

A network diagram consisting of several interconnected nodes (colored red, orange, purple, white) connected by thin lines, set against a teal background with a pattern of various mobile-related icons like smartphones, Wi-Fi signals, and SMS messages.

A New MIPI RFFE for the Emerging 5G Era

Jim Ross, RFFE WG Chair
Vic Wilkerson, RFFE WG Vice Chair
Lalan Mishra, RFFE WG Vice Chair

2 June 2020

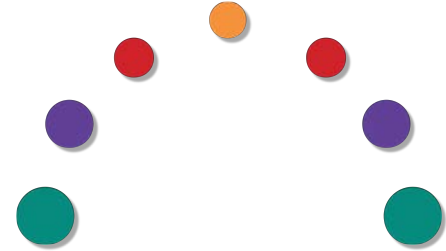
Webinar Agenda

About MIPI Alliance

- Peter Lefkin, Managing Director

A New MIPI RFFE for the Emerging 5G Era

- RFFE Background and History
- Challenges with 5G and Need for RFFE v3.0
 - Additional Extended Triggers
 - Timed Triggers
 - Mappable Triggers
- Next Steps in RFFE — Call for Participation
- Q & A





About MIPI Alliance

Peter Lefkin
Managing Director, MIPI Alliance

2003

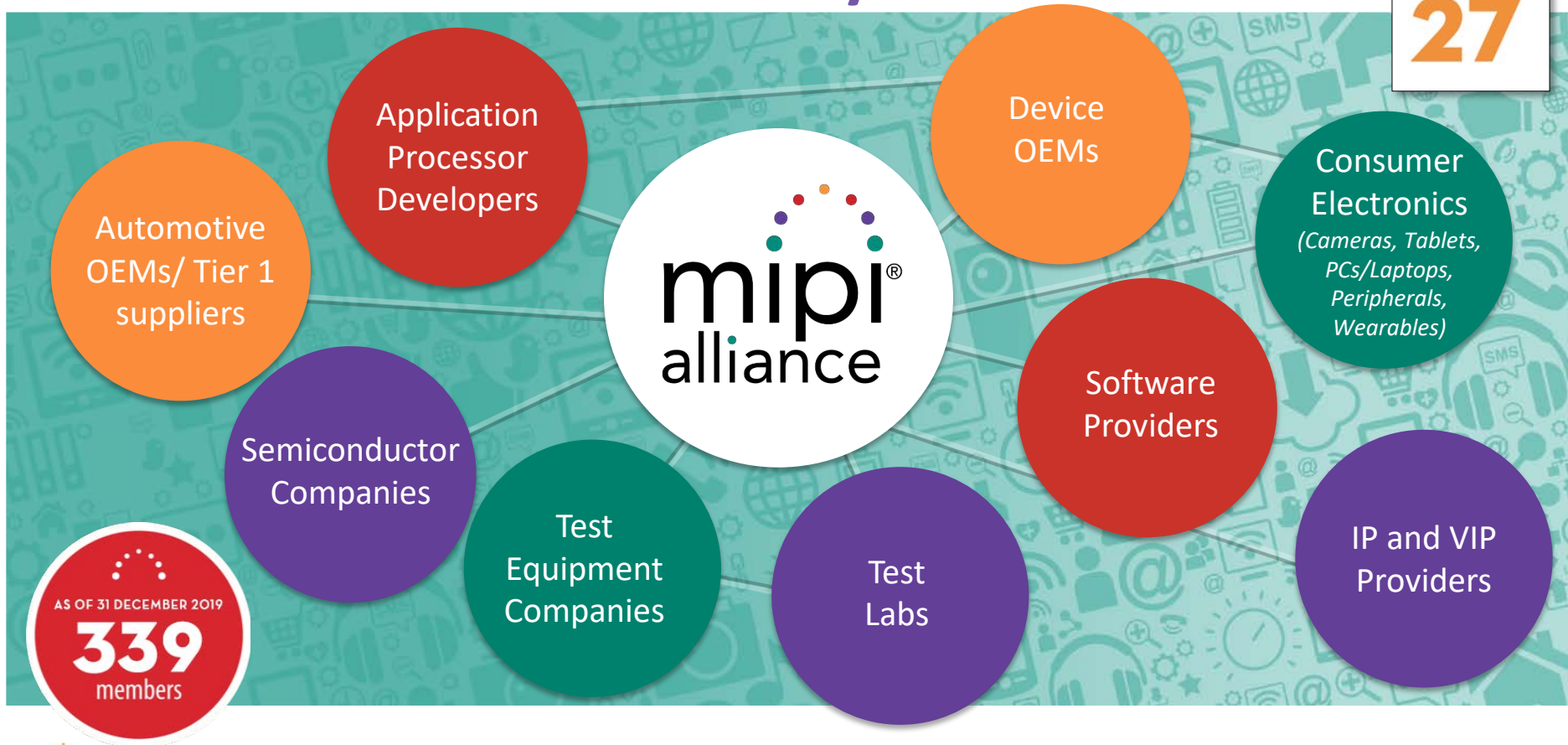
**MIPI ALLIANCE
FORMED TO
STANDARDIZE
CAMERA AND
DISPLAY
INTERFACES**



MIPI Alliance Member Ecosystem

Number of countries

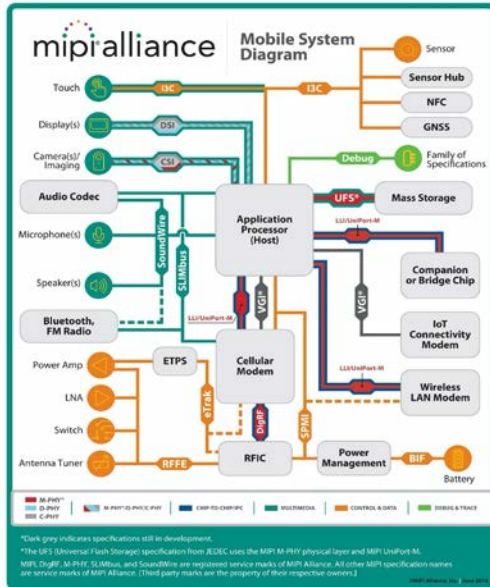
27



AS OF 31 DECEMBER 2019
339
members

MIPI Specifications Leveraged Beyond Mobile

Number of current specifications
48



Fundamentally, usage rights are granted to members royalty free for implementation of MIPI specifications from all MIPI members

