XMC in Application – Dimmable LED Current Control

XMC Microcontrollers

October 2015

Learning objectives

- Know the key features of the dimmable LED current control application
- Understand how the peripherals of the XMC1000 microcontroller can be used to implement the key features of the dimmable LED current control application

Agenda

1. Overview
2. Key Features
3. Specification
4. System Block Diagram
5. Hardware Overview
6. Highlight MCU Features
7. Resource Listing

Dimmable LED Current Control – Overview

- This training slides showcase a low cost yet high quality dimmable LED current control solution for a single LED channel, using an XMC1000 microcontroller.
- The HOT covers the key features and controls of the dimmable LED current control solution.

Dimmable LED Current Control – Key Features

Target Application

- Dimmable LED Current Control

Key Features

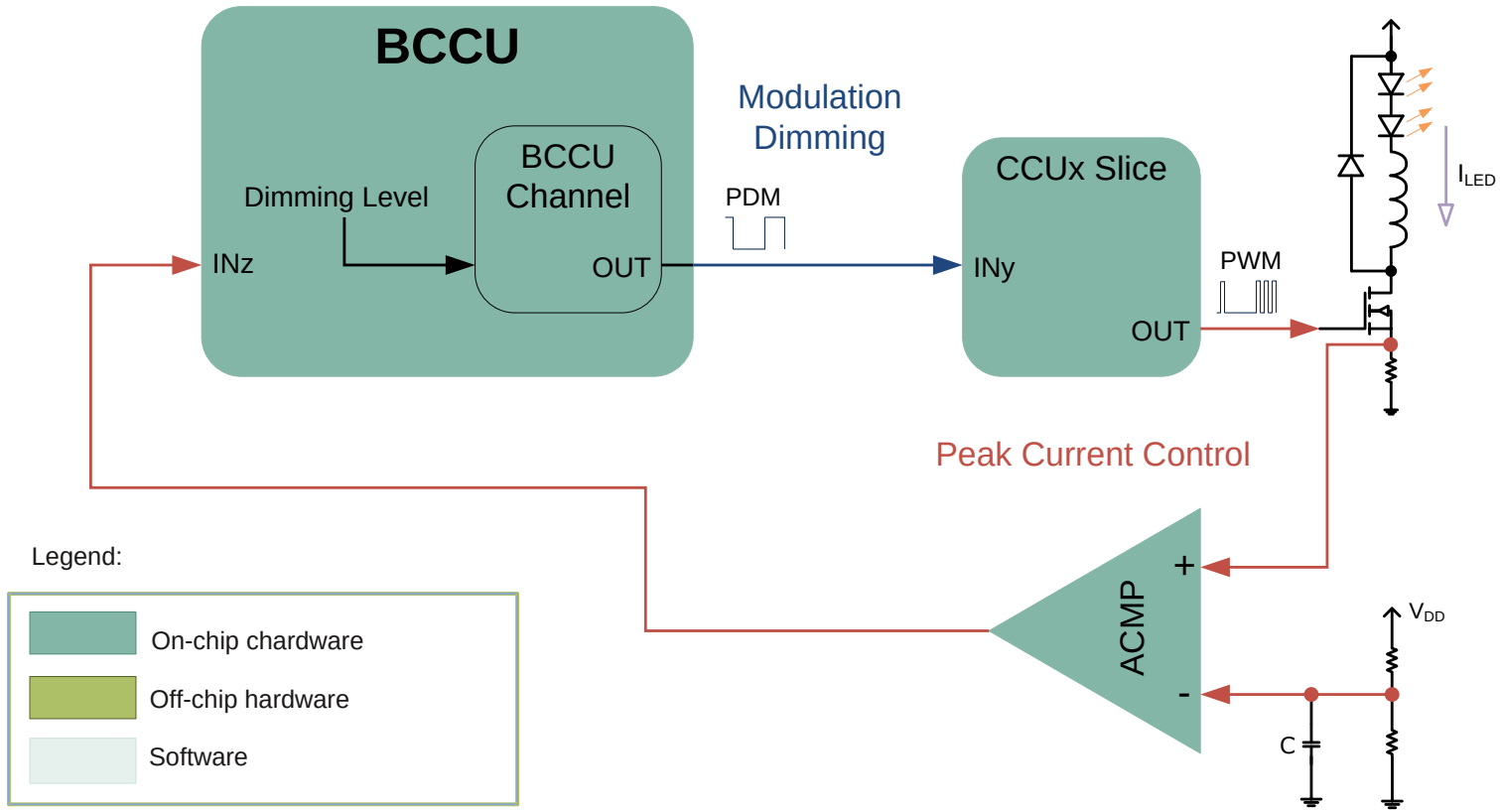
- Inverse-buck with peak current control
  - Fast LED current control for flicker-free light (switching speed up to 3MHz)
- Modulation dimming for accurate dimming levels
- High efficiency
- Compact low cost design

Dimmable LED Current Control – Specification

Specifications

- Up to $30V_{DC}$ input voltage
- Up to 700mA average output current
- Up to 1A peak current

Dimmable LED Current Control – System Block Diagram



System Block Diagram: Dimmable CCM Buck

Dimmable LED Current Control – Highlight MCU Features

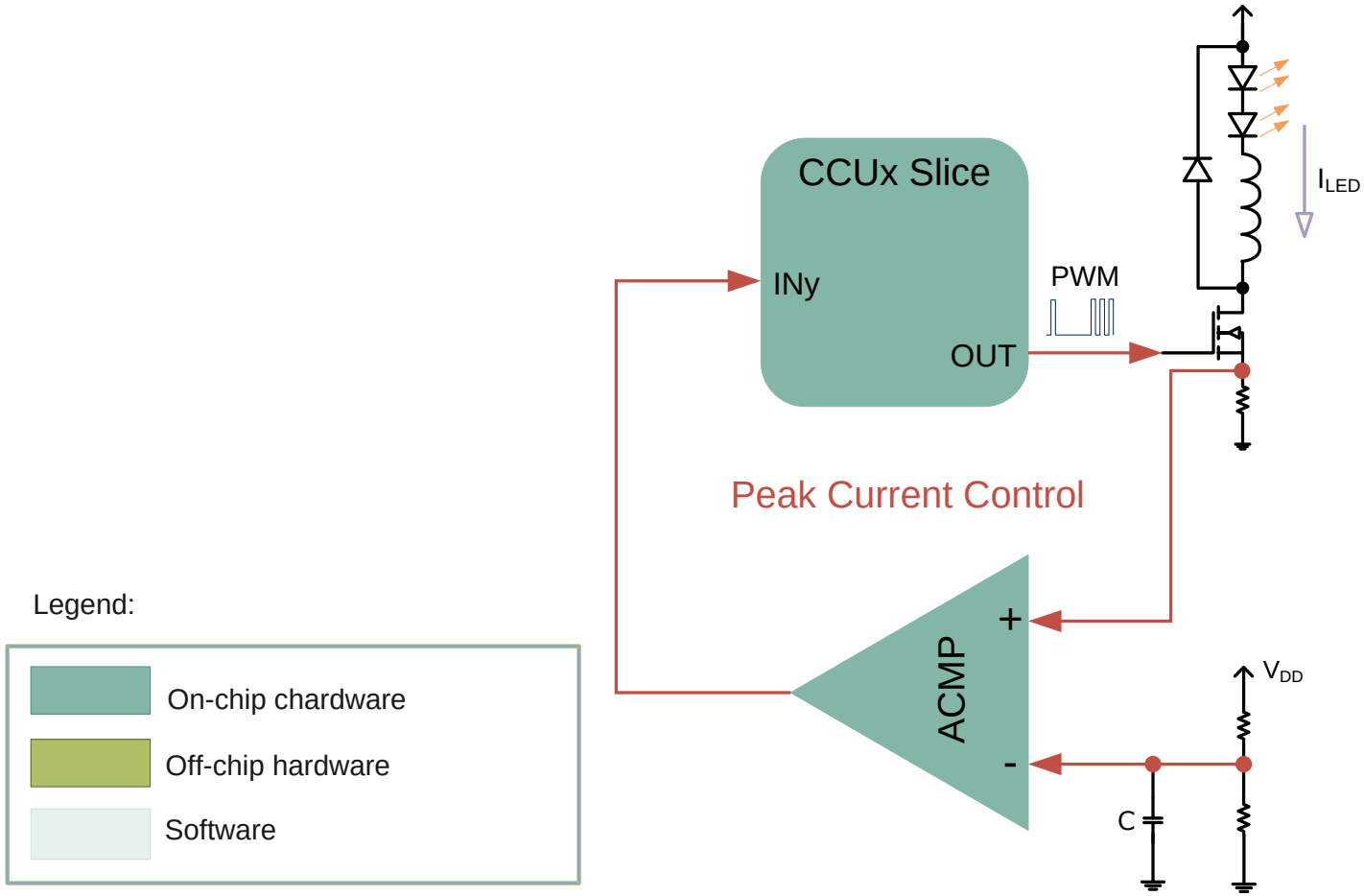
- CCU4/8 PWM
  - Generate PWM signal for driving MOSFET
  - External stop function with ACMP for peak current control
  - Timer function for fixed current ripple off-time
  - External modulation function with BCCU for dimming control
- ACMP
  - Peak current detection
  - Gating input signal for BCCU
- BCCU
  - LED dimming control
  - Modulation signal for CCUx

