GTM:
Using GTM-IP in Electric Vehicles

ME-IC/PRM-IP | March 15th, 2024

BOSCH

Using GTM-IP in Electric Vehicles

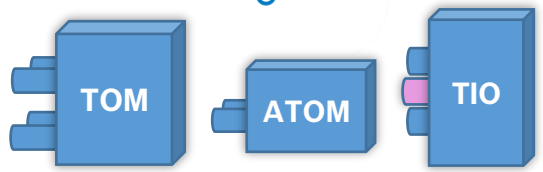
Agenda

1. PWM and PCM generation
2. PWM type overview
3. High resolution PWM support
4. Special cases of PWM generation
5. Multi channel synchronous PWM
6. Modify PWM with deadtime using DTM
7. Fast shut off functionality using DTM

01

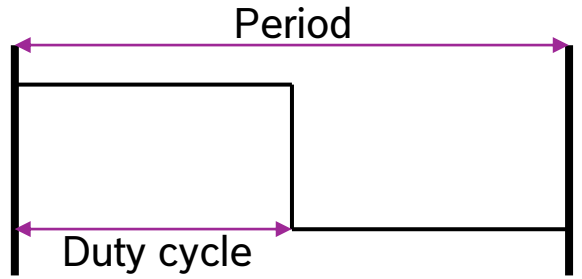
PWM and PCM generation

Using GTM-IP in Electric Vehicles
PWM generation with GTM

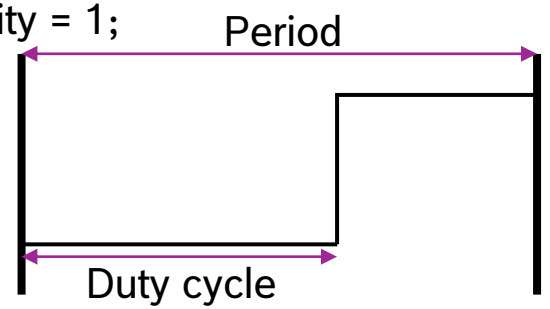


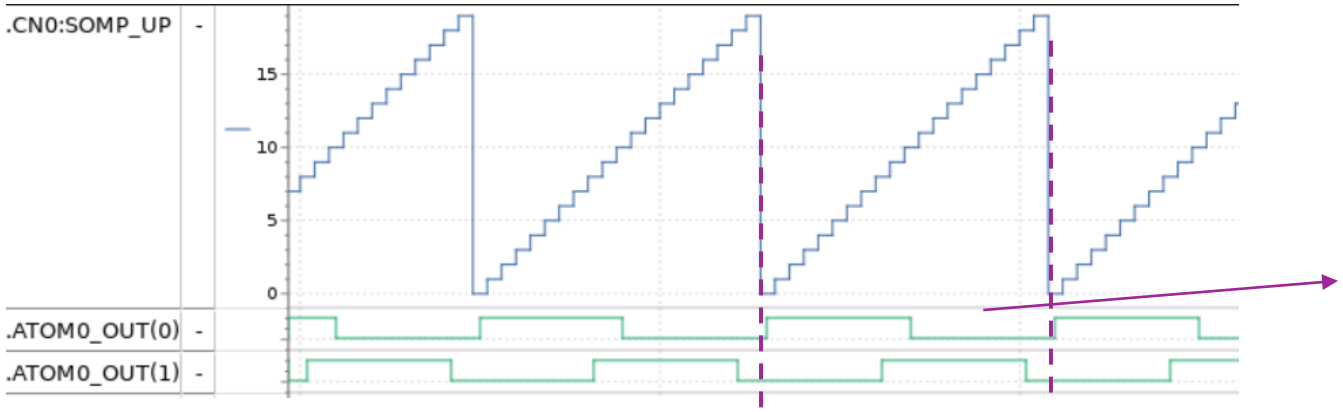
- Functionality
  - Single pulse with the length of duty cycle
  - After the end of the period, the pulse will be repeated
  - Waveform depends on period, duty cycle and polarity
- Applicable modules
  - TOM; ATOM; TIO
- Implementation example
  - Generate a PWM via configuring the period and duty cycle of the PWM
  - Generate a PWM via setting the position of the first edge and second edge of the PWM

Polarity = 0;



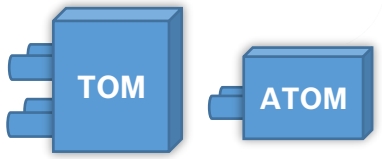
Polarity = 1;



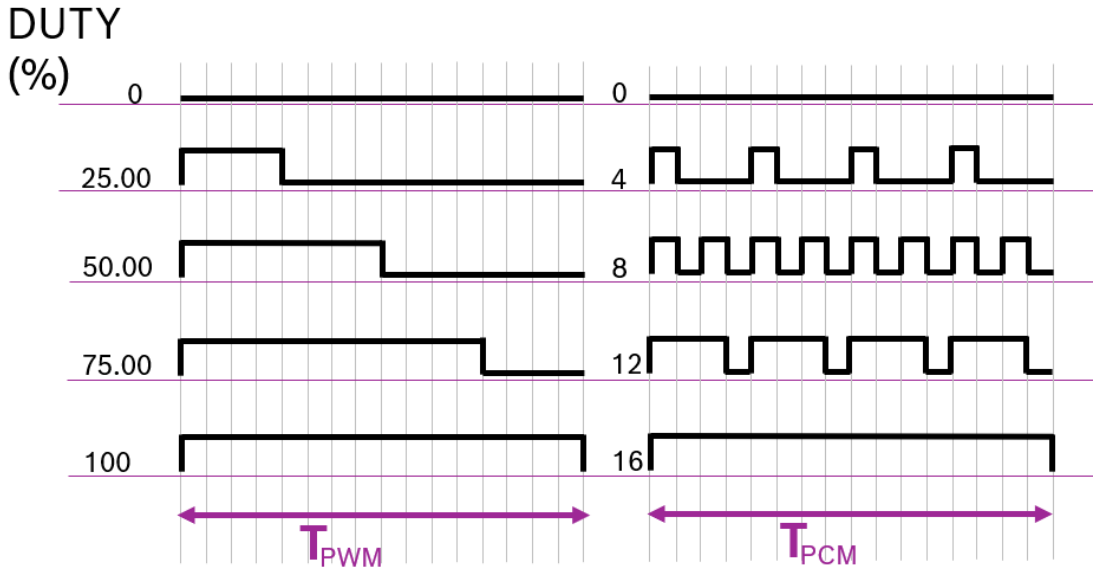


Two PWMs with different duty cycle and polarity

Using GTM-IP in Electric Vehicles
PCM as alternative to PWM



- Functionality
  - High pulses will be evenly spread in period time frame
  - Duty cycle is equal to the integration of high pulses
- Applicable modules
  - TOM channel 15; ATOM channels 1,3,5,7
- Implementation example
  - ATOM_CH1: Generate a PCM as alternative to PWM
  - ATOM_CH2: Generate a standard PWM