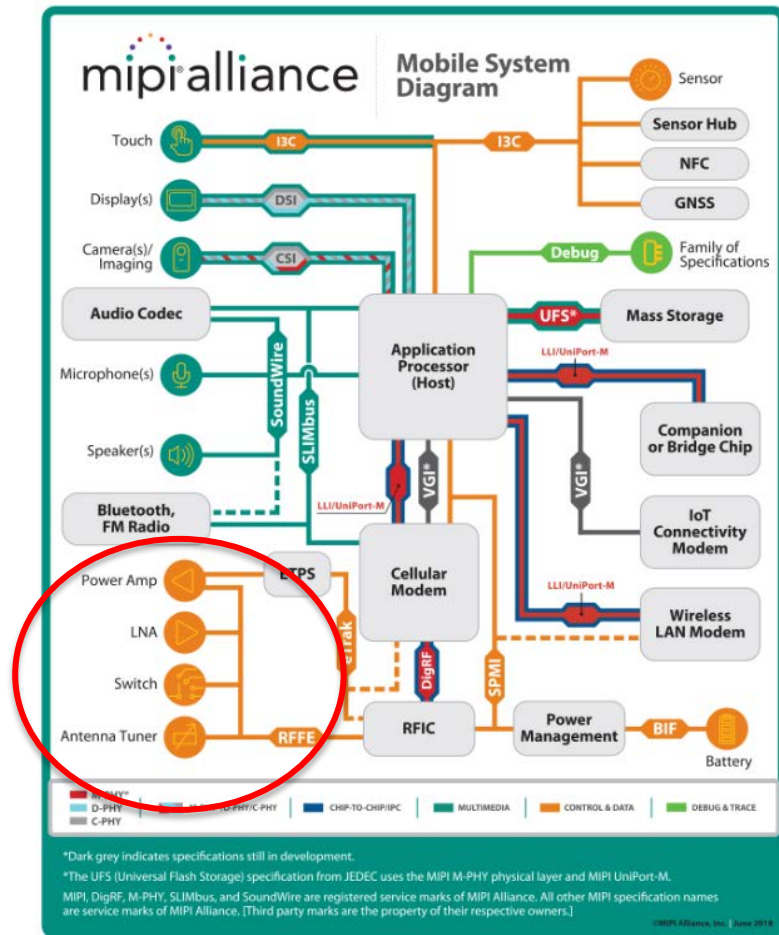


A New MIPI RFFE for the Emerging 5G Era

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RFFE Control Interface

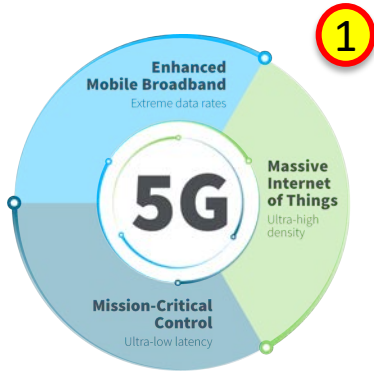
- RFFE has been the de facto standard for RF control for almost 10 years
- Multiple versions of the specification have adapted to ever-evolving 3GPP wireless standards
 - Backward compatibility
- RFFE pervades the Wireless Communication space
 - Cellular
 - IoT
 - Automotive
 - Etc. ...



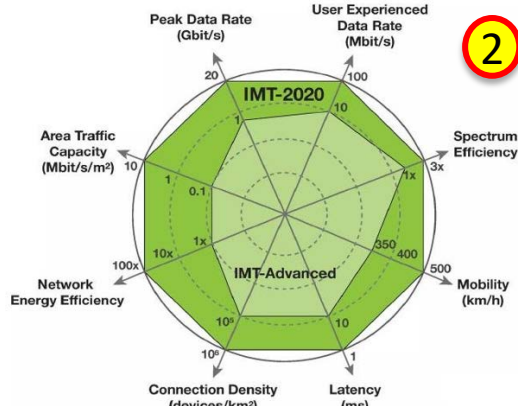
10 Years of RFFE Evolution

V1.0 Adopted July-2010	V1.1 Adopted Nov-2011	V2.0 Adopted Dec-2014	V2.1 Adopted April-2018	V3.0 Adopted April-2020
<ul style="list-style-type: none">• 1st release• 26-MHz• 3-Triggers	<ul style="list-style-type: none">• Bug Fixes• No major enhancements	<ul style="list-style-type: none">• Synchronous Read• Extended-Speed (52 MHz)• Multi-Master Support	<ul style="list-style-type: none">• Masked-Write• Master Context Transfer• Longer Reach• Extended Trigger• Master Context Transfer• Reserved Reg-Space Expansion	<ul style="list-style-type: none">• Additional Extended-Triggers• Timed-Triggers• Mapped-Triggers

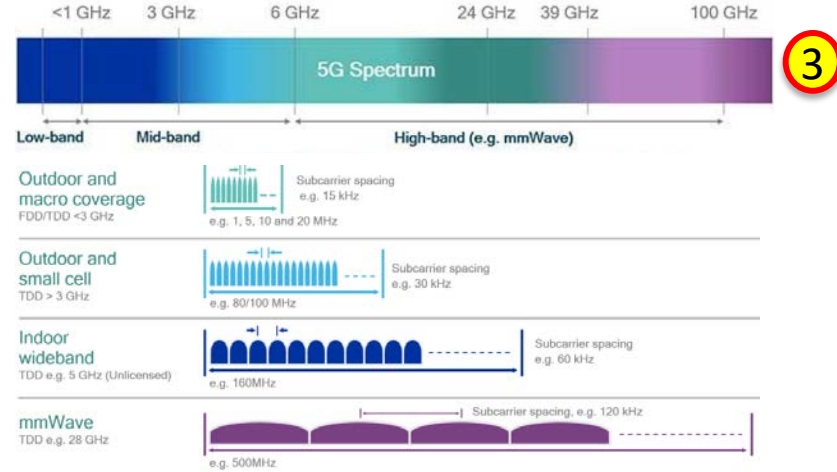
RFFE v3.0 Driven By 5G



The Core Vision of 5G ¹



5G KPI-Envelope Expansion ²



5G Spectrum and Subcarrier Spacing ³

- 5G evolution is stretching the Mobile-Wireless KPI-Envelope to new limits
- Higher-order MIMO and resource sharing offer new challenges
- From the RF-Front-End control PoV, Timing-Budget is shortening
- Shorter Firing-Timing and configuration flexibility of “Triggers” are essential to meet 5G operational requirements

¹ <https://www.itu.int/5g>
² https://www.researchgate.net/publication/351695956_5G_key_performance_indicators_Survey (ITL R-2020-0111, Rev. 1) 4/20/2020
³ <https://www.3gpp.org/technologies/5g/5g-technologies/5g-technologies-3gpp-2020-0111>
⁴ <https://www.3gpp.org/technologies/5g/5g-technologies/5g-technologies-3gpp-2020-0111>