Dimmable LED Current Control – Hands-on Training

1. Key Feature – Peak Current Control
2. Key Feature – Modulation Dimming
3. Hands-on Training

1. Key Feature – Peak Current Control

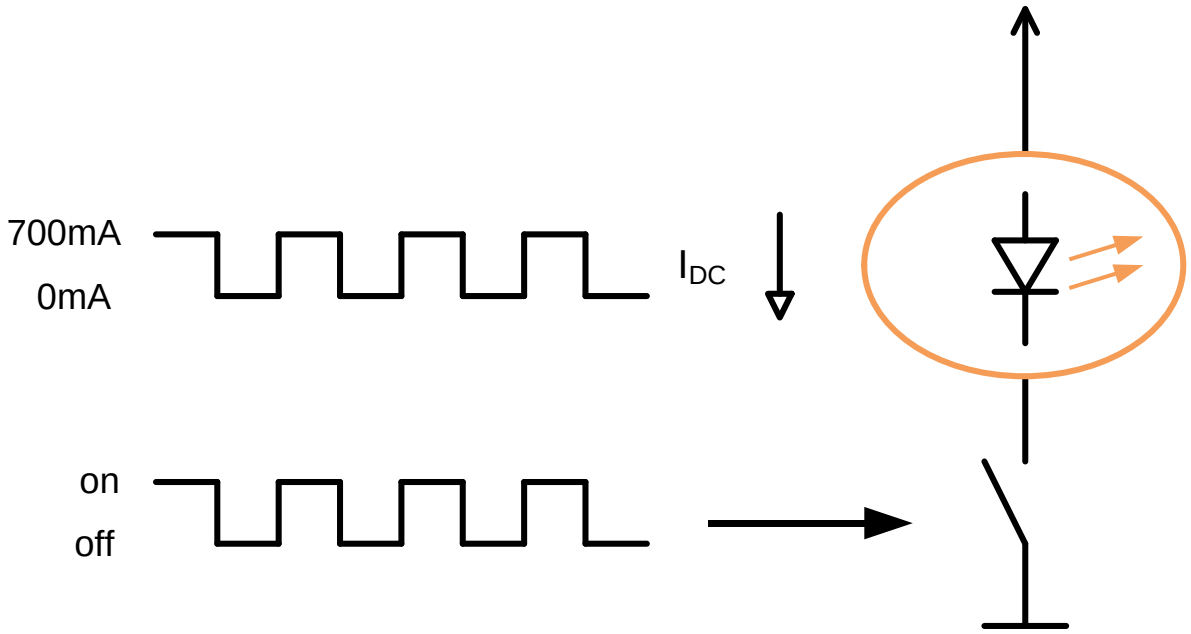
Peak Current Control Block Diagram



Block Diagram: Dimmable LED Current Control – Peak Current Control

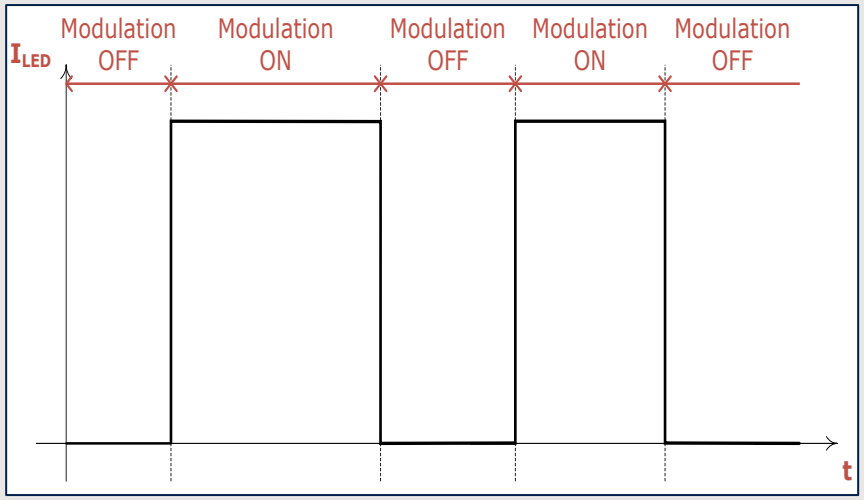
Peak Current Control – LED Current (1/3)

- LEDs are usually driven by a modulating signal
  - Periods of ON and OFF
- The main objective:
  - Ensure LED current is stable during ON times



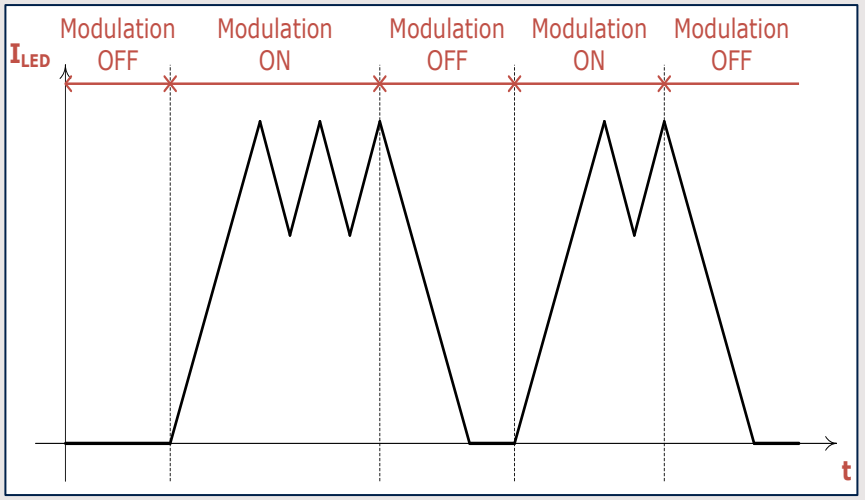
Peak Current Control – LED Current (2/3)

Ideal



- Current rises and falls instantly
- No ripple
- Fast modulation for high quality light possible

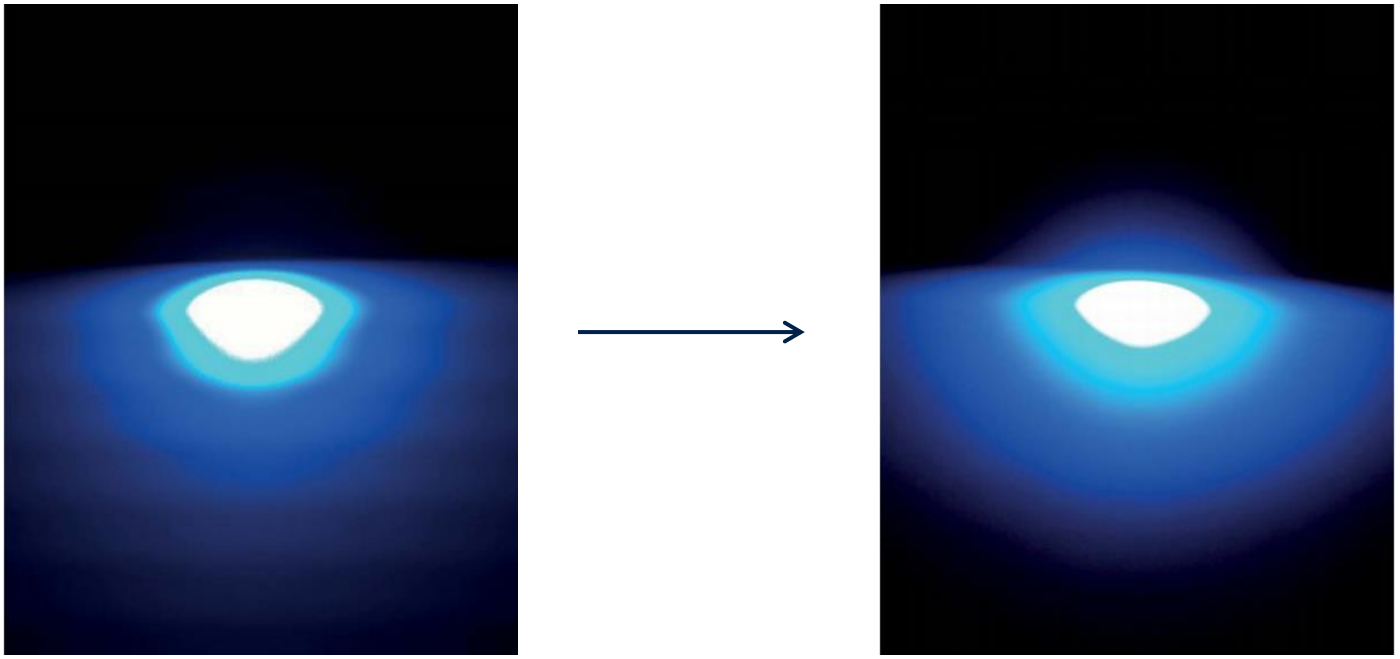
Reality



- Current takes time to rise and fall
- Ripple (switch-mode control)
- Fast modulation for high quality light challenging

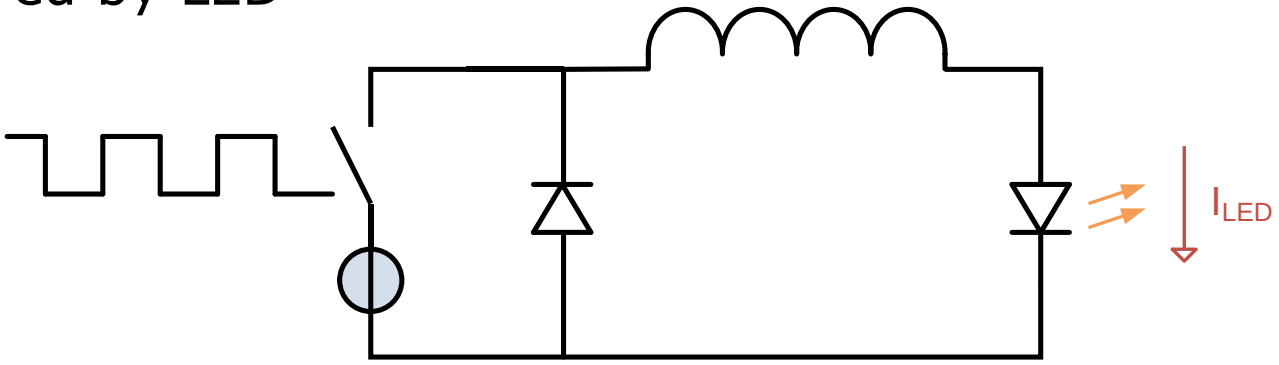
Peak Current Control – LED Current (3/3)

- Fast control loop is required for flicker-free light
  - High speed modulation dimming
  - Fast changes in current required

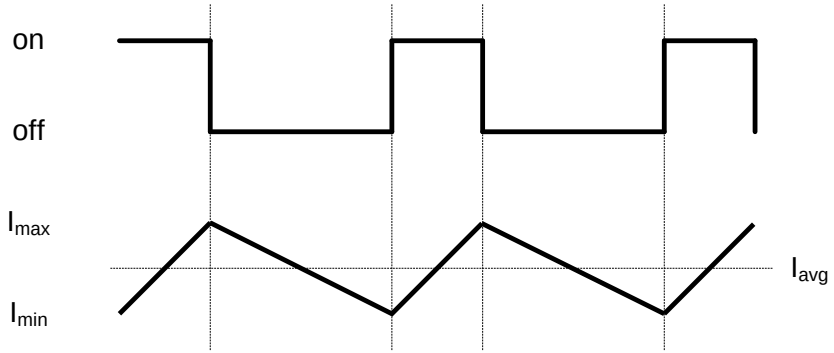


Peak Current Control – LED Current Control Circuit (1/3)