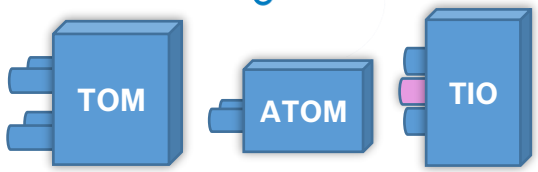


PWM and PCM with different duty cycles

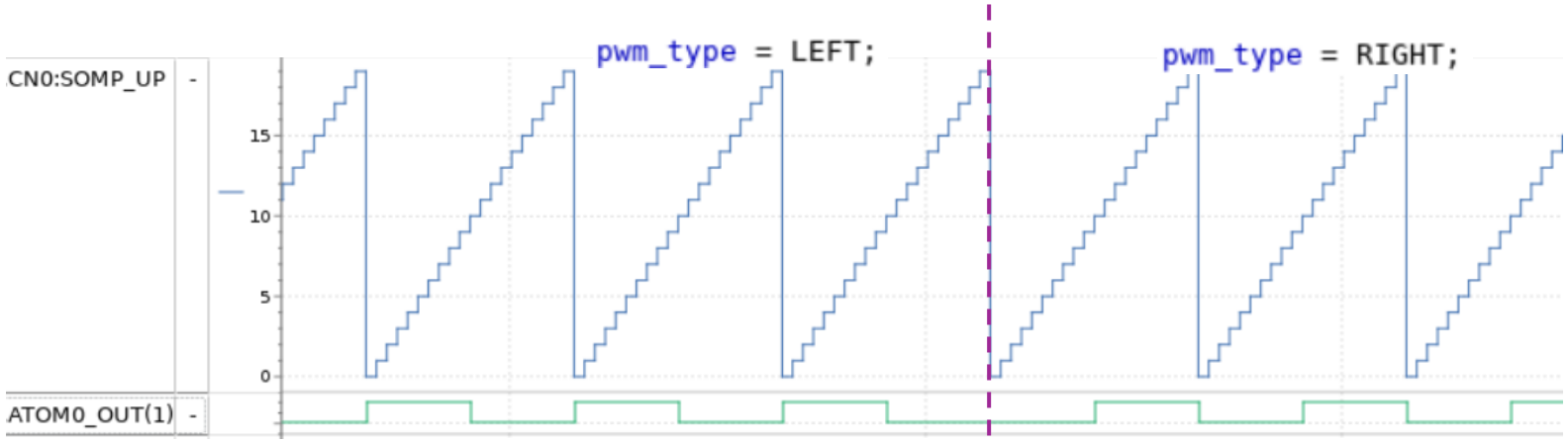
02

PWM type overview

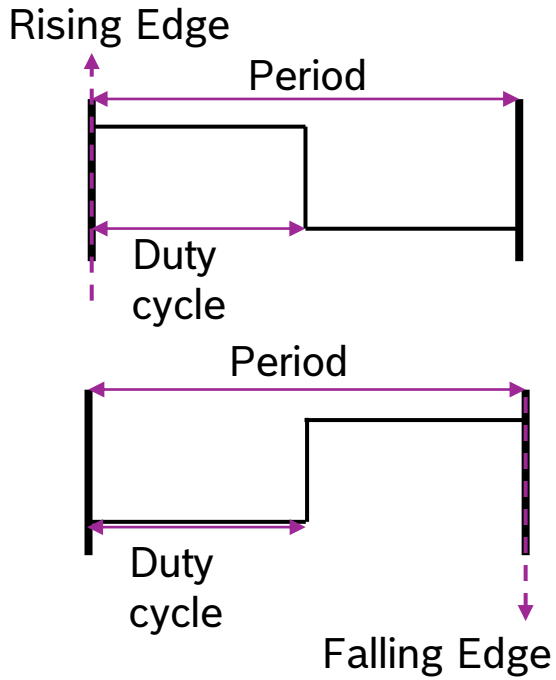
Using GTM-IP in Electric Vehicles
Edge-Aligned PWM



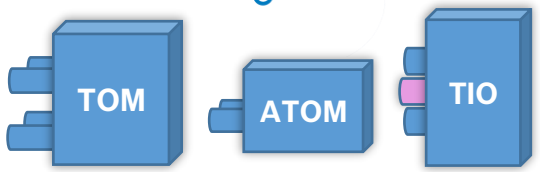
- Description
  - Generate left and right aligned PWMs
    - LEFT: The rising edge of the PWM is aligned to start of the period
    - RIGHT: The falling edge of the PWM is aligned to end of the period
- Applicable modules
  - TOM; ATOM; TIO
- Implementation example
  - Switch the PWM type by setting the PWM type parameter to LEFT/RIGHT



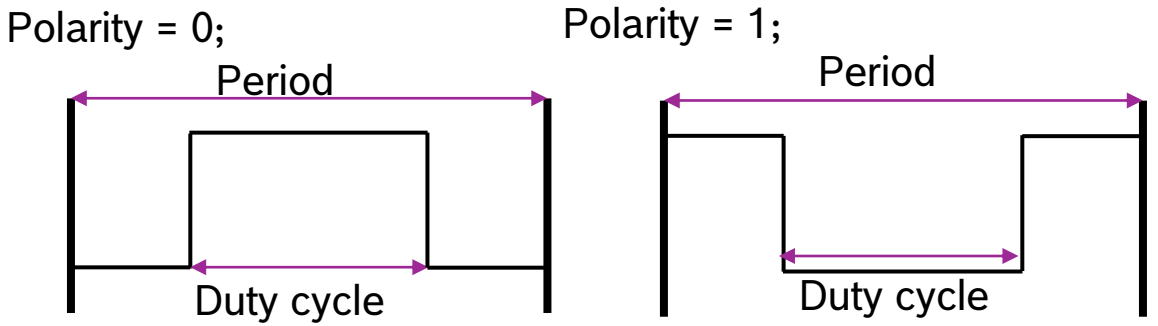
Polarity = 0;