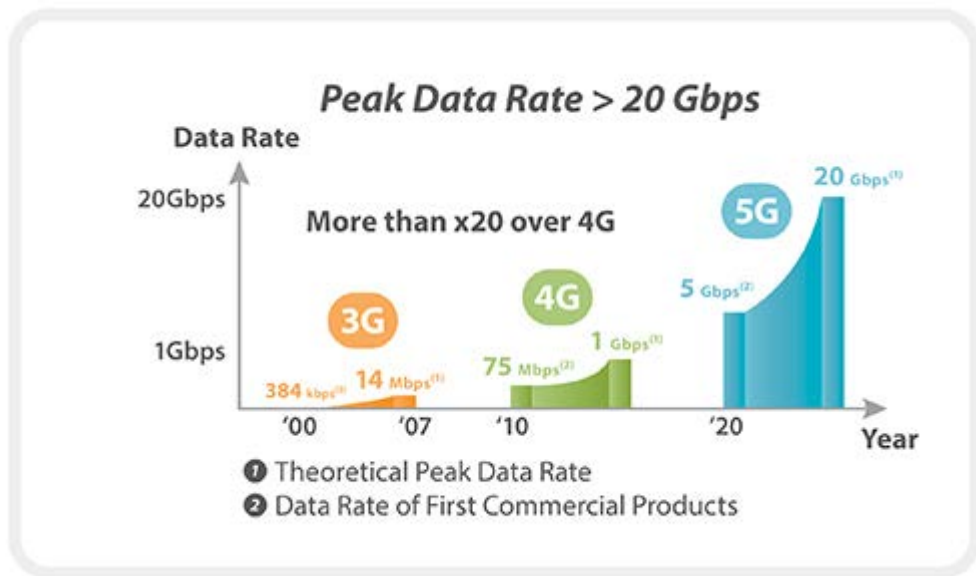
4

μ	SCS (kHz)	T_U (μ s)	Type CP	T_{CP} (μ s)	Slot (μ s)	Slots
0	15	66.66	Normal	5.21/4.69	1000	1
1	30	33.33	Normal	2.60/2.34	500	2
2	60	16.66	Normal	1.30/1.17	250	4
			Extended	4.16	250	4
3	120	8.33	Normal	0.65/0.59	125	8
4	240	4.17	Normal	0.33/0.29	62.5	16

5G Numerology and Critical Timings ⁴

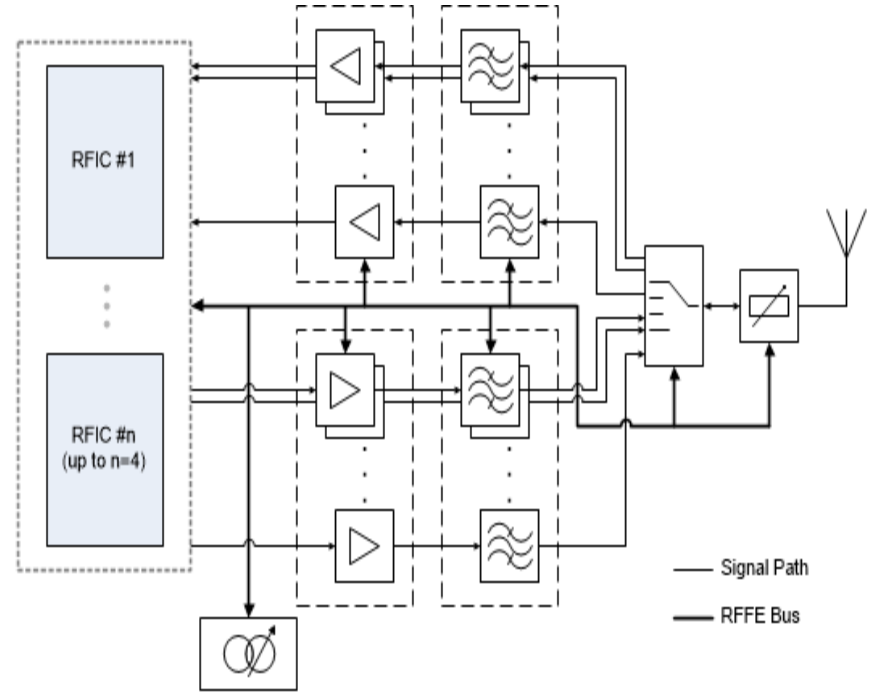
RFFE v3.0

- The data rates of 5G complicates the RF control in a number of different areas
 - Increased number of available bands
 - Decrease symbol/slot interval for reduced latency
 - Carrier Aggregation combinations
- RFFE v3.0 addresses the critical time requirements as a result of 5G
 - ~20x timing precision improvement



RFFE v3.0 Timing Precision

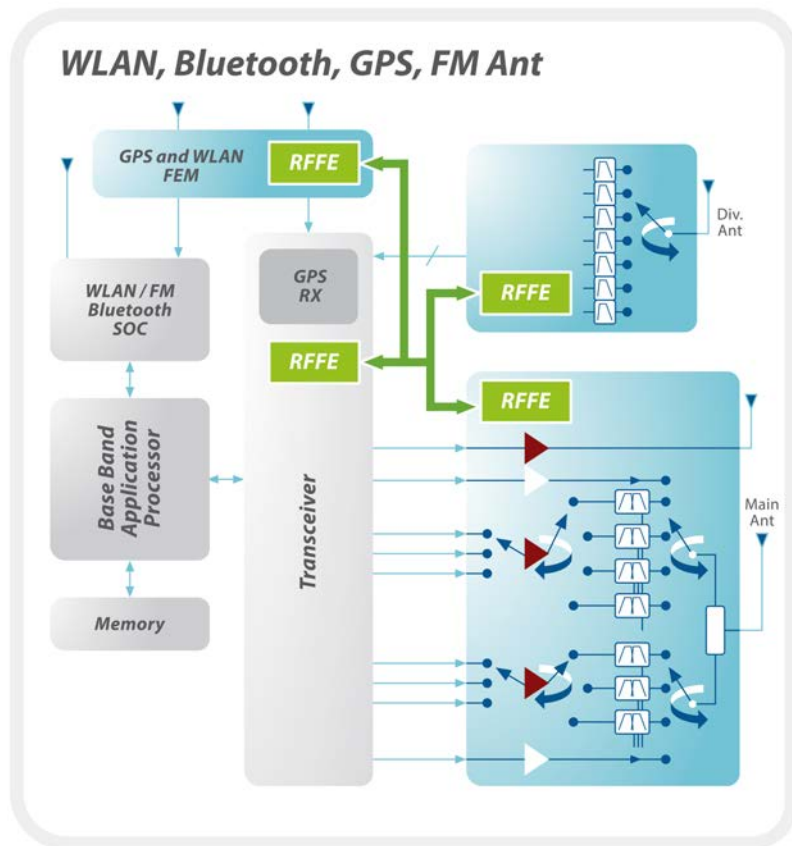
- Timing precision is key in the RF Front End Control.
- RFFE v3.0's focus is increasing timing precision across the RF devices. This is accomplished by enhancing and adding additional triggering features to the specification.
 - These enhancements make it possible for a single/multiple Master(s) to control up to 15 Slave devices and multiple registers/functions within a single device simultaneously.