- Buck converter is commonly used
  - Efficient for converting supplied voltage down to voltage required by LED

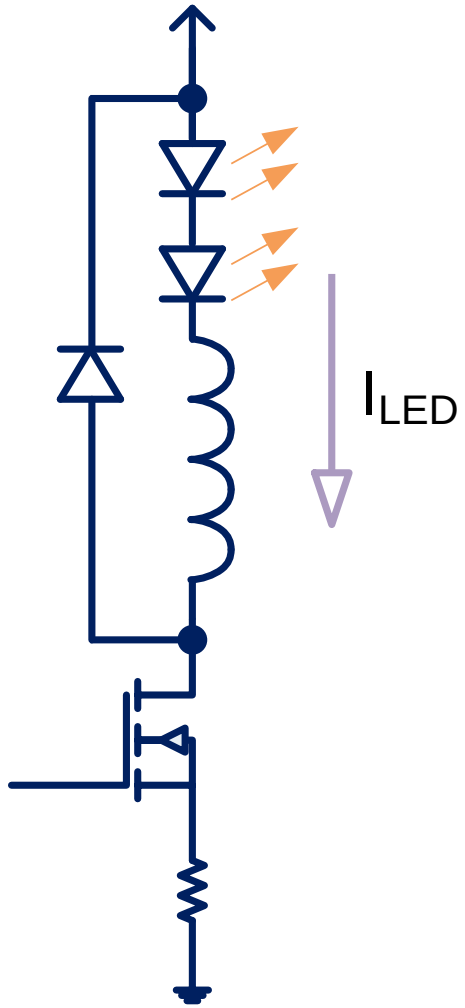


  - Continuous operation mode



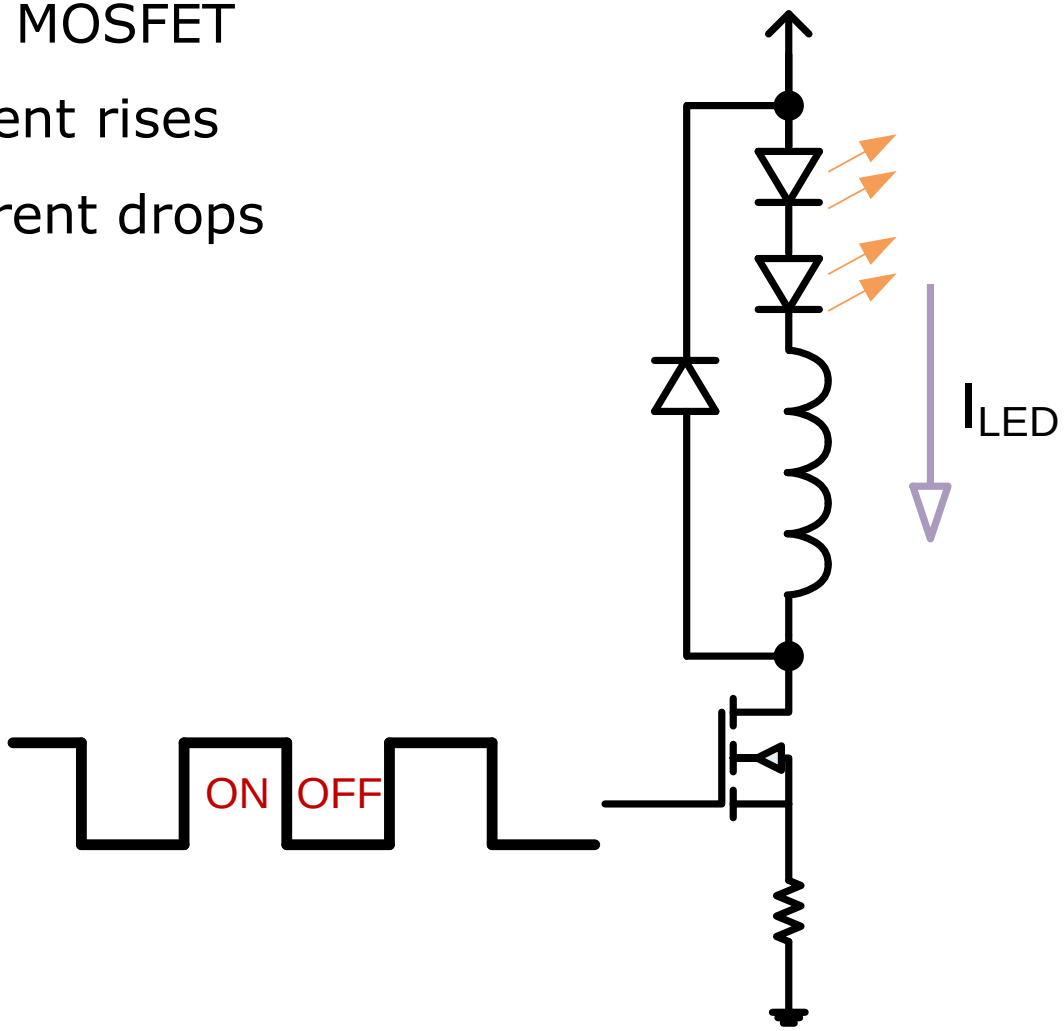
Peak Current Control – LED Current Control Circuit (2/3)

- Inverted buck topology
- Low cost
  - 1 MOSFET
  - 1 inductor
  - 1 diode
  - 1 shunt



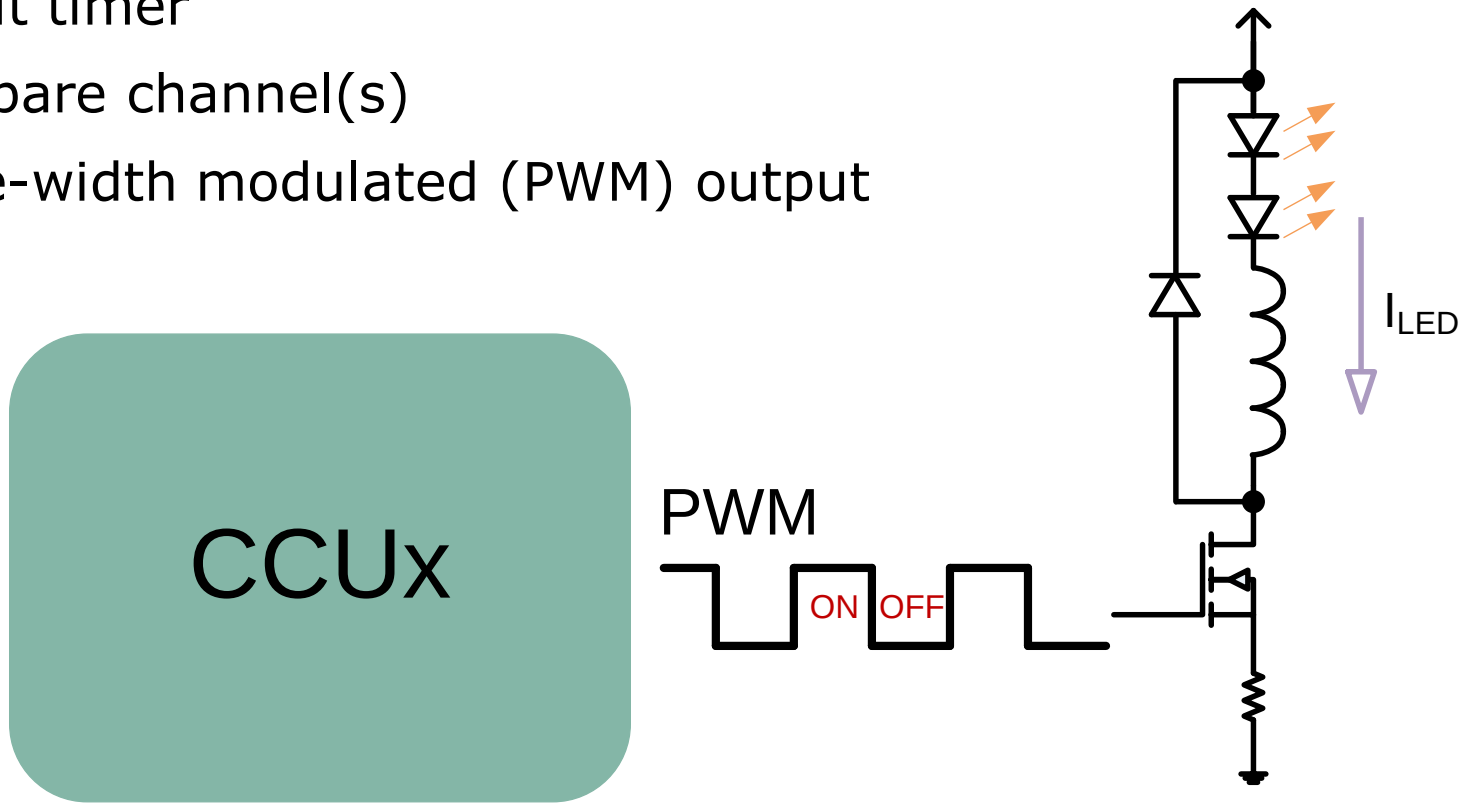
Peak Current Control – LED Current Control Circuit (3/3)

- Modulation signal drives MOSFET
- MOSFET ON → LED current rises
- MOSFET OFF → LED current drops