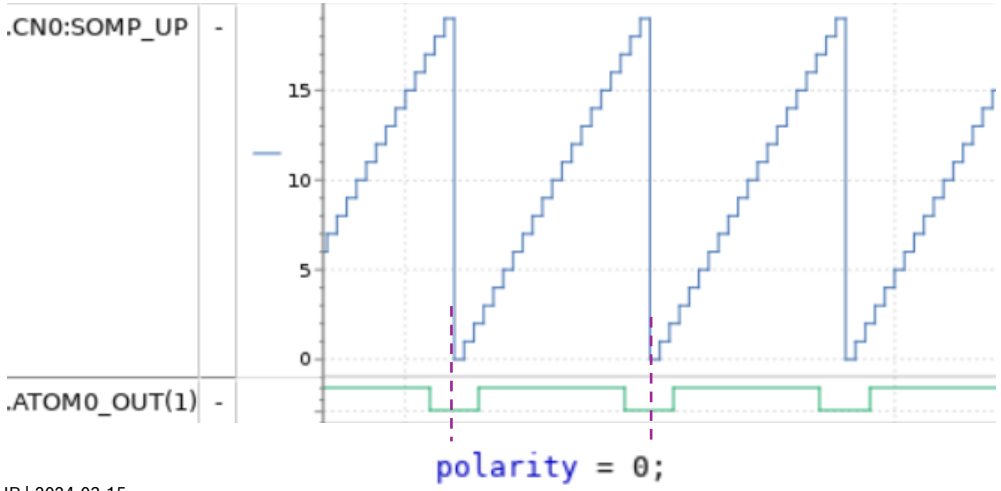


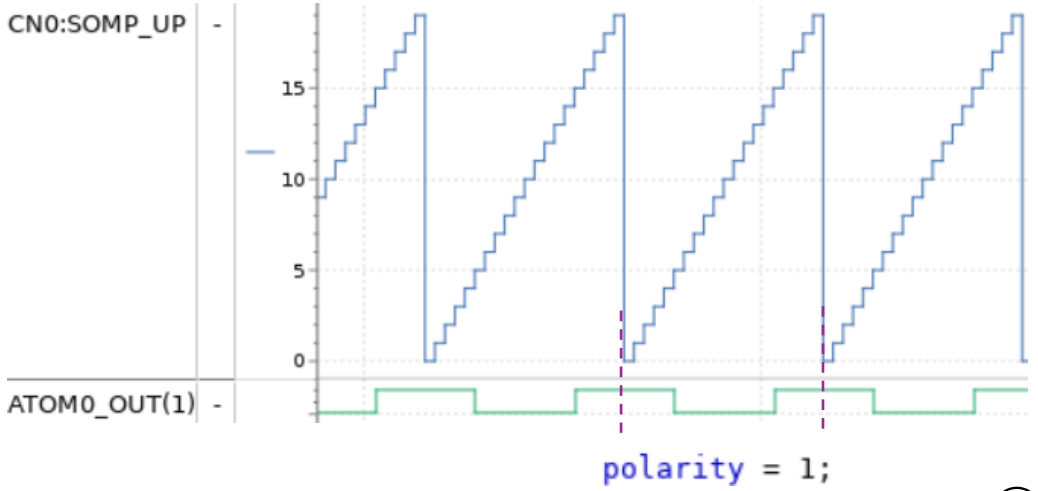
Using GTM-IP in Electric Vehicles
Center-Aligned PWM



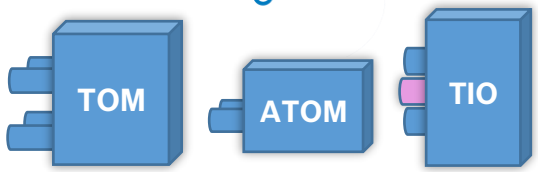
- Description
  - The rising and falling edges of the PWM have the same distance to the center of the period
- Applicable modules
  - TOM, ATOM, TIO
- Implementation example
  - Set the PWM type parameter to CENTER
  - Change of polarity





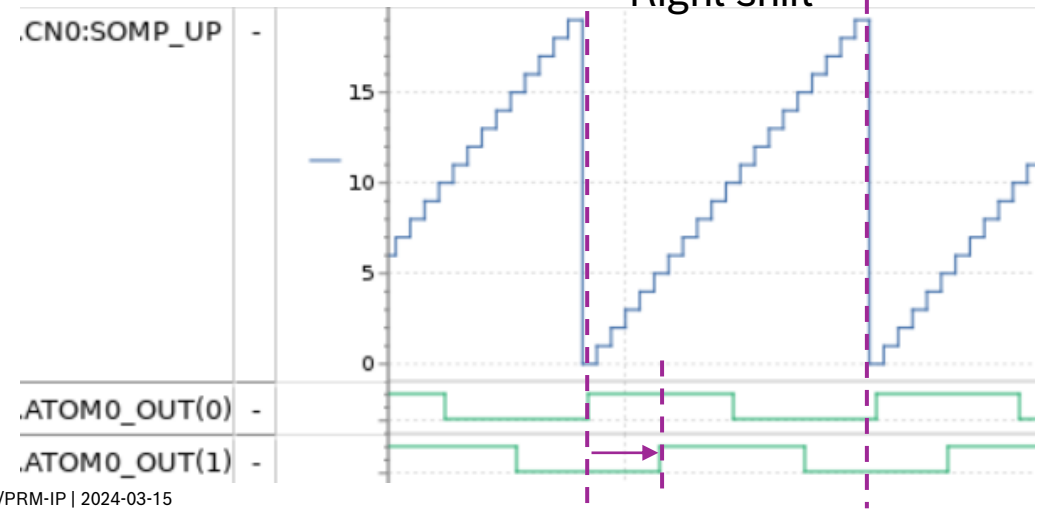


Using GTM-IP in Electric Vehicles
Shifted PWM within period border

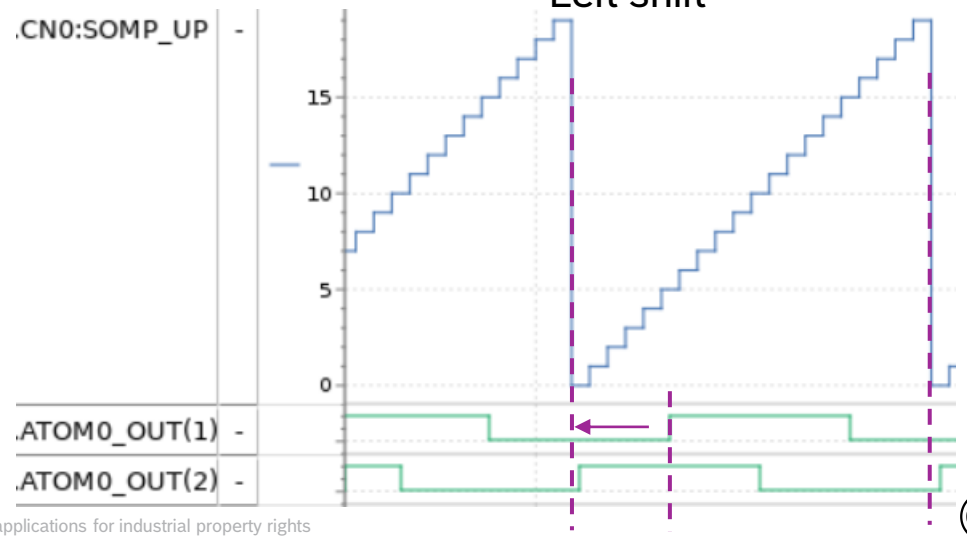


- Description
  - By shifting left or right, the PWM waveform can be modified
- Applicable modules
  - TOM; ATOM; TIO
- Implementation example
  - Right shift: ATOM_OUT(0) for standard PWM, ATOM_OUT(1) for shifted PWM
  - Left shift: ATOM_OUT(1) for standard PWM, ATOM_OUT(2) for shifted PWM