5G And New Requirements

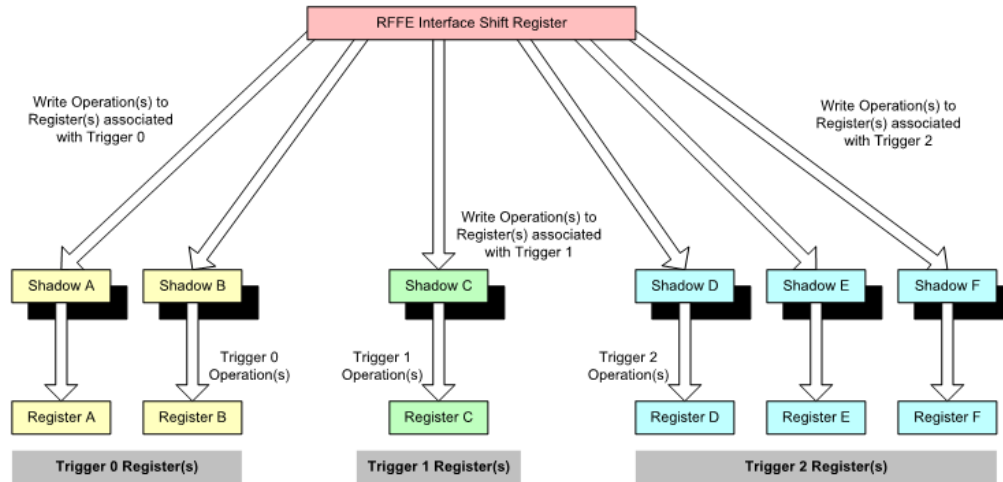
In addition to Timing precision for RF Front End Control, evolving use cases also demand:

- **Additional Triggers**
 - **Solution:** Extended-Triggers
- **Narrow Timing Budget**
 - **Solution:** Timed Triggers
- **Dynamic Mapping of Triggers**
 - **Solution:** Mappable Triggers

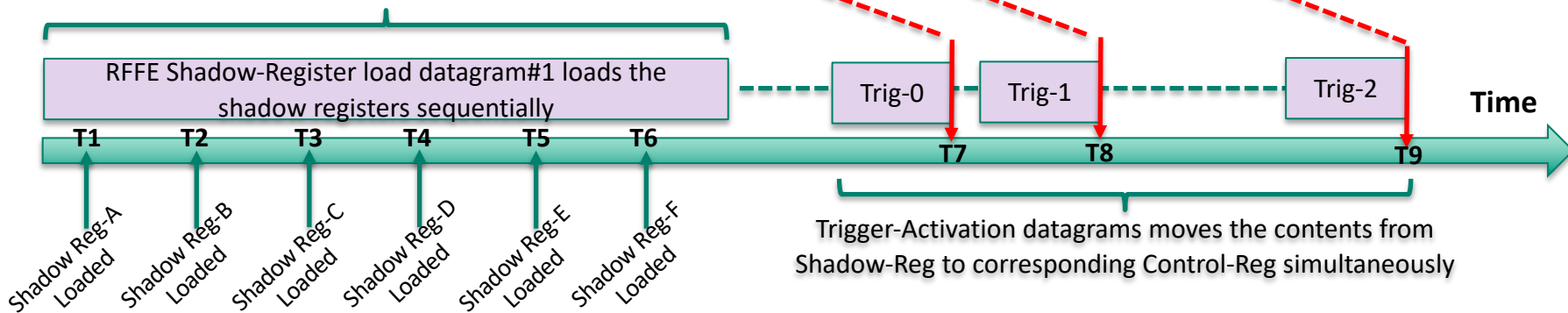
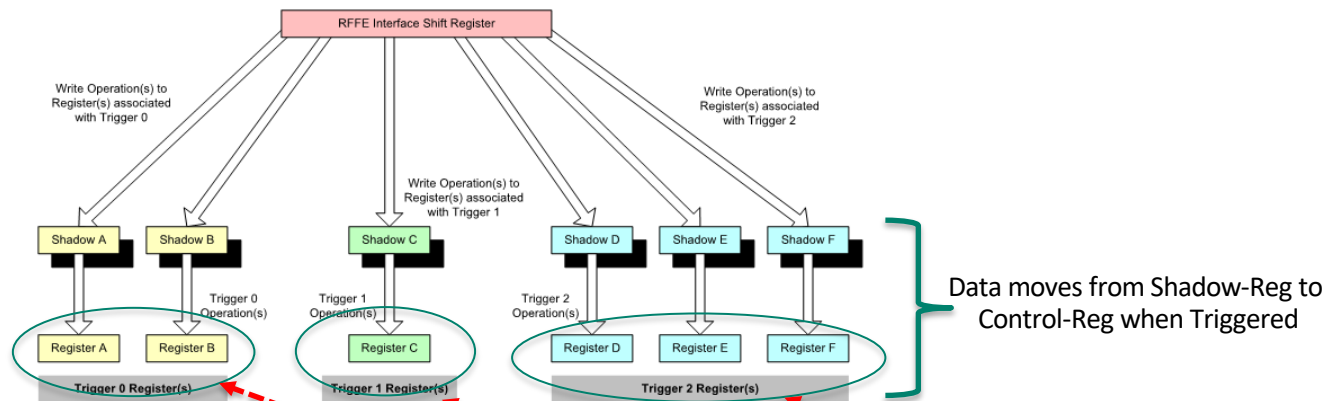


RFFE v3.0 Triggering Evolution in RFFE

- Simultaneously triggering in RFFE has been key feature since the first specification release v1.0
 - Standard Triggers includes 3 predefined triggers (0, 1, and 2)
 - Triggers are used to synchronize multiple registers/controls within a device
 - Triggers are used via Broadcast and Group Command Sequence to also synchronize across multiple devices



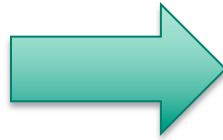
Basics of RFFE Trigger Operation



RFFE v3.0 Triggering Evolution in RFFE

- In v2.1 of the specification the addition of Extended Triggers was introduced
 - This was due to the increased requirements of 4G LTE
 - 4G LTE Data requirements
 - MIMO
 - LNA positioning in the RF Front End

v1.0
3 Triggers



v2.1
11 Triggers

RFFE v3.0 Triggering Evolution in RFFE

- v3.0 of the specification further expands the triggering capabilities
 - An Additional 7 Triggers to a total of 18 pre-defined Triggers
 - Standard Triggers (0, 1, and 2)
 - Block A Triggers (Extended Trigger 3 to 10)
 - Block B Triggers (Extended Trigger 11 to 17)
 - Timed Triggers
 - Mappable Triggers



Trigger Evolution in RFFE

RFFE v1.0
(Total: 3 Triggers)

RFFE v2.1 (Total: 11 Triggers)

RFFE v3.0 (Total: 18 Triggers)

Trig 0	Trig 1	Trig 2
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Trig 3	Trig 4	Trig 5	Trig 6	Trig 7	Trig 8	Trig 9	Trig 10
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Trig 11	Trig 12	Trig 13	Trig 14	Trig 15	Trig 16	Trig 17
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Nomenclature