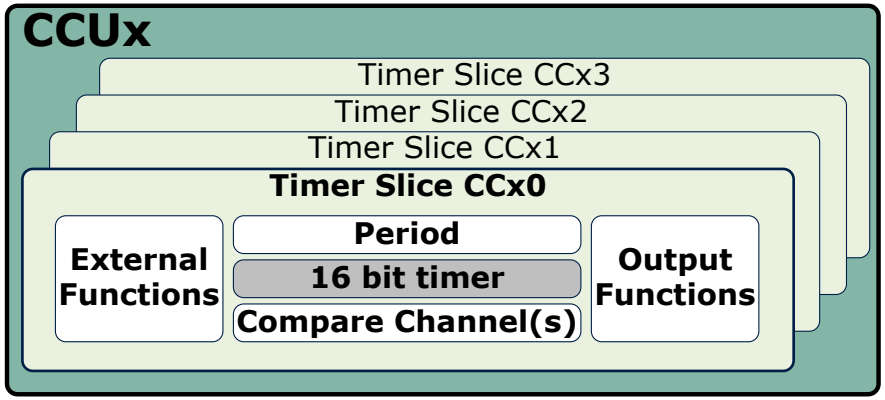
Peak Current Control – LED Current Control with XMC1 (1/13)

- Capture/Compare Unit (CCUx)
  - 16-bit timer
  - Compare channel(s)
  - Pulse-width modulated (PWM) output



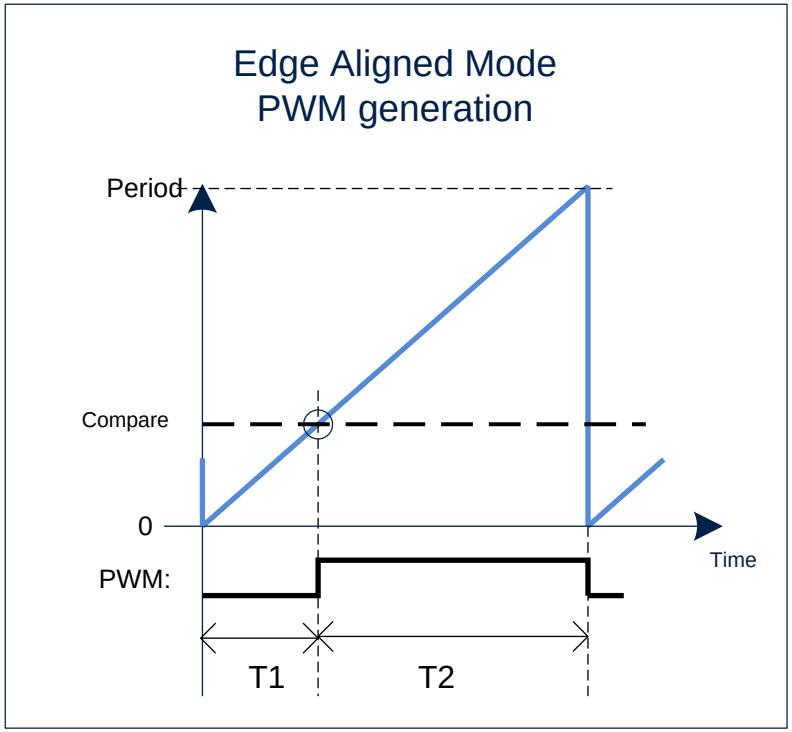
Peak Current Control – LED Current Control with XMC1 (2/13)

- Each CCUx kernel has 4 identical timer slices
- Each timer slice can be configured independently from one another
  - Which means we can have 4 different timers!
  - Timer operation modes:
    - Center aligned/**edge aligned**
  - External functions:
    - **External** start/**stop**/modulation
  - Output functions:
    - Passive level
    - Trap



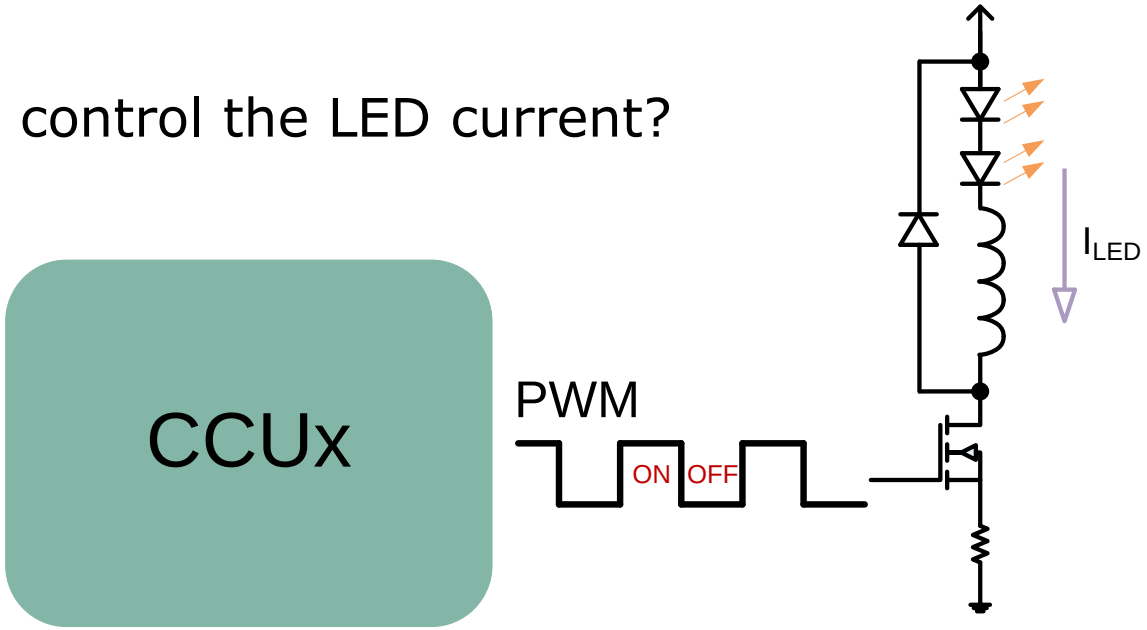
Peak Current Control – LED Current Control with XMC1 (3/13)

- 16-bit CCUx slice timer starts counting up
- PWM signal stays passive till timer reaches compare value (compare match)
- PWM signal stays active till timer reaches period value (period match)
- Timer gets cleared and restarts counting
- $Duty\ cycle = \frac{T2}{T1+T2} \times 100$



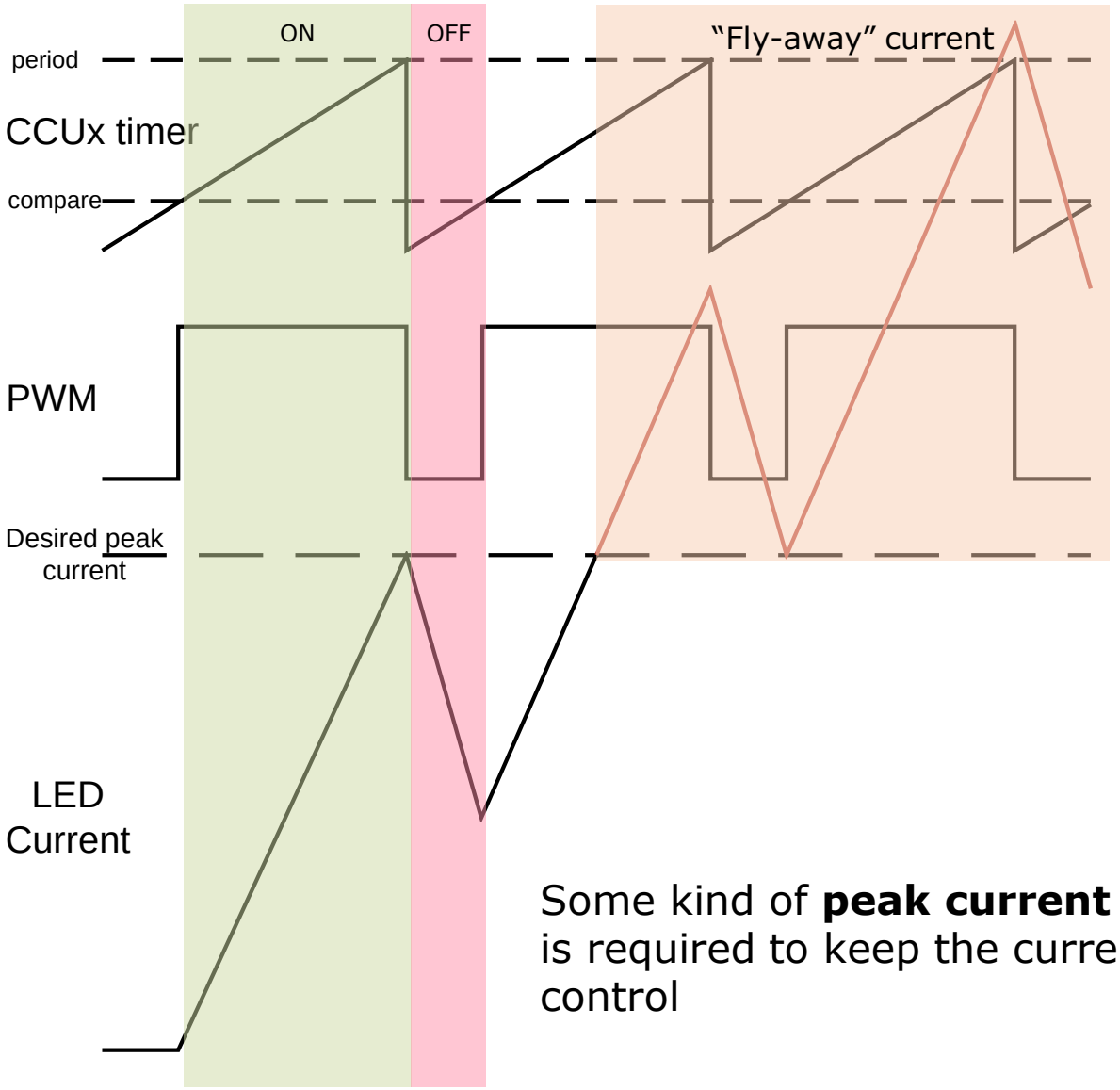
Peak Current Control – LED Current Control with XMC1 (4/13)

- CCUx PWM signal
  - Is this enough to control the LED current?



- No! What problems can you foresee?

