, a tamper event or comparator event,
- Implementing blanking windows in COMP modules,
- Connecting internal analog channels to ADC, COMP and OPAMP units,
- Using the COMP outputs as timer external triggers or break inputs.

Application examples

From	To	Purpose
System errors	TIM1, TIM8, TIM15-17, TIM20, HRTIM	TIM1/TIM8/TIM15-17/TIM20 break inputs and HRTIM system fault input gather MCU internal fault events coming from: ➢ The clock failure event generated by the clock security system (CSS) ➢ The PVD output ➢ The SRAM parity error signal ➢ The Cortex-M4 LOCKUP (Hardfault) output ➢ Flash ECC double error detection. The purpose of the break function is to protect power switches driven by PWM signals generated by the timers.
TIM16, TIM17	IRTIM	General-purpose timer (TIM16/TIM17) output channel TIMx_OC are used to generate the waveform of infrared signal output

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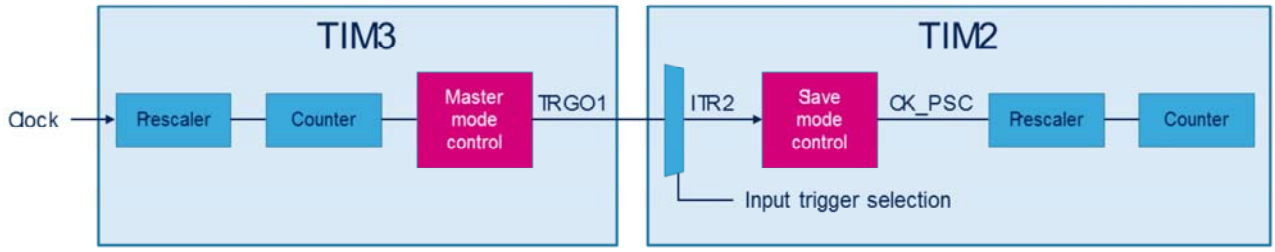
Other use cases:

- 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.

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
TIM1-8, TIM15-17, TIM20, LPTIM1, HRTIM	TIM1-5, TIM8, TIM15-17, TIM20	✓	✓	✓	✓		
TIM7, TIM16, TIM17	HRTIM	✓	✓	✓	✓		
TIM1-4, TIM6-8, TIM15-16, TIM20, HRTIM, LPTIM, and EXTI	ADC	✓	✓	✓	✓		
ADC	TIM1, TIM3, TIM20, HRTIM	✓	✓	✓	✓		
TIM1-4, TIM6-8,1 TIM5, HRTIM, EXTI	DAC	✓	✓	✓	✓		
HSE, LSE, LSI, HSI16, MCO, RTC	TIM2, TIM14, TIM16, and TIM17	✓	✓	✓	✓		
TIM1, TIM2, TIM3, and TIM15	TIM2, TIM14, TIM16, and TIM17	✓	✓	✓	✓		
RTC, COMP1-7	LPTIM	✓	✓	✓	✓	✓	✓
TIM1-4, TIM8, TIM15, TIM20	COMP1-7	✓	✓	✓	✓		
Internal analog sources (Temperature Sensor, VREFINT, VBAT), ADC input channels, OPAMP1-5 output and DAC outputs	ADC1-5, COMP1-7, OPAMP1-6	✓	✓	✓	✓		
COMP1-7	TIM1-5, TIM8, TIM20, HRTIM	✓	✓	✓	✓		
System errors	TIM1, TIM8, TIM15-17, TIM20, HRTIM	✓	✓	✓	✓		
TIM16, TIM17	IRTIM						