RFFE 2.1 → *Extended-Triggers*

RFFE 3.0 → *Extended-Triggers “Block-A”*

RFFE 3.0 → *Extended-Triggers “Block-B”*

Implementation Options

Timed-Trigger Feature Supported

Timed-Trigger Feature Supported

Mapped-Trigger Feature Supported

Mapped-Trigger Feature Supported

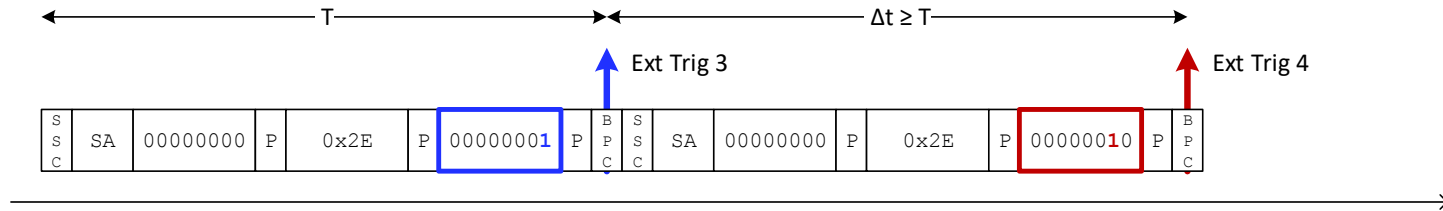


RFFE v3.0 Timed Triggers

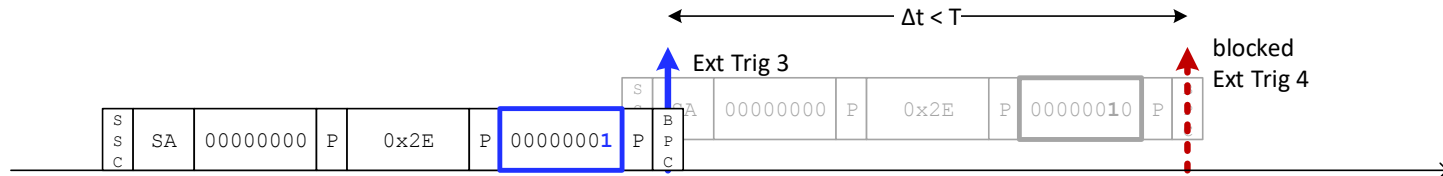
RFFE v3.0 Timed Triggers

- Before the Introduction of Timed Triggers the smallest delta of time between adjacent firing of trigger was limited by the length of the Command Sequence