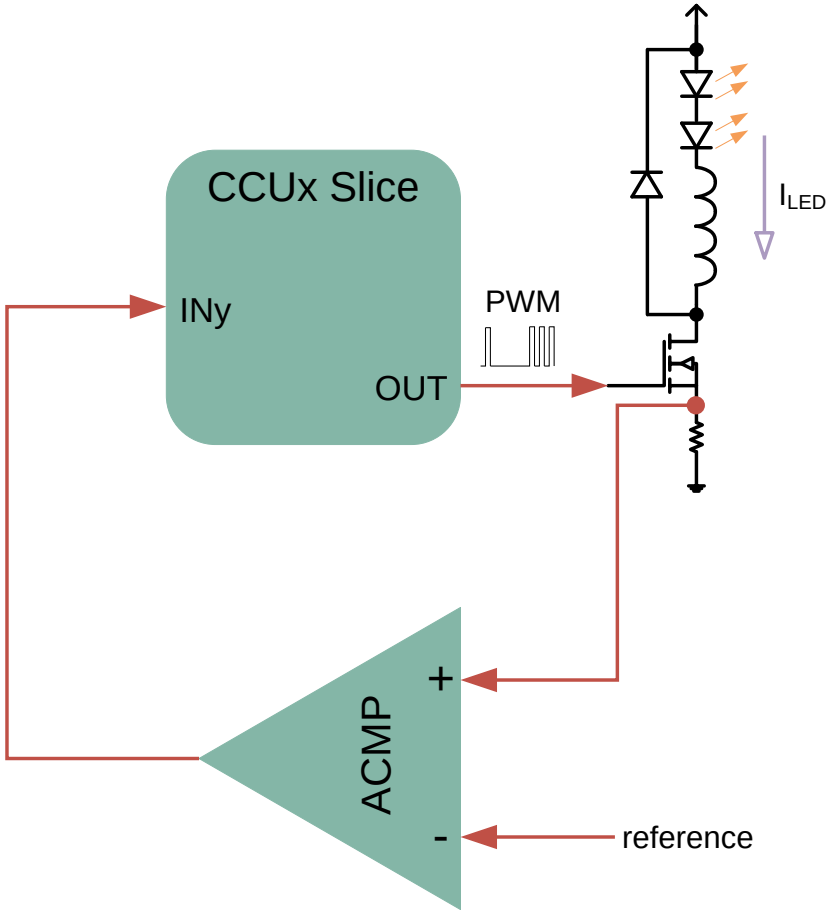
Peak Current Control – LED Current Control with XMC1 (5/13)



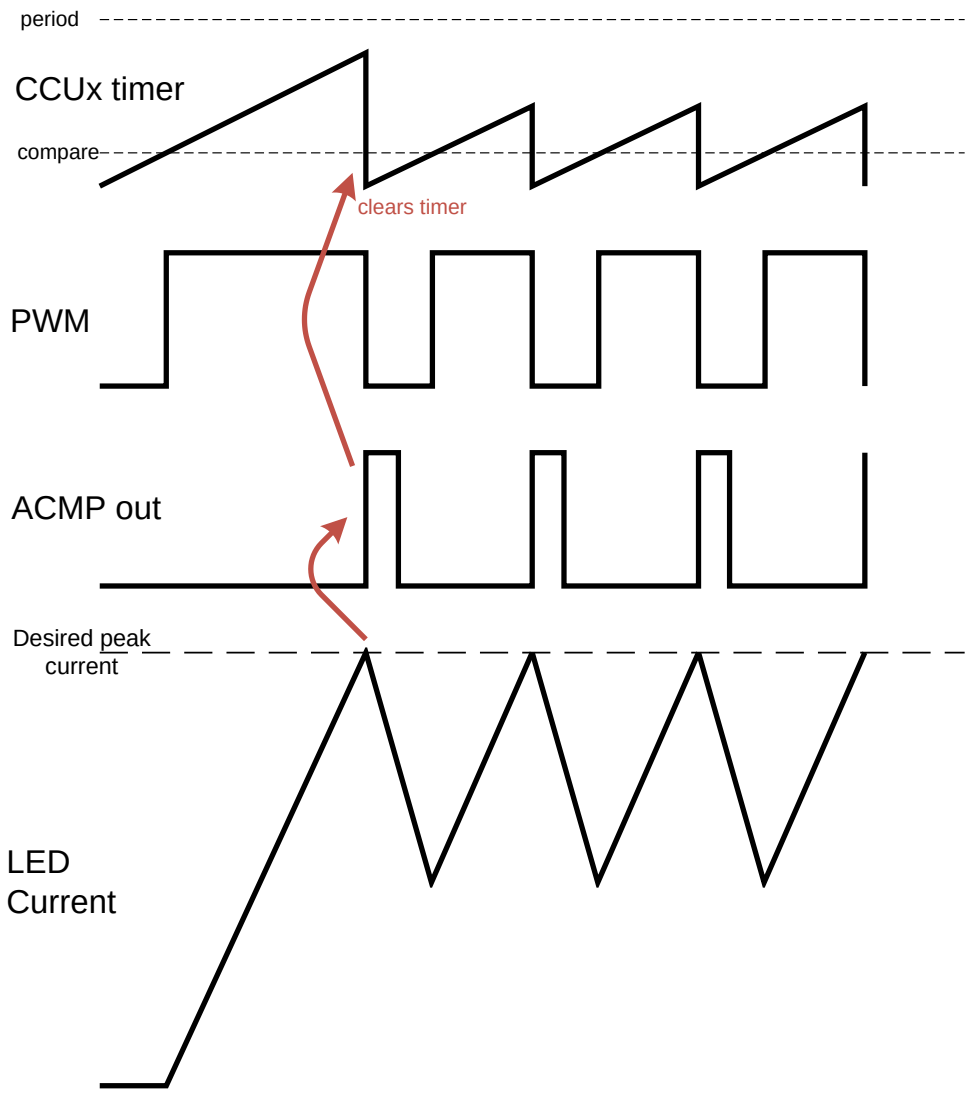
Some kind of **peak current detection** is required to keep the current under control

Peak Current Control – LED Current Control with XMC1 (6/13)

- Analog comparator (ACMP)
  - Detects when desired peak level is reached
  - Sends a trigger signal to CCUx to turn MOSFET OFF
    - Stops LED current from rising further
- CCUx
  - Upon receiving trigger signal from ACMP, clears its timer and starts counting up again
    - This is the external stop feature

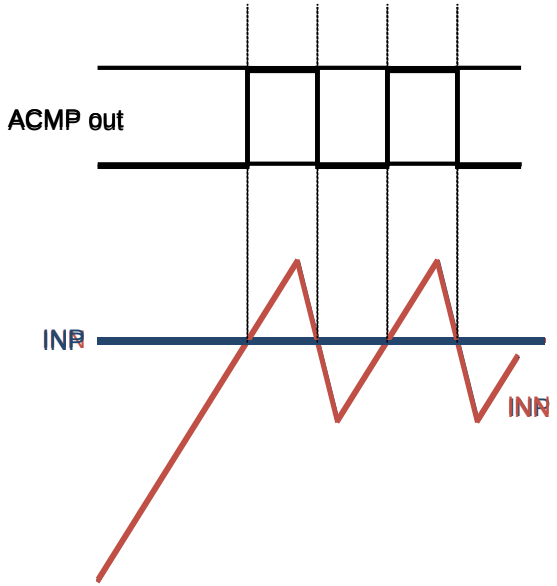


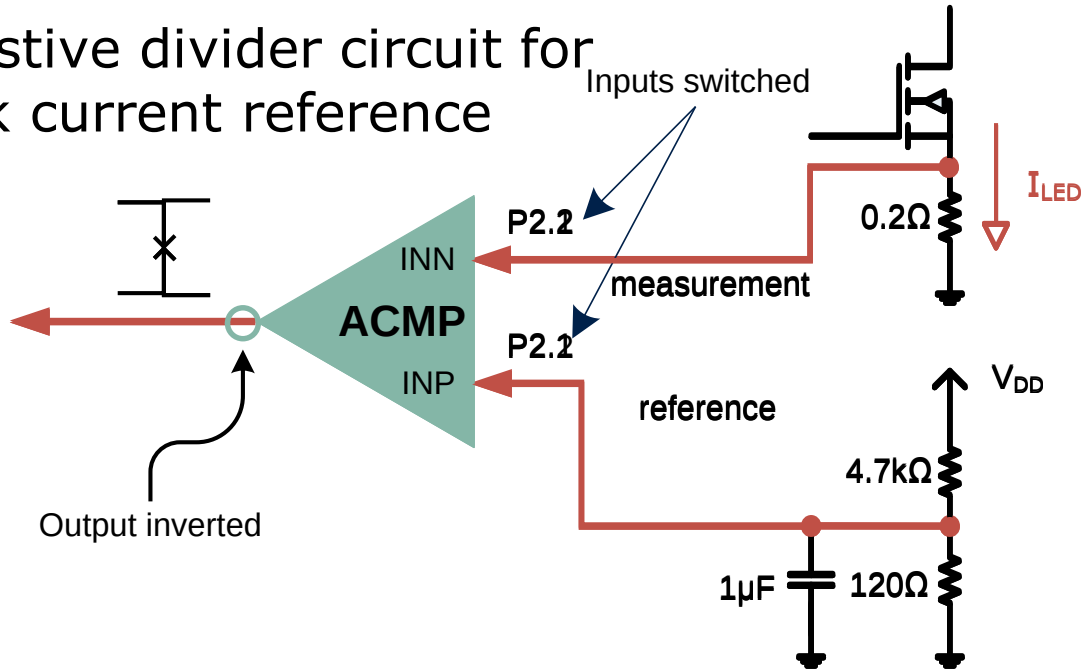
Peak Current Control – LED Current Control with XMC1 (7/13)



Peak Current Control – LED Current Control with XMC1 (8/13)