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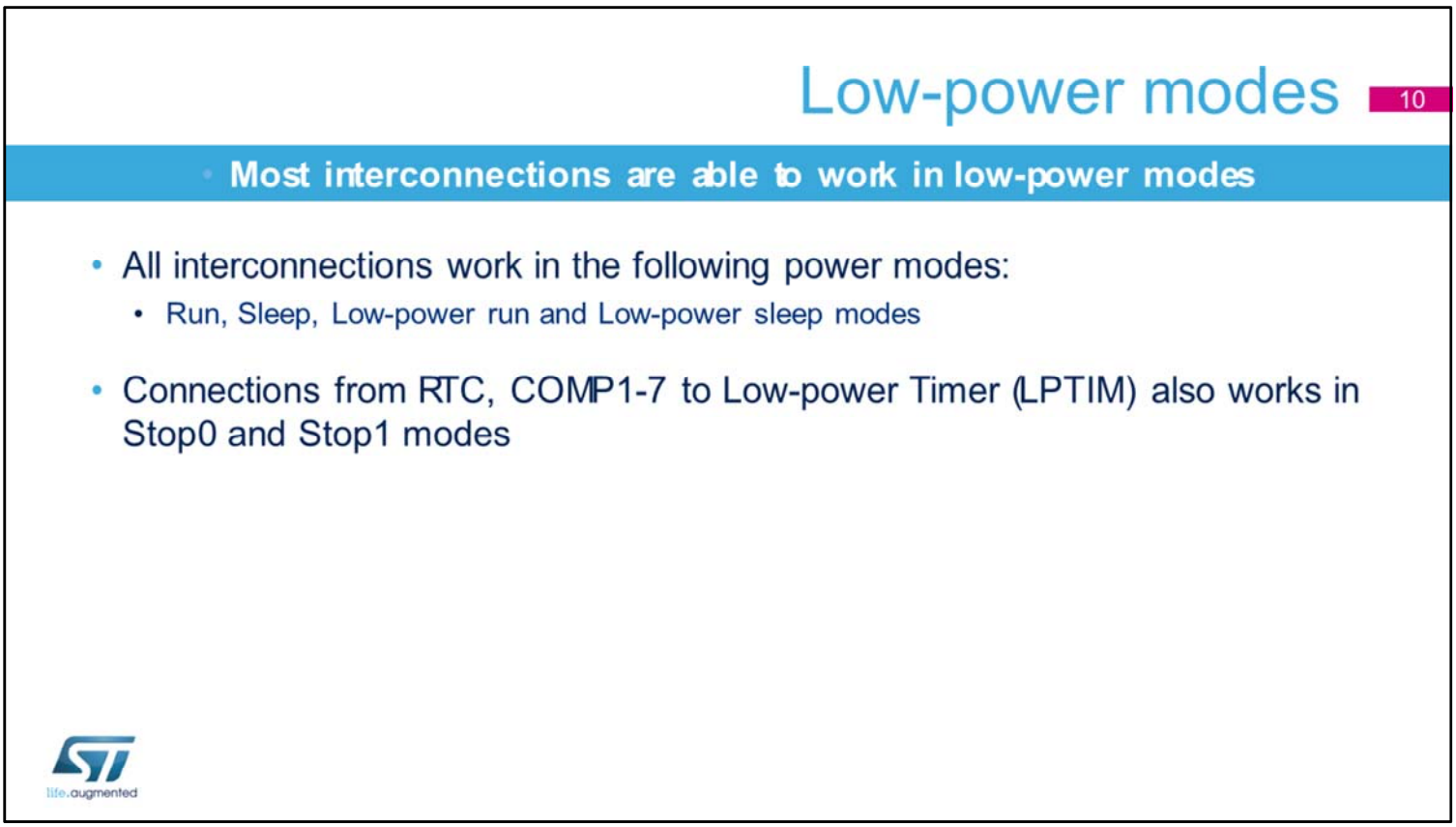
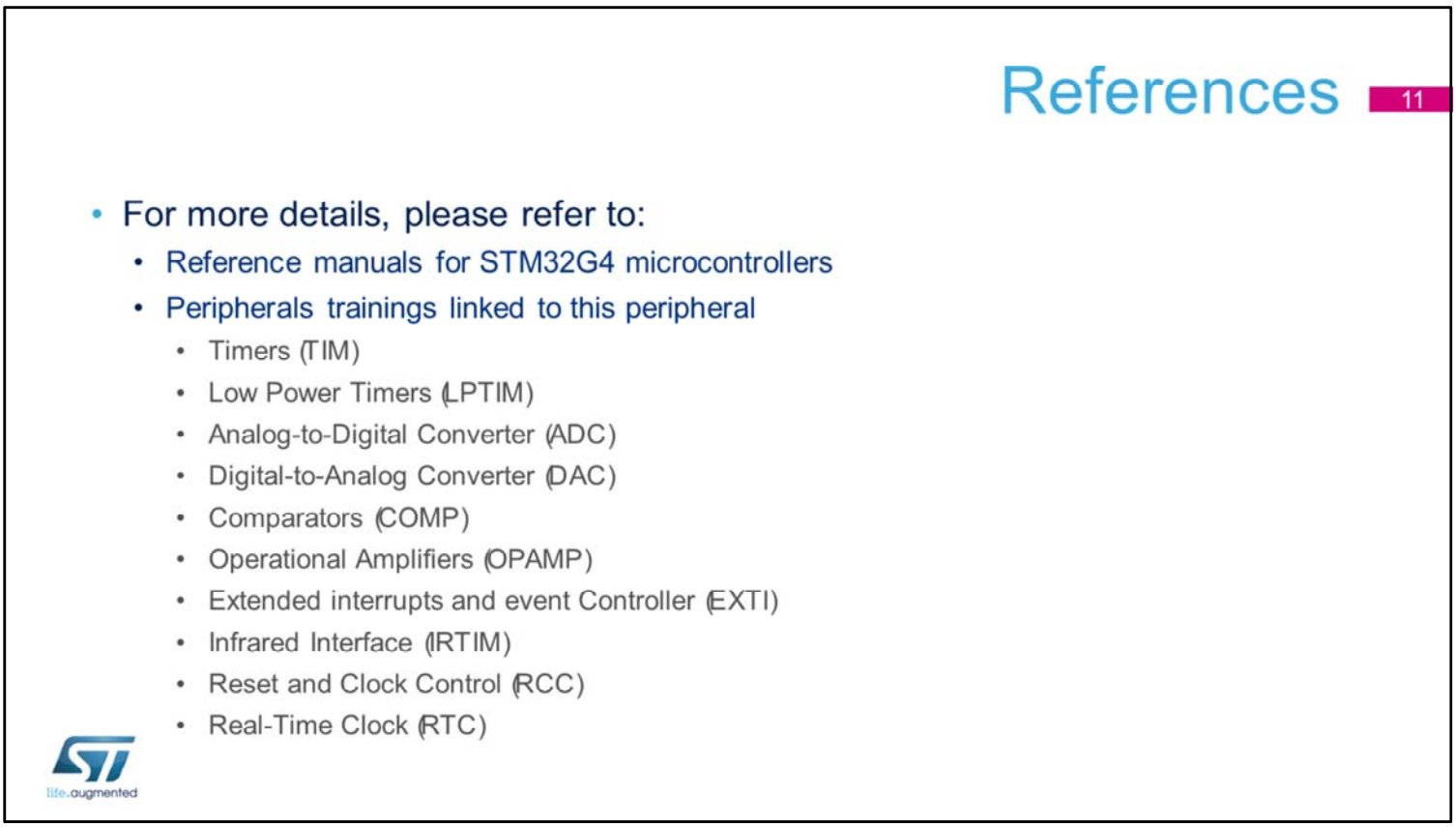
Peripherals can be interconnected using the Interconnect Matrix even when the circuit is in a low-power mode. This table indicates in which low-power modes, the interconnection between peripherals remains active.



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.



For more details about the Interconnect Matrix, refer to the reference manual for STM32G4 microcontrollers. Refer also to these trainings for more information if needed:

- Timers
- Low-Power Timers
- Analog-to-Digital Converter
- Digital-to-Analog Converter
- Comparators
- Operational Amplifiers
- Extended interrupts and event Controller
- Infrared Interface
- Reset and Clock Control
- Real-Time Clock