Right shift



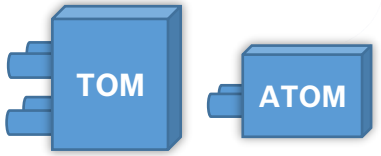
Left shift



03

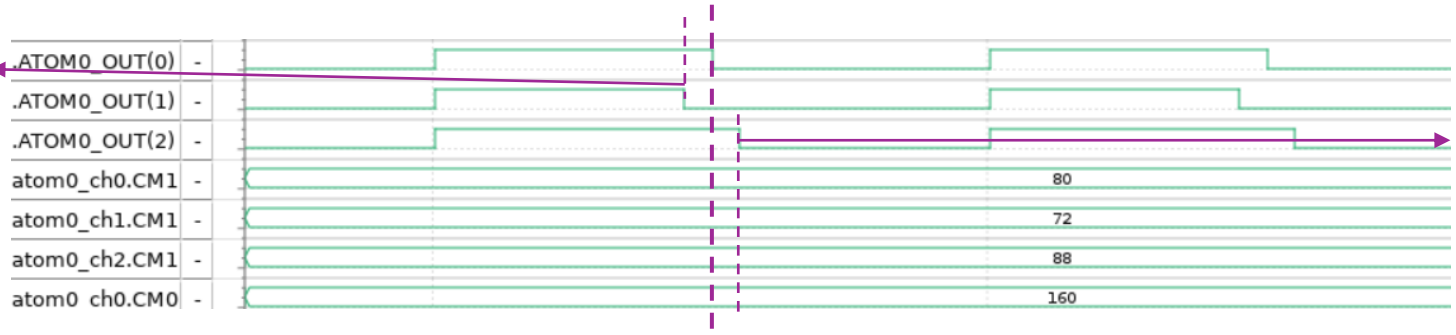
High resolution PWM support

Using GTM-IP in Electric Vehicles
High resolution



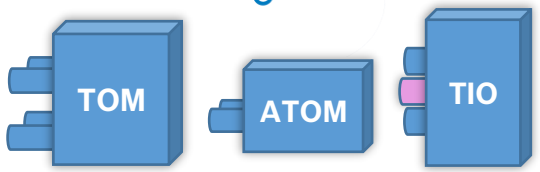
- Description
  - Factor 32 higher resolution for the PWM generation
  - Generate more accurate frequencies depending on the cluster clock
  - Perfect for situations that require precise control over voltage or current, such as chargers
- Applicable modules
  - TOM; ATOM
- Implementation example
  - ATOM operates on 200 MHz cluster clock -> 5 ns resolution for each counter tick
  - One edge with a resolution of 0.156 ns in 32 Steps(n=5 bit) -> 5 ns/32= 0.156 ns
  - Generate a high resolution PWM by scaling the duty cycle/period parameter by 32

Duty cycle decrease
by 8 high resolution ticks



Duty cycle increase
by 8 high resolution ticks

Using GTM-IP in Electric Vehicles
High resolution



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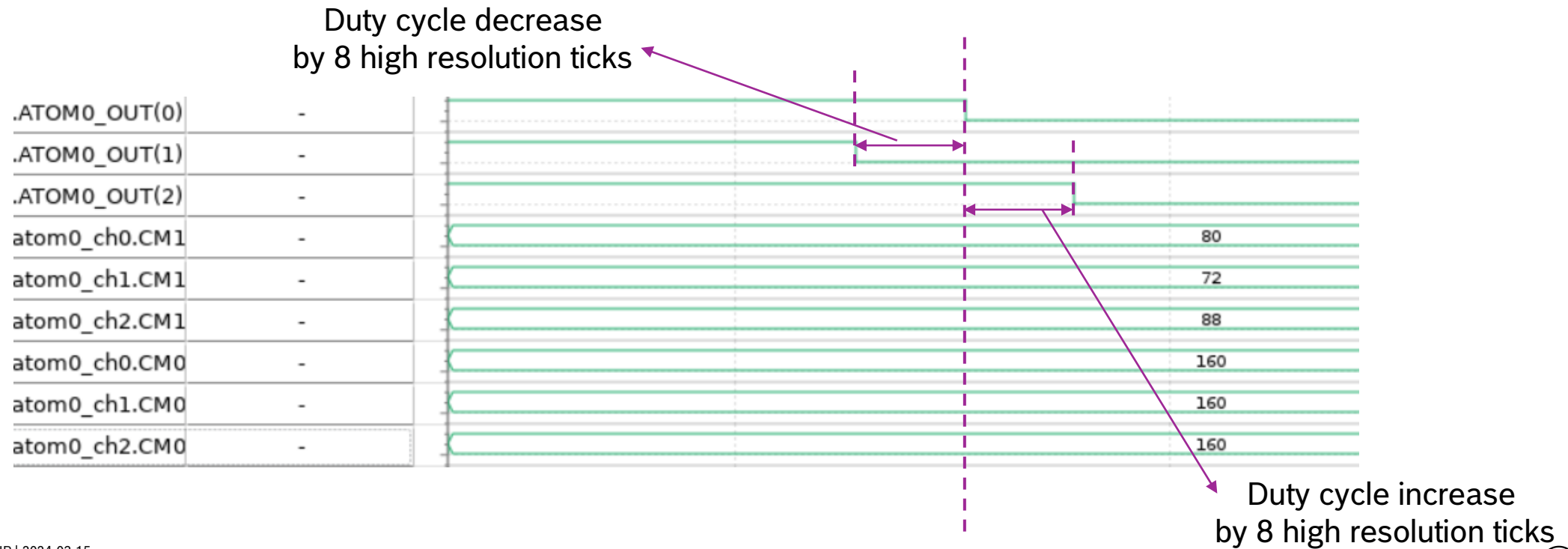
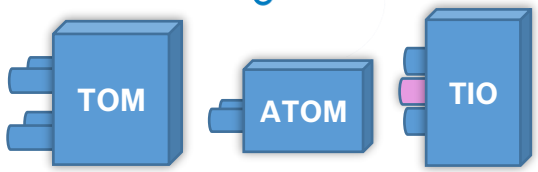


04

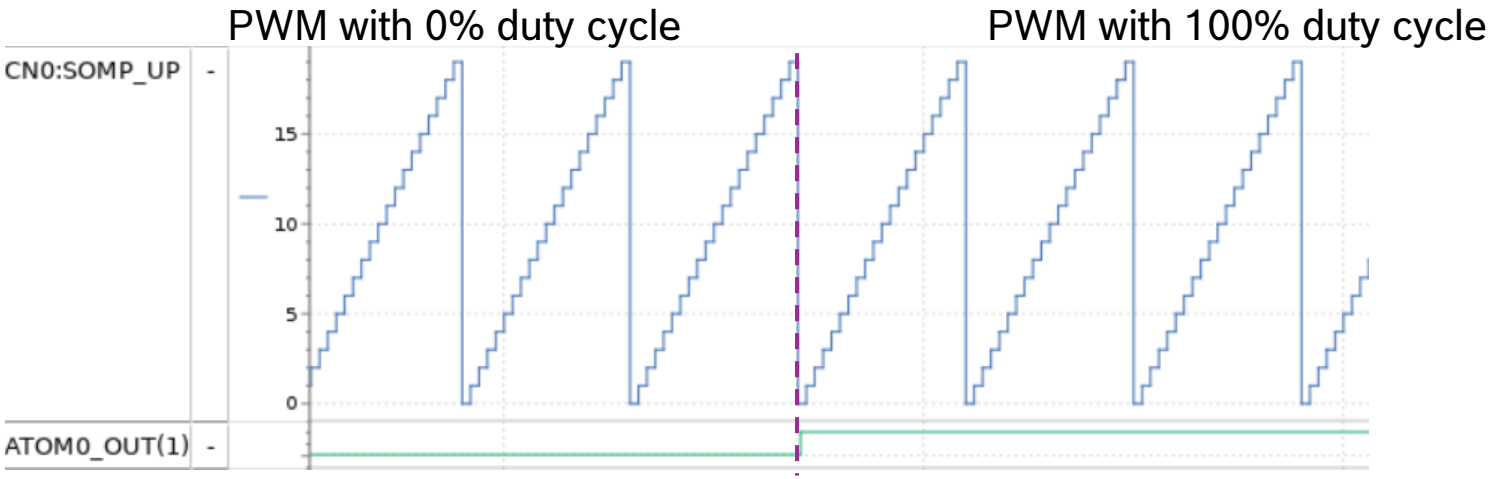
Special cases of PWM generation

Using GTM-IP in Electric Vehicles

PWM generation with 100% and 0% duty cycle



- Description
  - PWM remains at a constant signal level for the entire duration of the period
- Applicable modules
  - TOM; ATOM; TIO
- Implementation example
  - Generate a PWM signal with a duty cycle of 100% or 0%, and switch between them