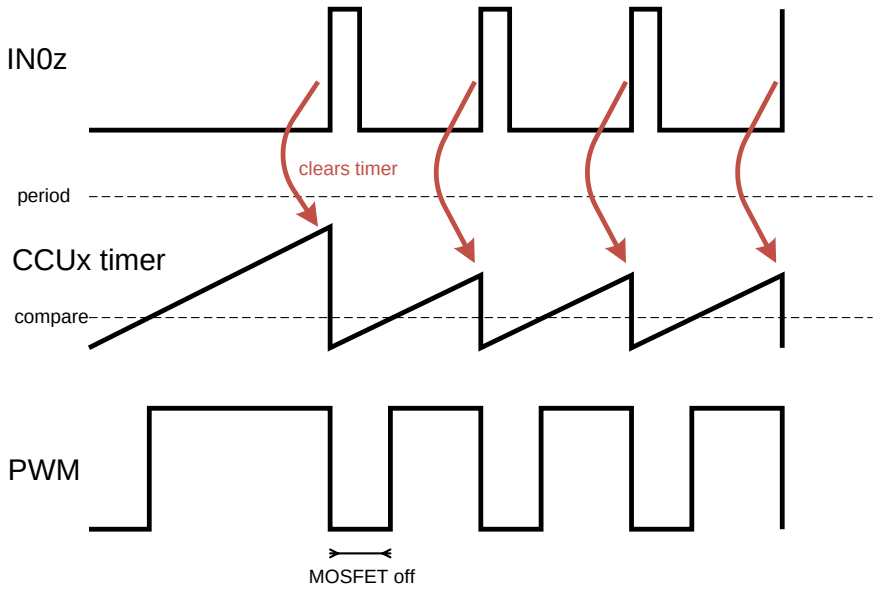
- ACMP Configuration
  - Filter active
  - Hysteresis OFF
  - Output inversion depends on input connections
  - Resistive divider circuit for peak current reference

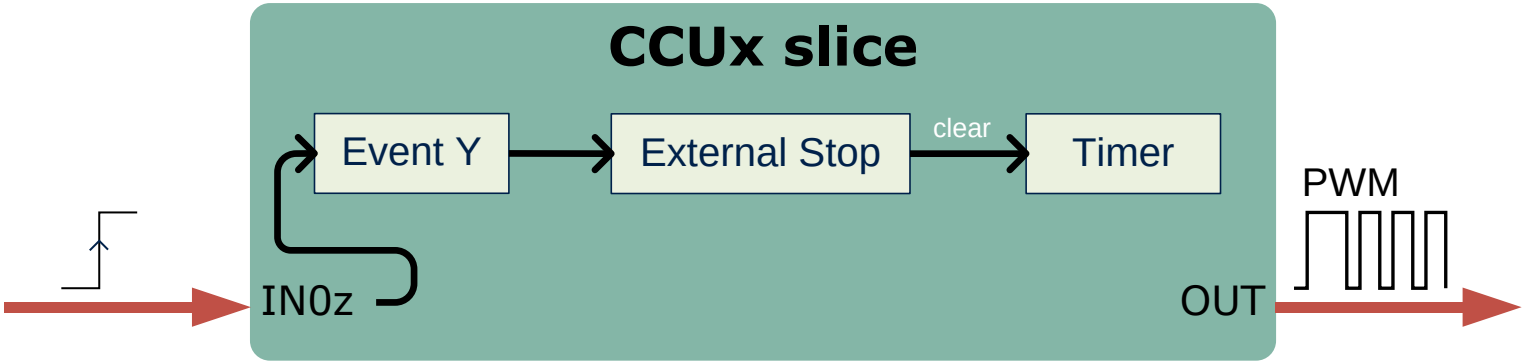




Peak Current Control – LED Current Control with XMC1 (9/13)

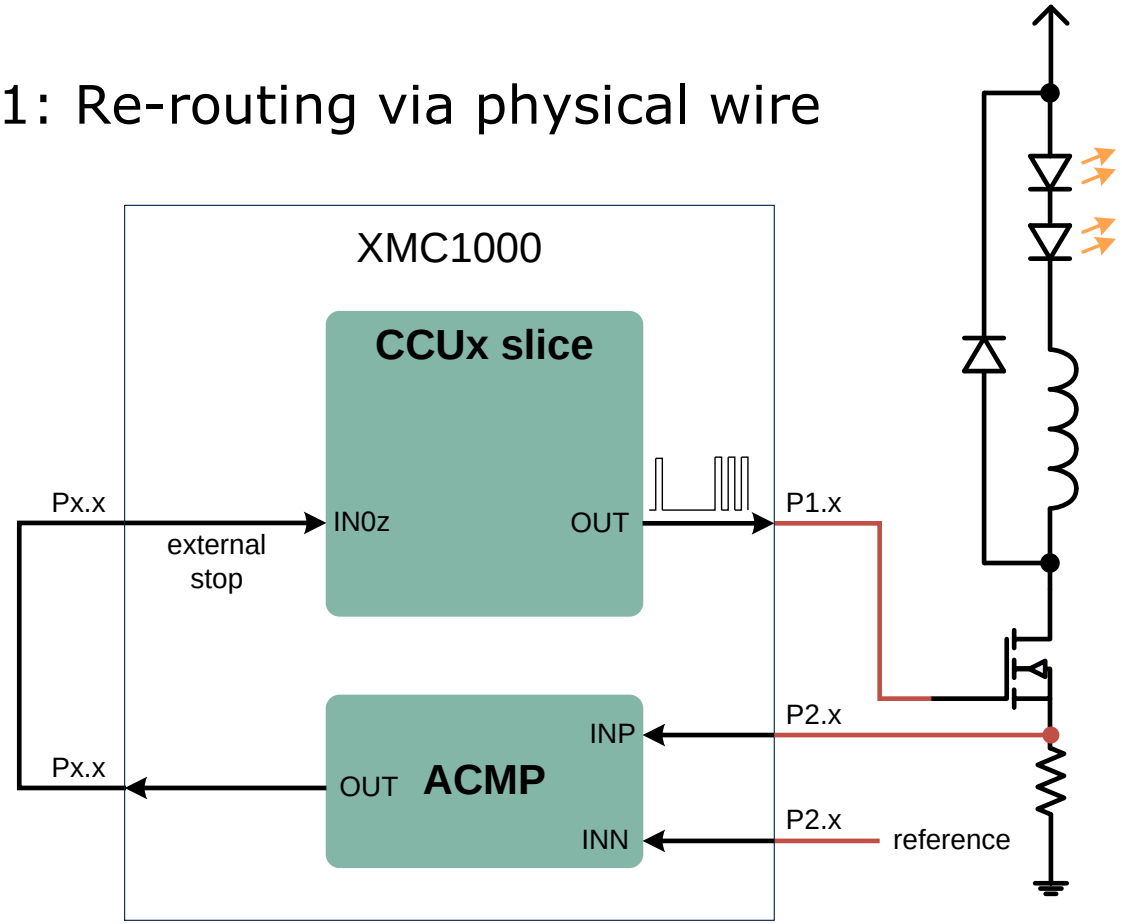
- CCUx Configuration
  - Event Y
    - Trigger on rising edge
    - Trigger external stop function
      - Clears timer (flush)





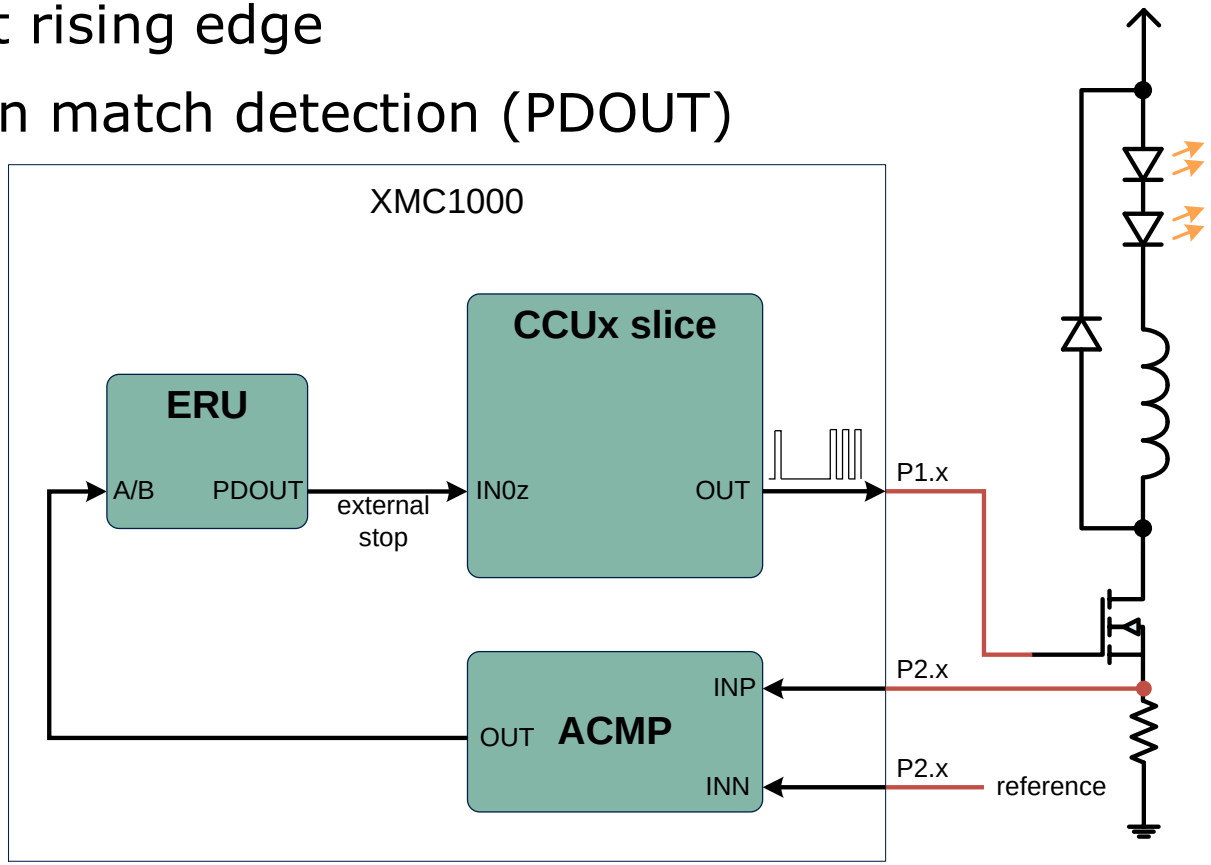
Peak Current Control – LED Current Control with XMC1 (10/13)

- No direct interconnection between ACMP and CCUx
- 2 options
  - Option 1: Re-routing via physical wire