Use Case 1: Time between adjacent Triggers $\Delta t = T$

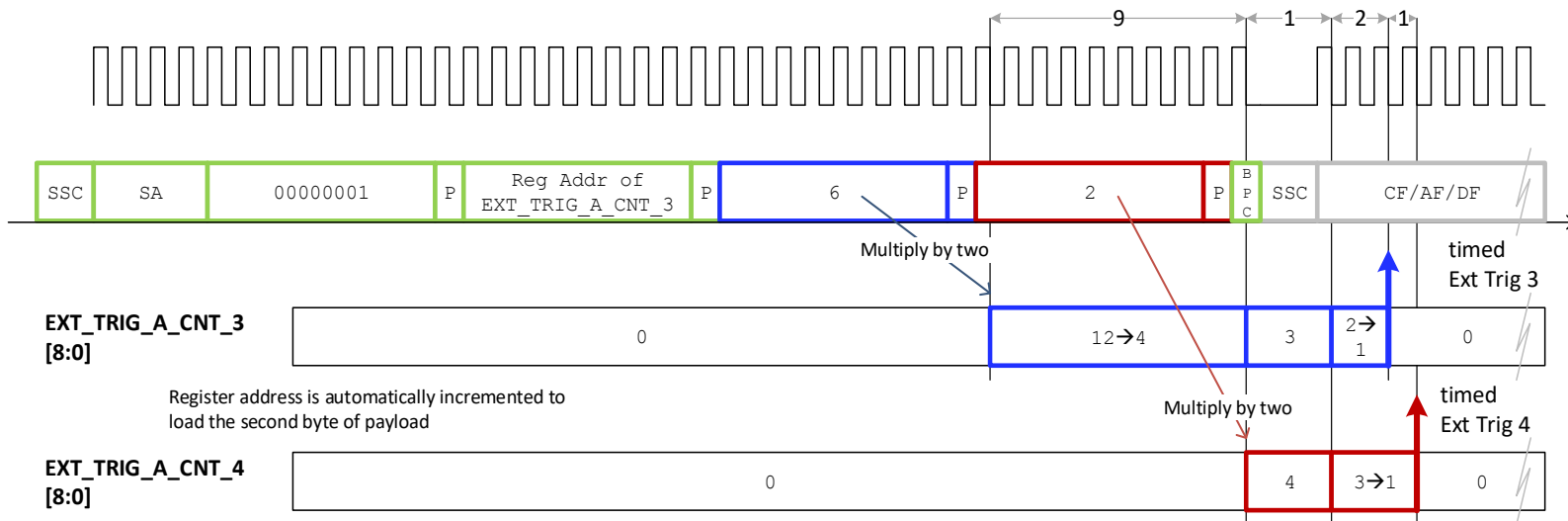


Use Case 2: Time between adjacent Triggers $\Delta t < T$

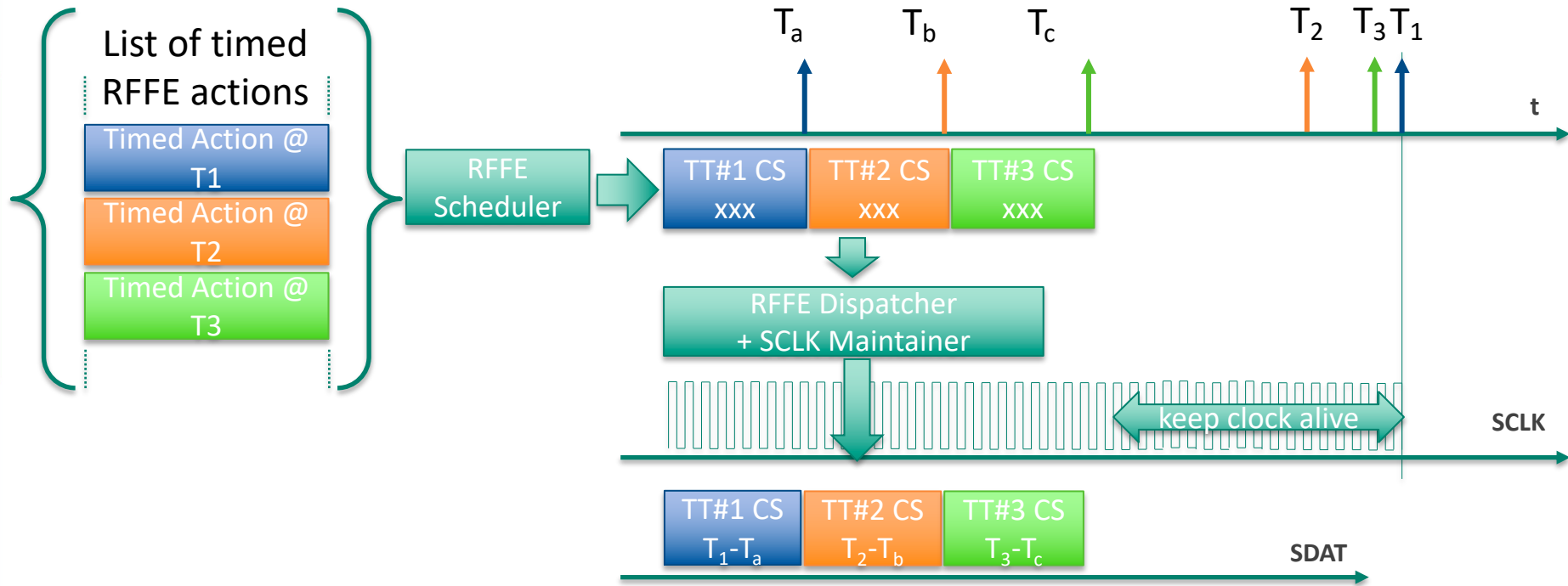


RFFE v3.0 Timed Triggers

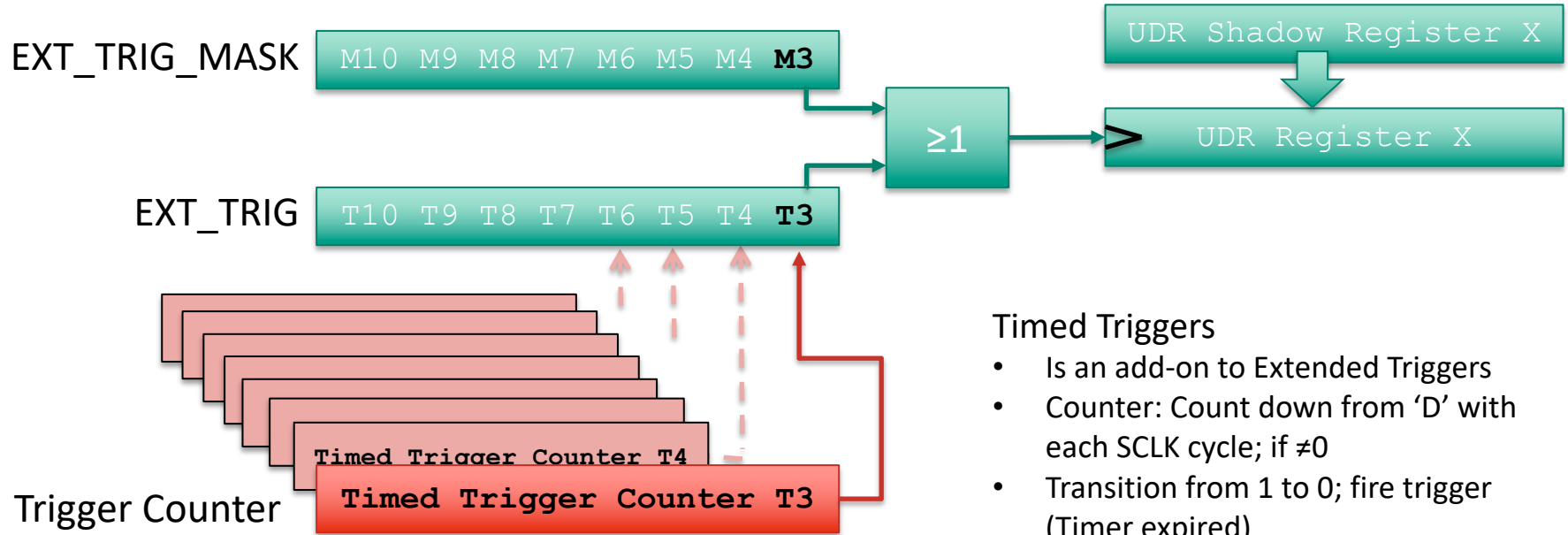
- Timed Triggers give the ability to fire adjacent Triggers within the resolution of SCLK cycles vs Command Sequences; useful for LTE/NR inter-band UL CA



RFFE v3.0 – Timing Precision Improvement



Adding Timed Triggers to RFFE Client Controller



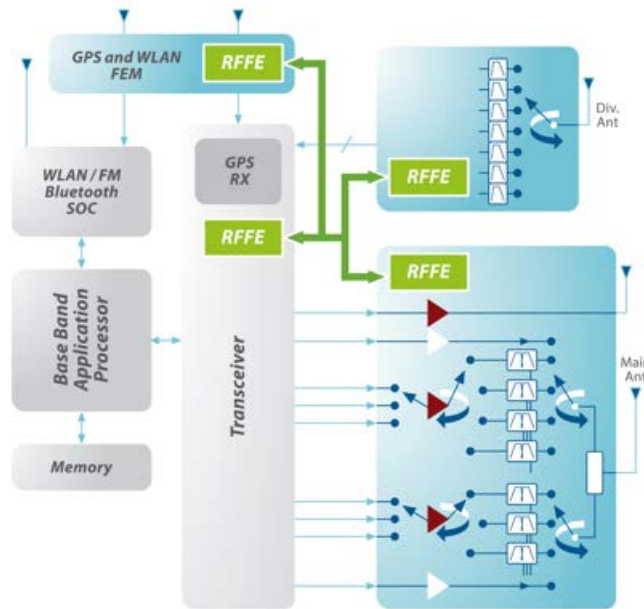
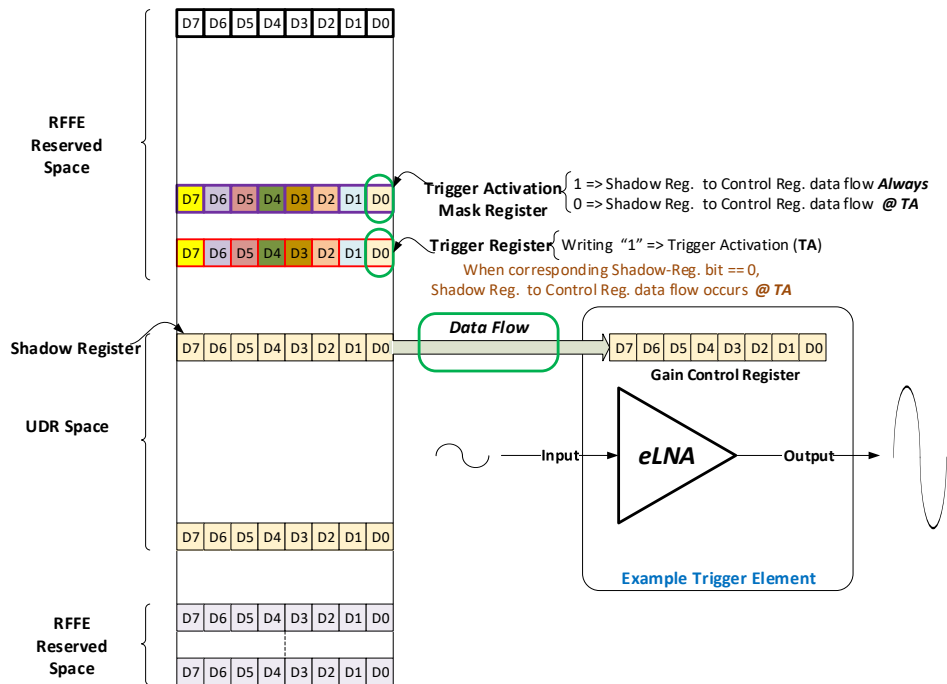
Timed Triggers