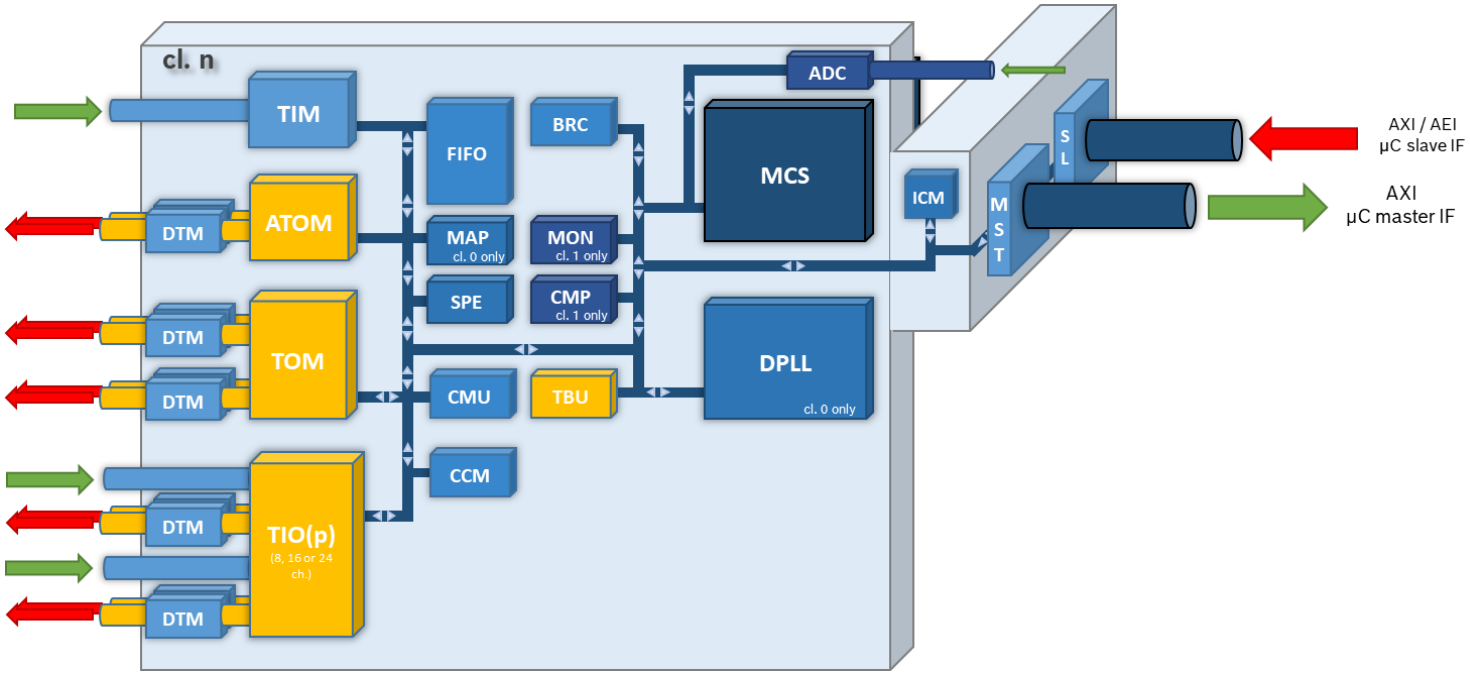


05

Multi channel synchronous PWM

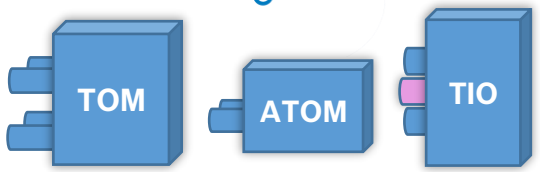
Using GTM-IP in Electric Vehicles
Multi channel synchronous PWM

- Use-Case/Benefits
  - For many applications e.g. electric motor control many PWM outputs must be synchronized
  - The GTM is able to synchronize up to 16 PWMs within one module
  - The GTM is able to synchronize up to 36 PWMs within one cluster



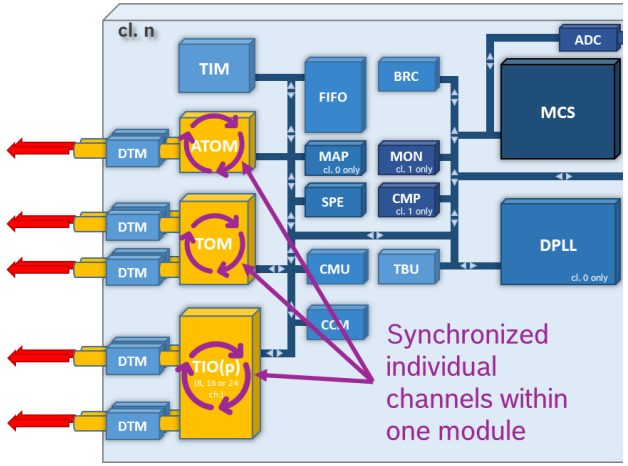
Using GTM-IP in Electric Vehicles

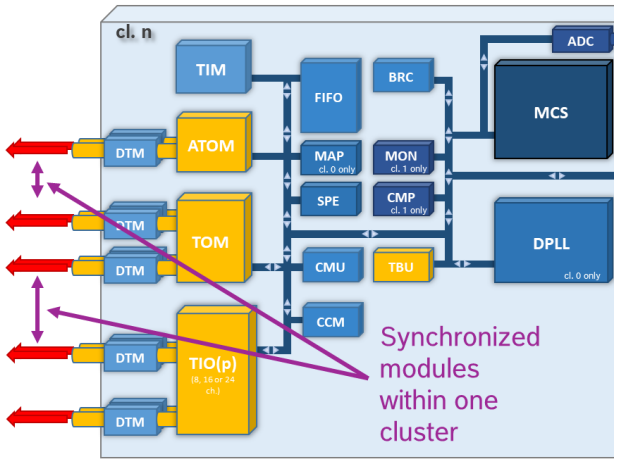
Multi channel synchronous PWM

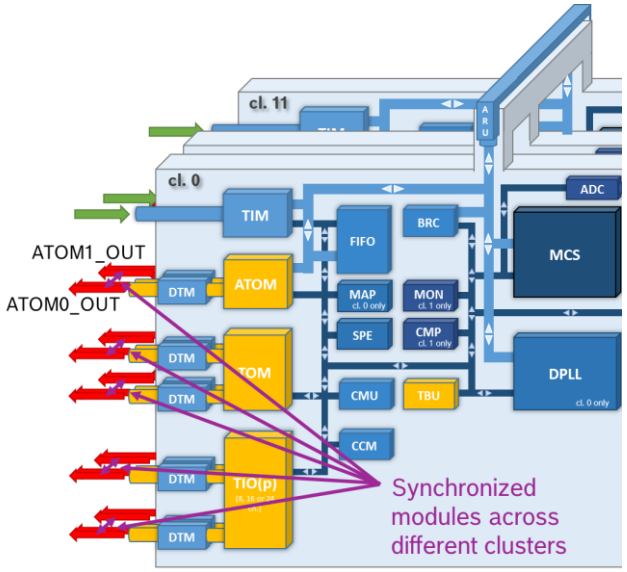


- Used functionalities
  - Synchronize individual TOM/ATOM/TIO channels within one module based on external or internal events
  - Synchronize TOM/ATOM/TIO modules within one cluster
  - Synchronize TOM/ATOM/TIO modules across different clusters