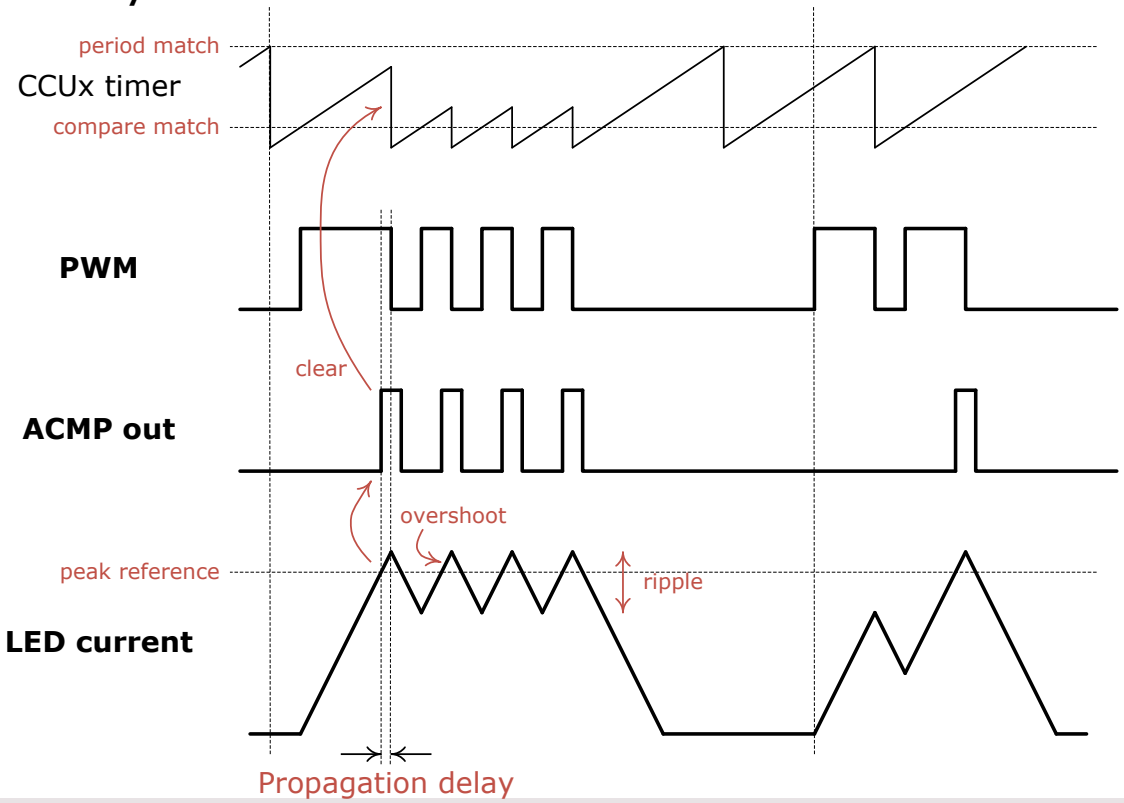
Peak Current Control – LED Current Control with XMC1 (11/13)

- Option 2: Re-routing via ERU
  - Direct input A or B
  - Detect rising edge
  - Pattern match detection (PDOUT)



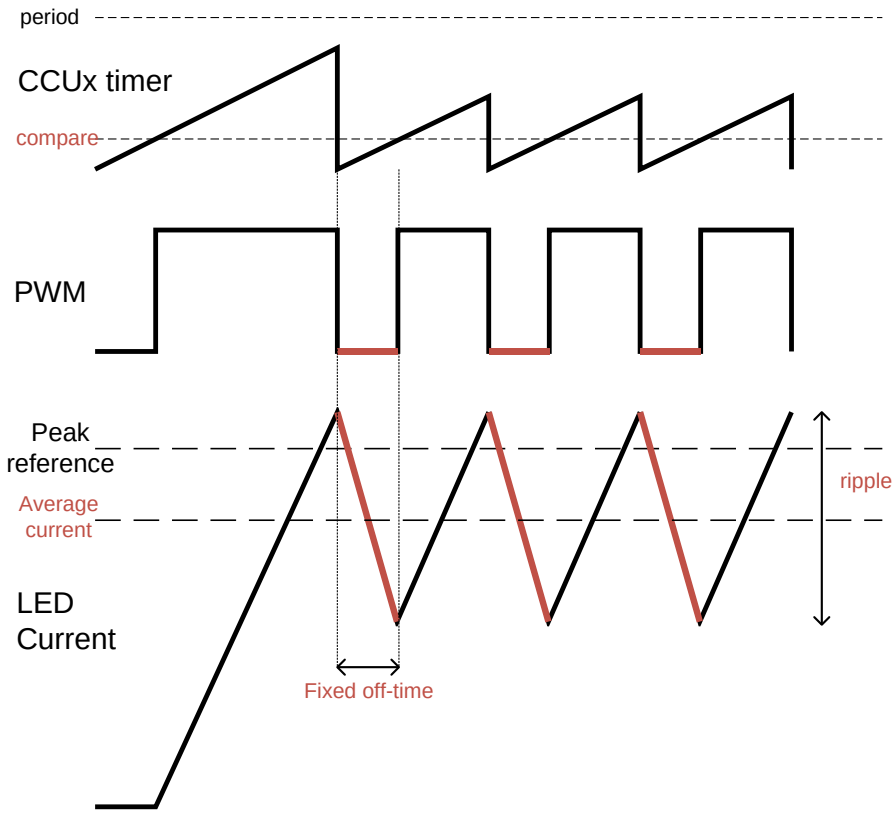
Peak Current Control – LED Current Control with XMC1 (12/13)

- Propagation delay
  - Between ACMP out trigger and clearing of CCUx timer
  - Results in LED current overshoot
  - Length of delay varies across routes



Peak Current Control – LED Current Control with XMC1 (13/13)

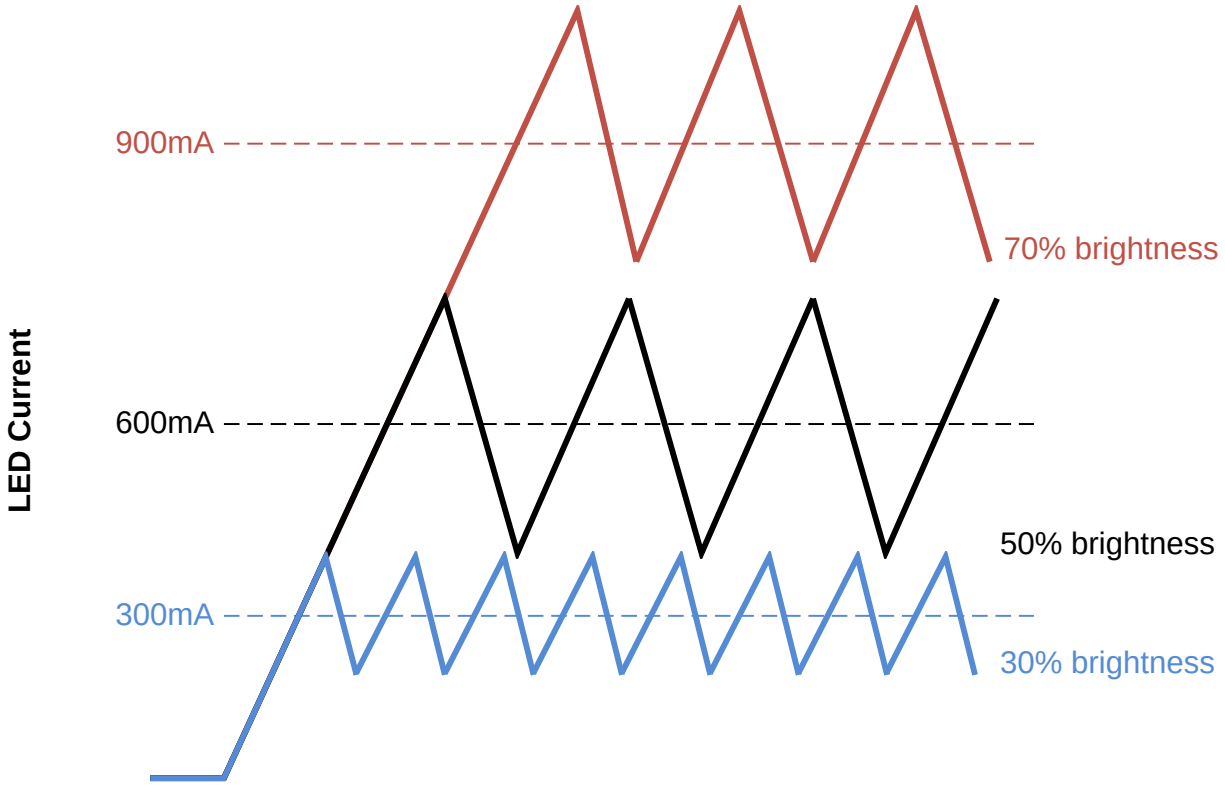
- CCUx timer compare value affects the MOSFET off-time
  - This affects the size of the current ripple (amount of current drop)
- LED average current is half of the current ripple
- Higher compare value = Larger ripple = Lower average current value
- Fixed off-time



2. Key Feature – Modulation Dimming

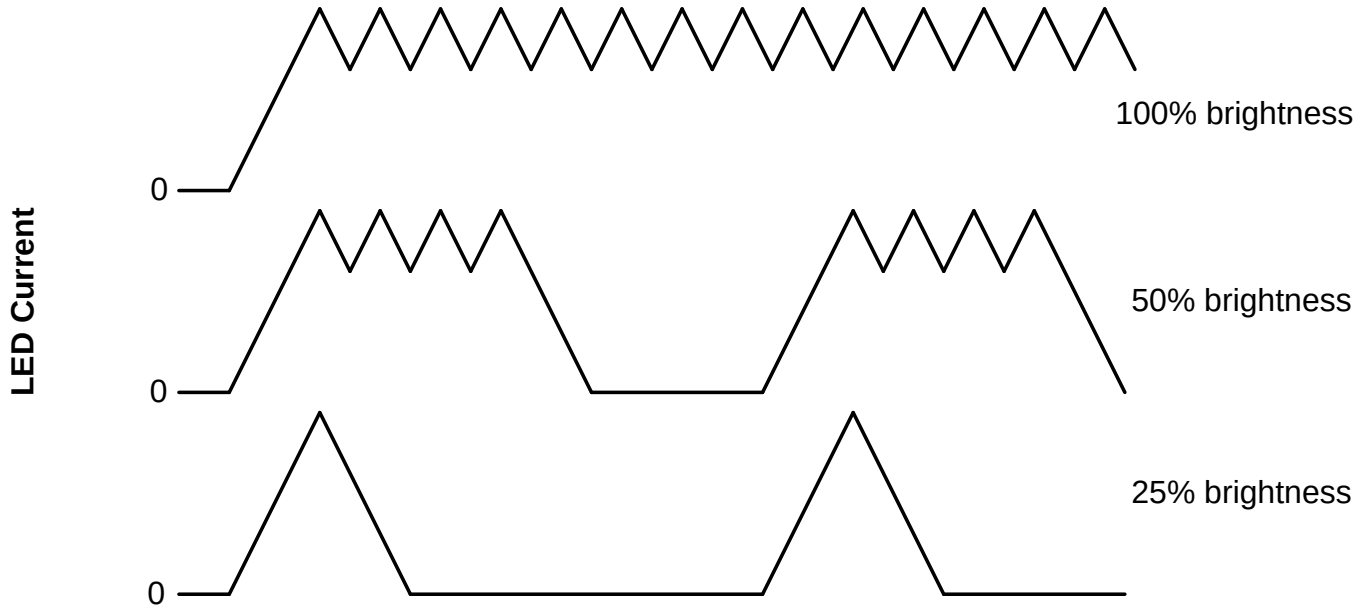
Modulation Dimming – Dimmable Current Control with XMC1 (1/8)