- Is an add-on to Extended Triggers
- Counter: Count down from 'D' with each SCLK cycle; if $\neq 0$
- Transition from 1 to 0; fire trigger (Timer expired)
- Counter must exist for each Trigger to be spaced discretely in time



RFFE v3.0 Mappable Triggers

RFFE v3.0 – Mappable Trigger



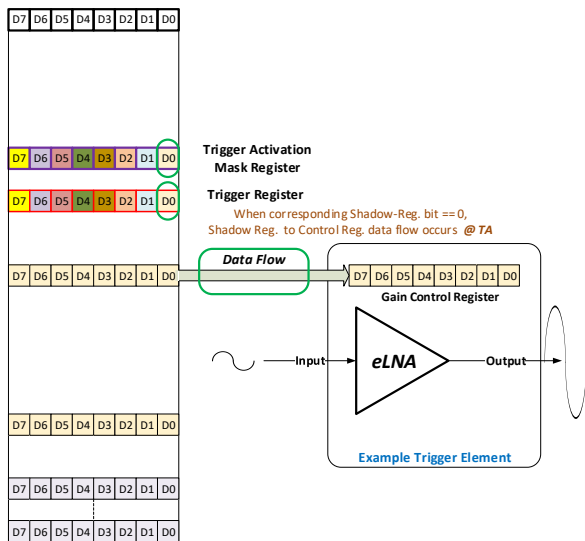
Complex 5G RF-Front-End demands dynamic Trigger-Association Configurability

RFFE v2.1 Trigger Association is "Hardened"

Mapped Trigger enables this dynamic Trigger-Association configurability

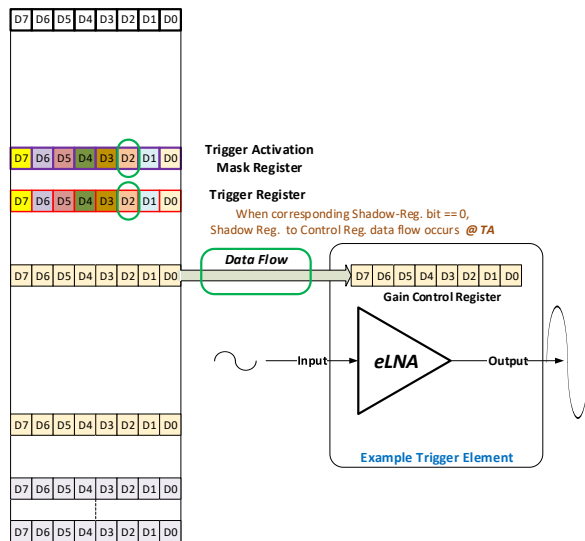
RFFE v3.0 – Mappable Trigger Illustrations

Examples Configuration-1



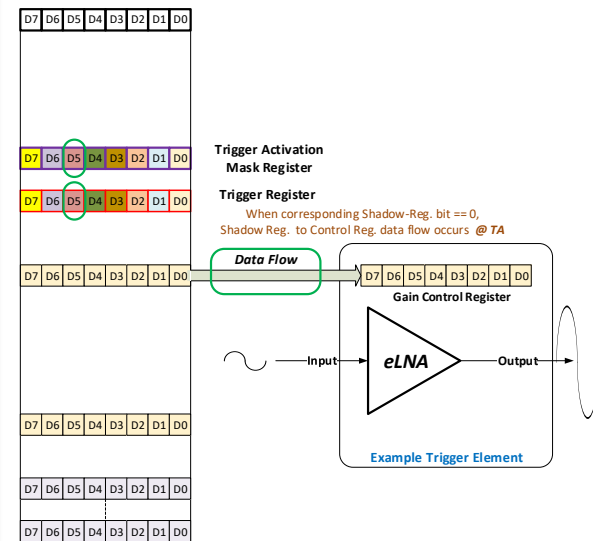
Assumed Trigger is Associated with **D0 bits** of Trigger and Mask Registers