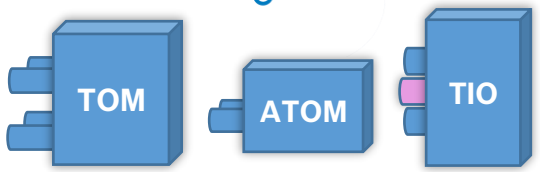
- Applicable modules
  - TOM; ATOM; TIO







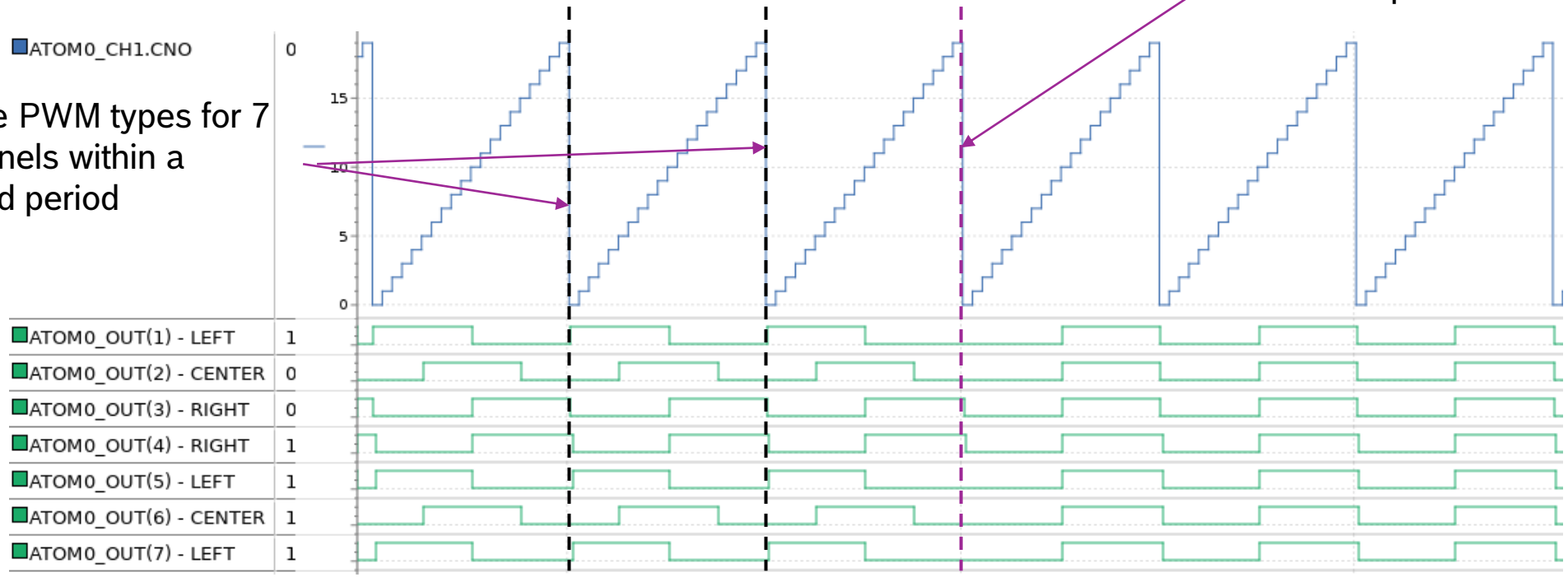
Using GTM-IP in Electric Vehicles
Multi channel synchronous PWM



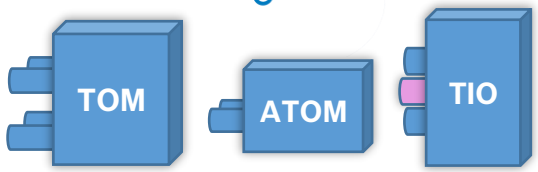
- Implementation example
  - 1. Synchronize 7 PWMs within one module
    - PWM_types = Left; Right; Center
    - Used module and channels: ATOM Cluster 0 Channel 1, 2, 3, 4, 5, 6, 7

Synchronized update of the PWM types to RIGHT at the end of a period for all channels

Configurable PWM types for 7 ATOM channels within a synchronized period

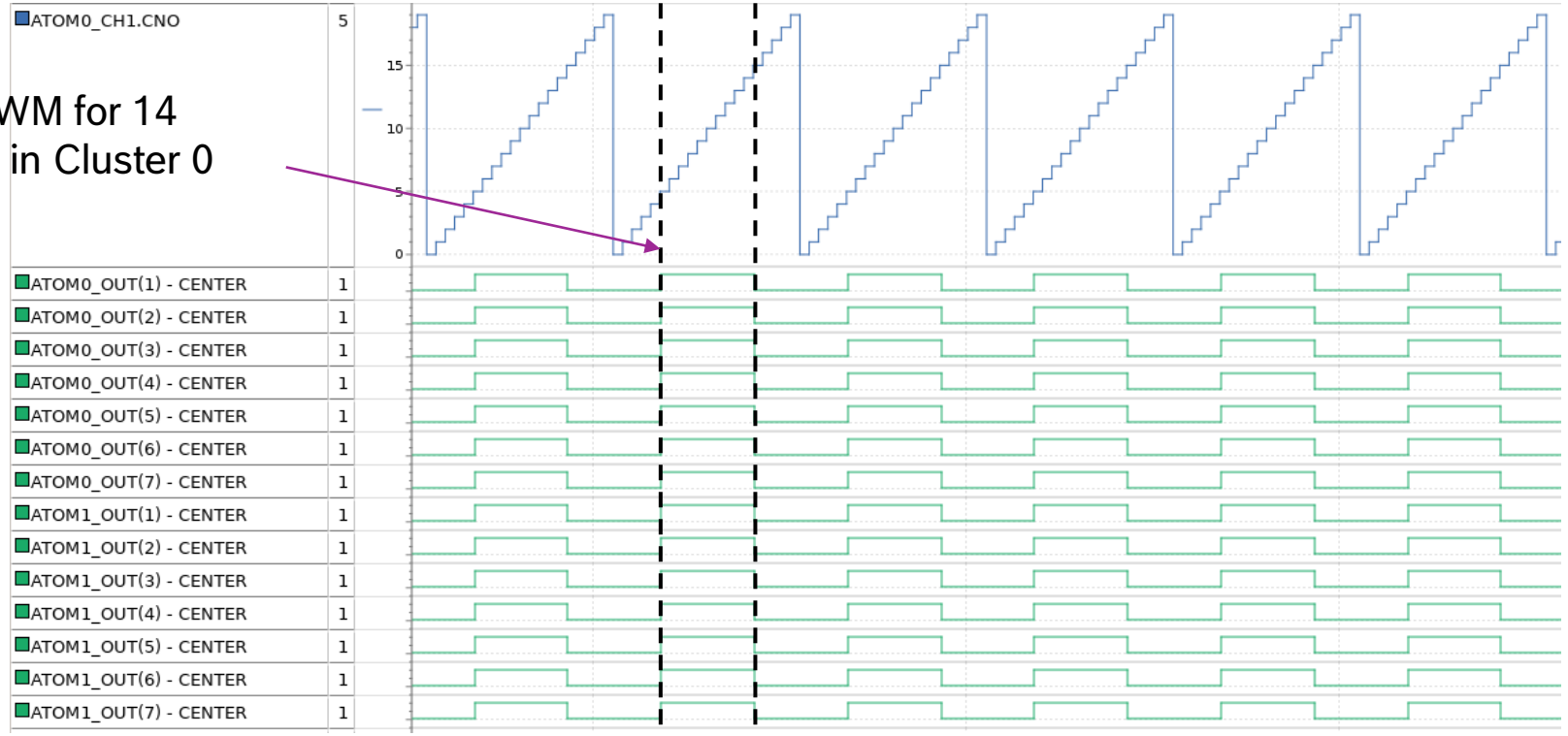


Using GTM-IP in Electric Vehicles
Multi channel synchronous PWM



- Implementation example
  - 2. Synchronize 14 PWMs across different clusters
    - PWM_types = Center
    - Used module and channels: ATOM Cluster 0 Channel 1, 2, 3, 4, 5, 6, 7 and ATOM Cluster 1 Channel 1, 2, 3, 4, 5, 6, 7

Synchronized PWM for 14 ATOM channels in Cluster 0 and Cluster 1

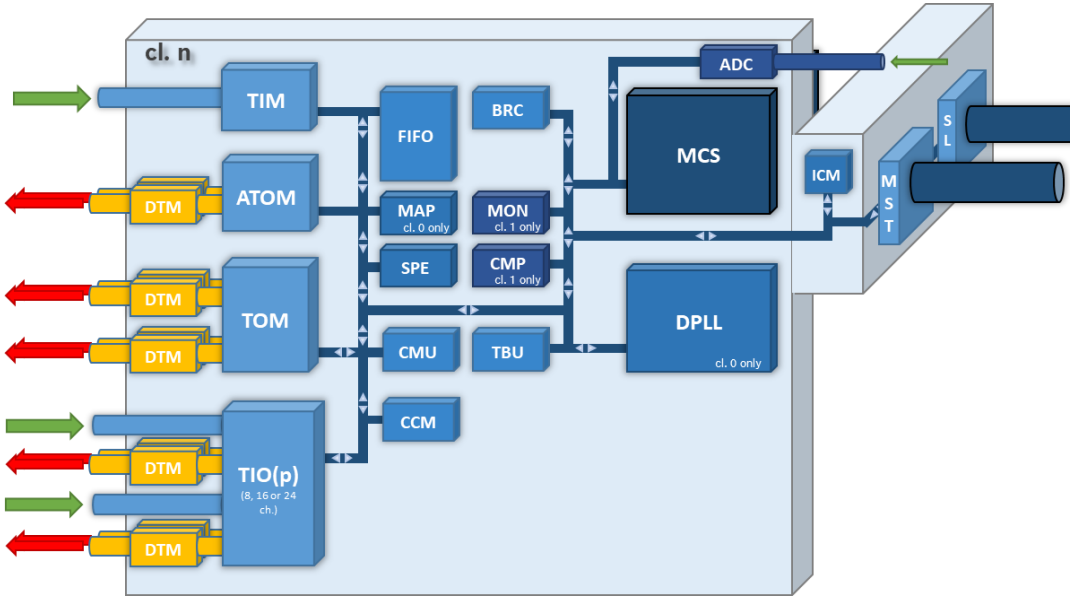


06

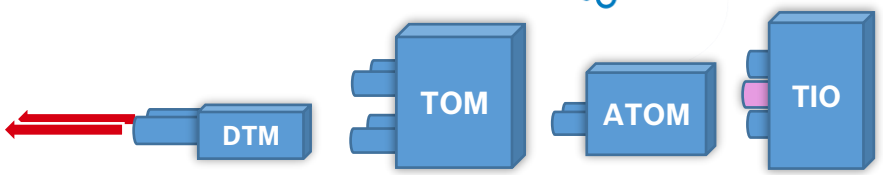
Modify PWM with deadtime using DTM

Using GTM-IP in Electric Vehicles
Modify PWM with deadtime using DTM

- Use-Case/Benefits
  - Delay edges:
    - Lengthen/ shorthen/ mask pulses
  - Use deadtime to avoid short-circuit currents
    - E.g. in H-bridges for power converters or motor controllers
- Used funtionalities of the DTM
  - The DTM is able to invert and apply deadtime or delay edges to the PWM signals coming from TOM, ATOM or TIO
- Applicable modules
  - DTM



Using GTM-IP in Electric Vehicles
Modify PWM with deadtime using DTM

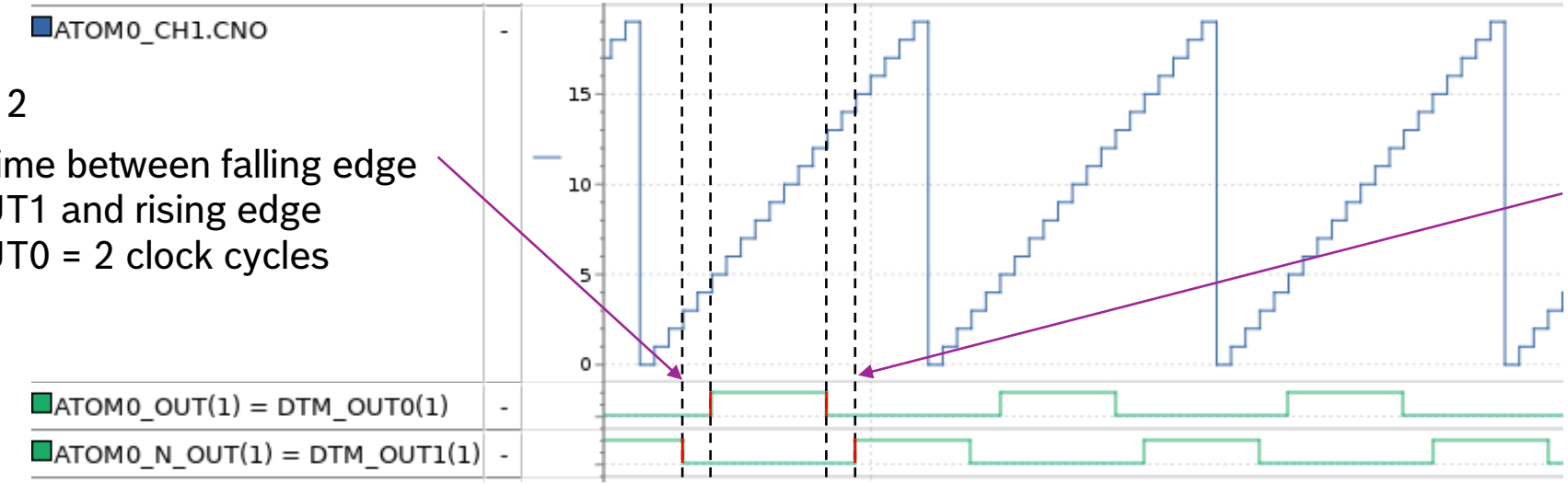


- Description
  - Used outputs
    - DTM_OUT0 → Same polarity as provided signal from TOM/ATOM/TIO
    - DTM_OUT1 → Inverted polarity to provided signal from TOM/ATOM/TIO