Examples Configuration-2



Assumed Trigger is Associated with **D2 bits** of Trigger and Mask Registers

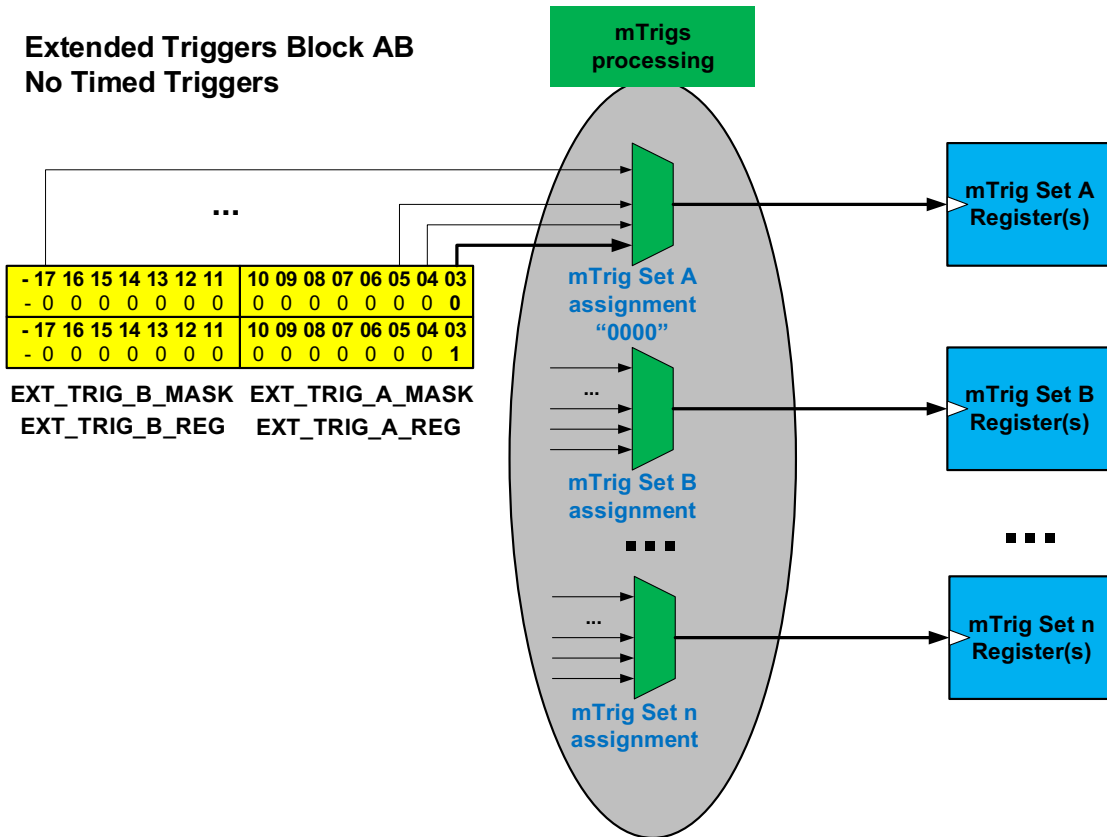
Examples Configuration-3



Assumed Trigger is Associated with **D5 bits** of Trigger and Mask Registers

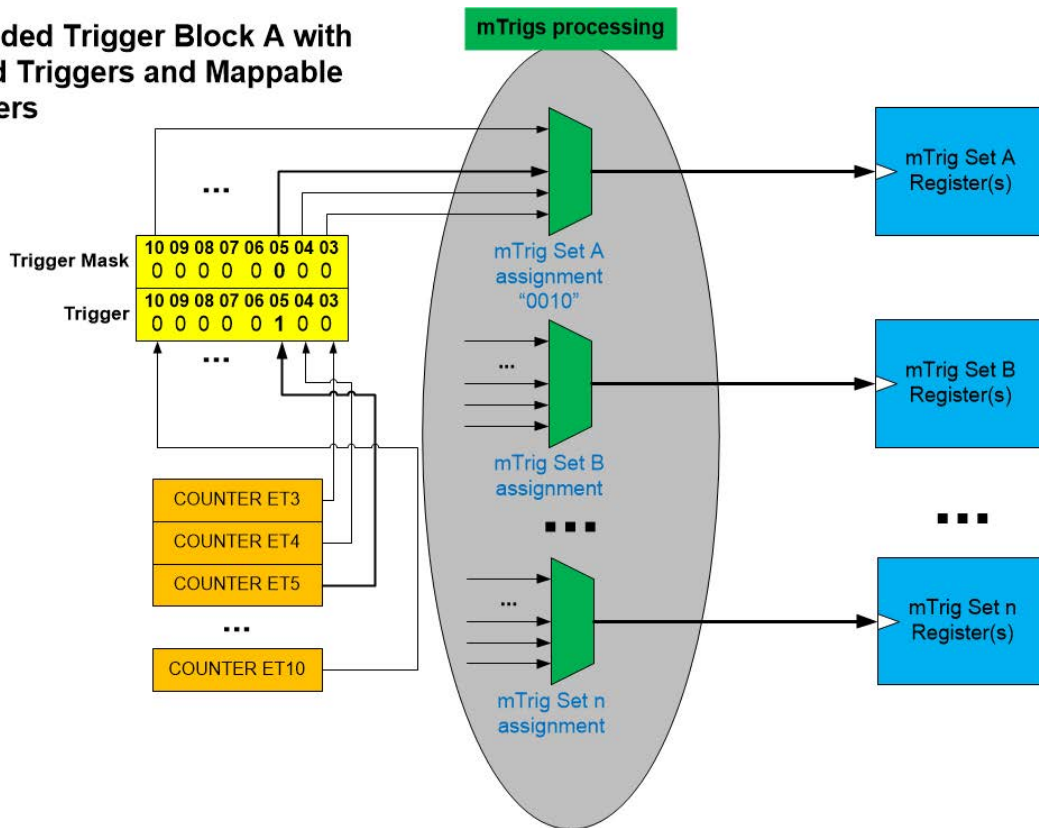
Notice that the association of Shadow-Register to Trigger-Element's Control-Register does not change

RFFE v3.0 – Key New Features

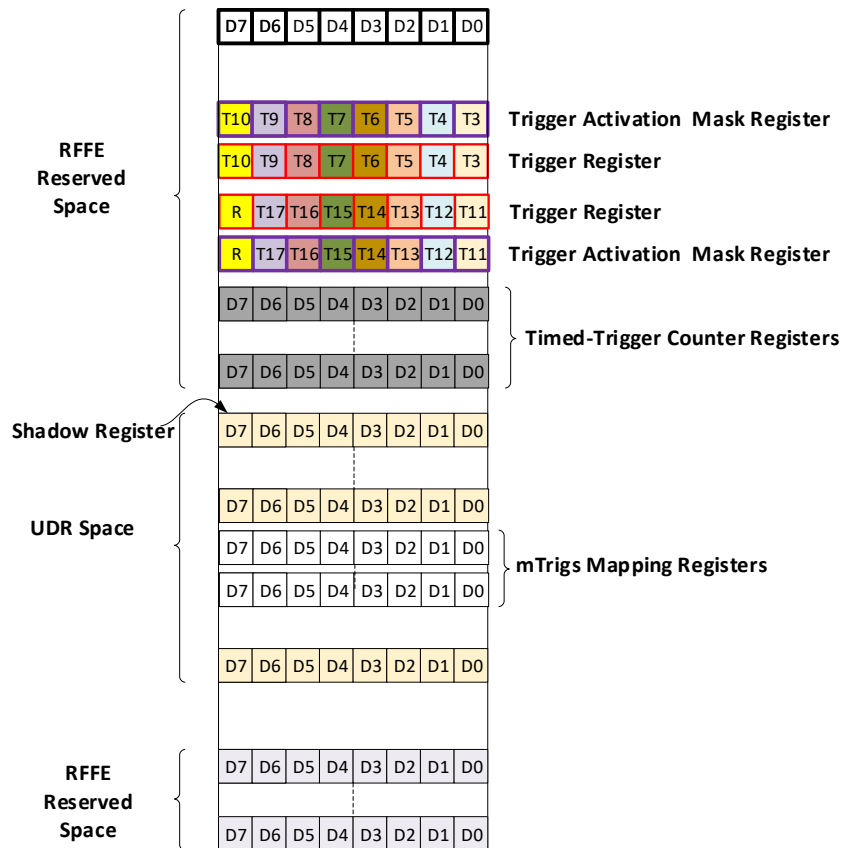


RFFE v3.0 – Key New Features

Extended Trigger Block A with
Timed Triggers and Mappable
Triggers



RFFE v3.0 – Trigger Register Utilization



What's Next in RFFE

- The latest version of RFFE v3.0 was adopted in April 2020
- WG is also completing work on the supporting documents for v3.0, the Application Note and FAQ, which will be available later this month.
- The WG is currently discussing proposals for the next version of RFFE.
 - To address further 5G capabilities and possible 6G evolution
 - Also looking at the challenges FR2 (mmWave) brings with regard to RF Front-End Control, and ways that the RFFE Specification needs to adapt
 - RFFE is always looking for additional contributors and new ideas/proposals

Questions?

- Learn more at:
 - www.mipi.org
- For contributing members, to join RFFE go to:
 - <https://www.mipi.org/groups/rf-front-end>
- Q & A