Combined delay of rising edge of DTM_OUT0 and rising edge of DTM_OUT1

Relrise = 2

→ Deadtime between falling edge DTM_OUT1 and rising edge DTM_OUT0 = 2 clock cycles



Relfall = 2

→ Deadtime between falling edge DTM_OUT0 and rising edge DTM_OUT1 = 2 clock cycles

07

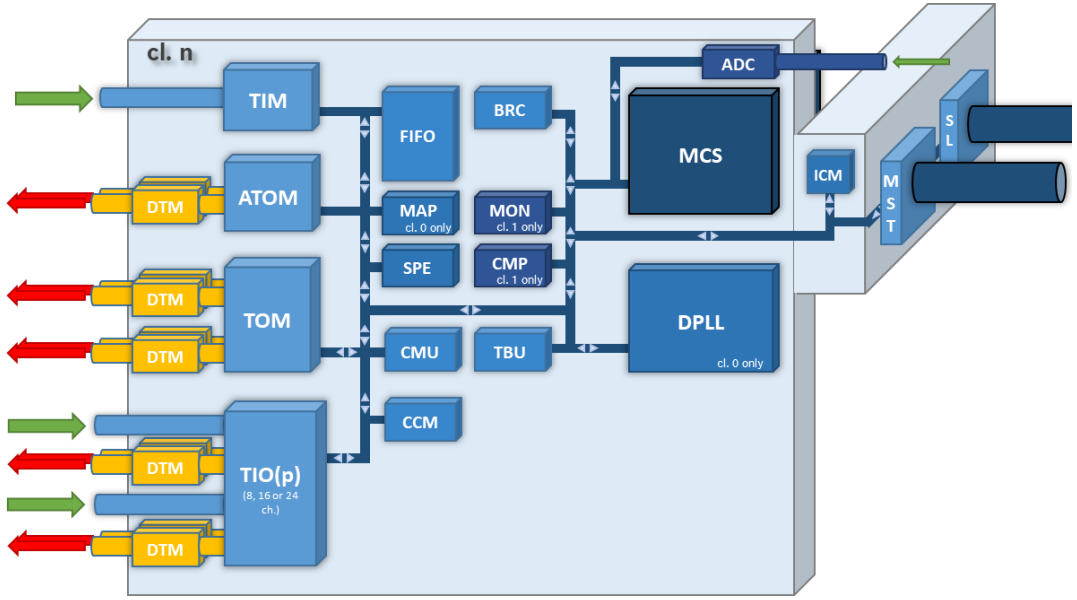
Fast shut off functionality using DTM

Using GTM-IP in Electric Vehicles
Fast shut off functionality using DTM

- Use-Case/Benefits
  - Set the DTM outputs to a defined level based on a selected event
  - Ensure that the outputs can switch in a safe state immediately
    - In case of emergency situations
    - In case of detected error in the application

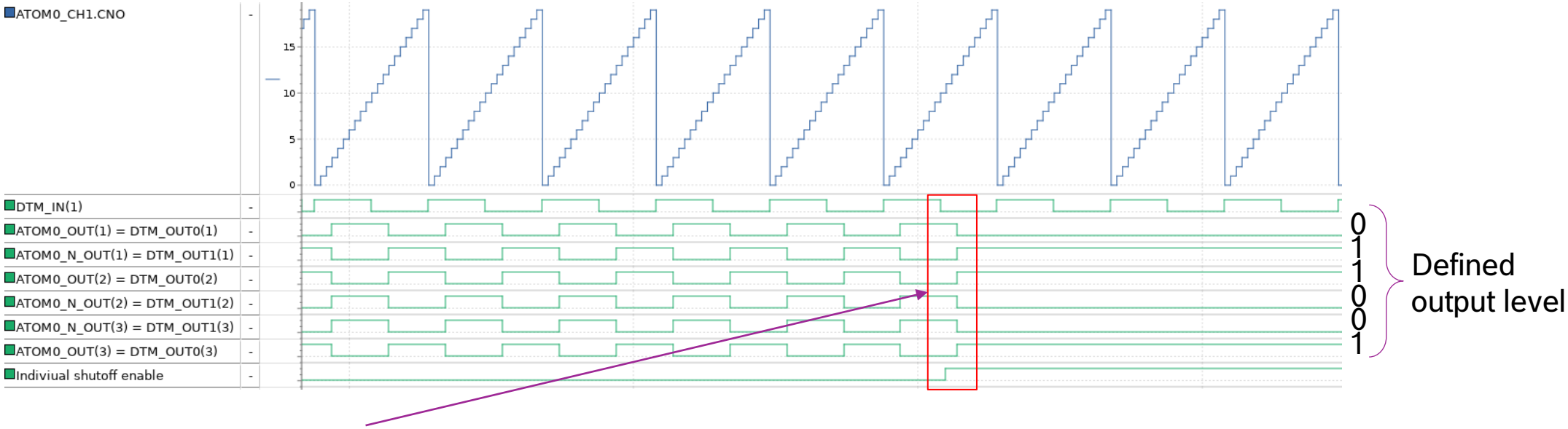
- Used funtionalities of DTM
  - DTM is able to set DTM outputs to defined level triggered by a defined input

- Applicable modules
  - DTM



Using GTM-IP in Electric Vehicles
Fast shut off functionality using DTM

- Implementation example
  - Synchronized shutoff of 3 DTM channels without deadtime



When „individual shutoff enable“ is set to 1 by software or trigger events, DTM outputs of 3 DTM channels are set to a defined level synchronously

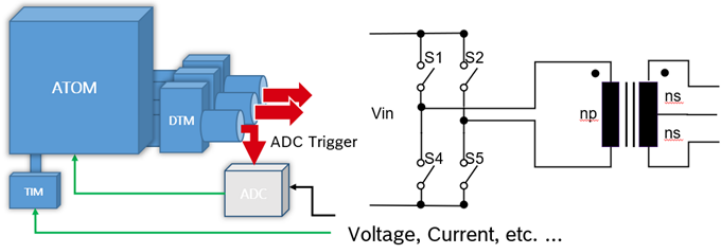
08

Summary

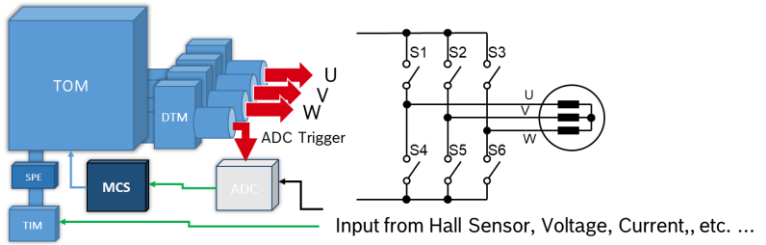
Using GTM-IP in Electric Vehicles
Summary

- GTM usage in Electric Vehicles
  - GTM provides many functionalities for multiple use cases e.g.:
    - Power converter
    - Electric motor control
  - GTM provides the option to combine many functionalities for multiple use cases e.g.:
    - PWM with High Resolution PWM Support
    - PWM with deadtime
    - PWM with deadtime and High Resolution PWM Support
    - Multi channel synchronous PWM with deadtime and High Resolution PWM Support

Power conversion example: Full Bridge PFC



Motor control example: BLDC (Brushless DC) Motor



→ The end user can decide which functionalities and combinations of functionalities are needed for the individual use cases

→ Example driver based on Coside can be used as helping guideline how to use GTM functionalities to set up applications more easy

Thank you for your attention!