- LED brightness can be controlled by varying the LED current
- Also known as analog dimming
- **Disadvantage**: Non-linear relationship between current and brightness



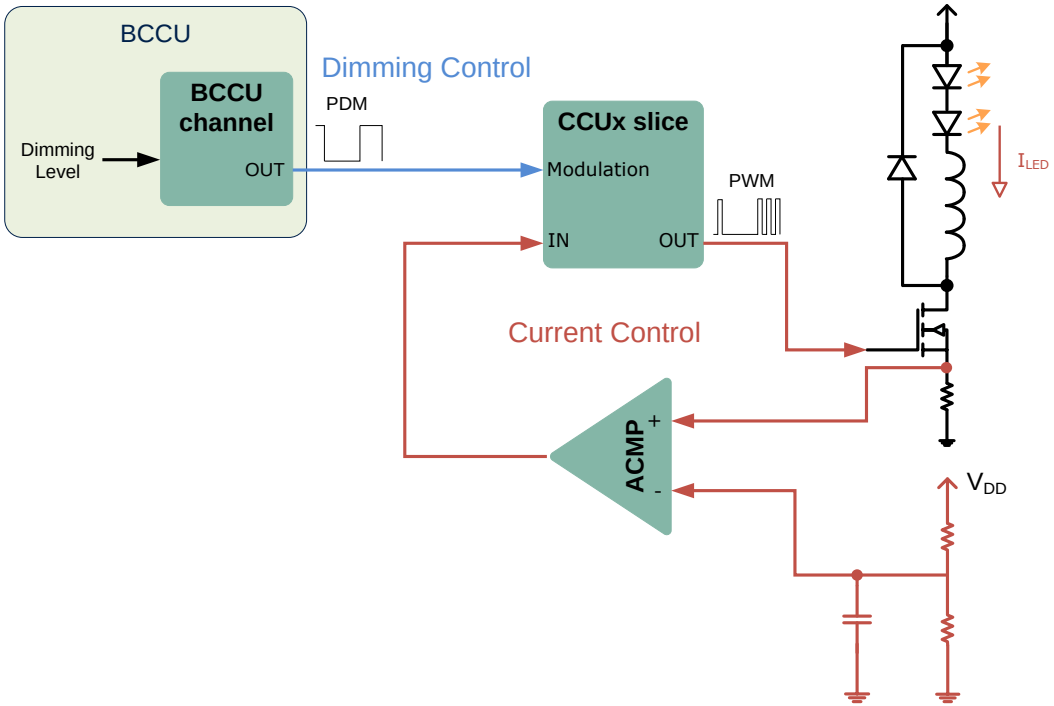
Modulation Dimming – Dimmable Current Control with XMC1 (2/8)

- Alternatively, LED brightness can be controlled by varying the duration of the LED current
  - i.e. MOSFET on-time
- Also known as modulation dimming
- **Advantage**: Linear relationship between on-time and brightness



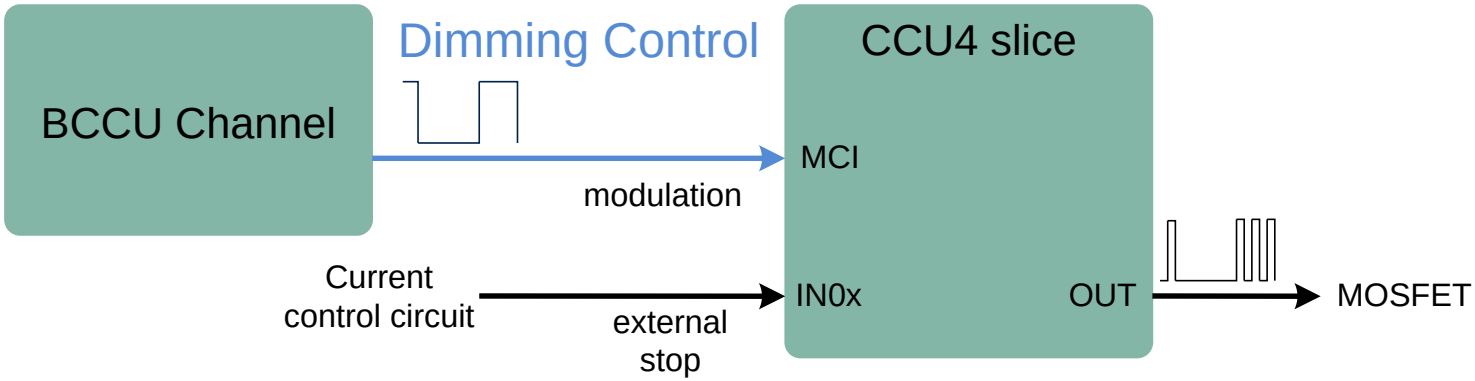
Modulation Dimming – Dimmable Current Control with XMC1 (3/8)

- BCCU channel generates PDM signal
  - Contains dimming level information
- PDM signal used as modulation input to CCUx slice
  - PWM signal is output only during PDM signal ON-times

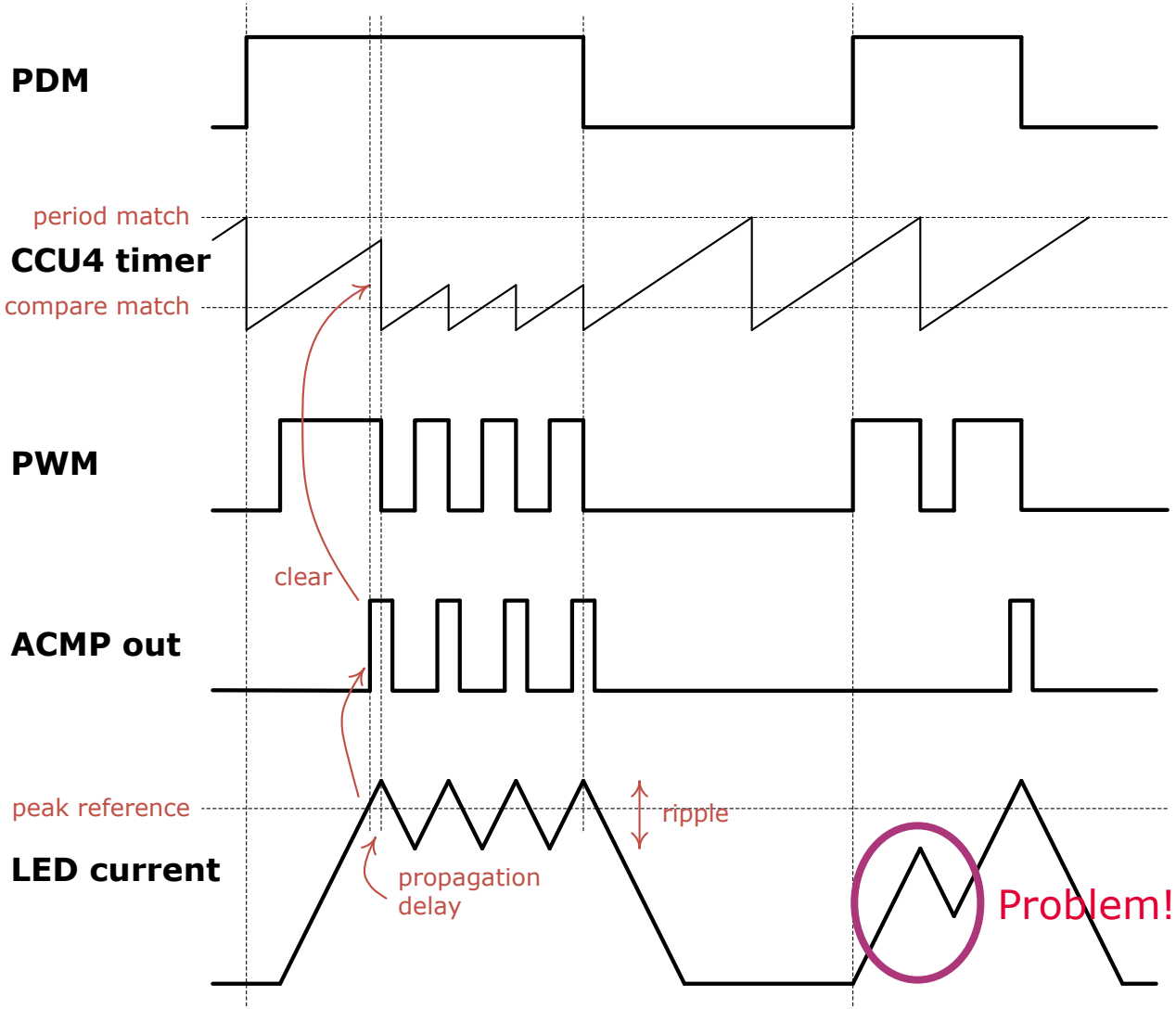


Modulation Dimming – Dimmable Current Control with XMC1 (4/8)

- Multi-channel mode enabled for CCU4 slice
  - PDM output used as multi-channel input control signal

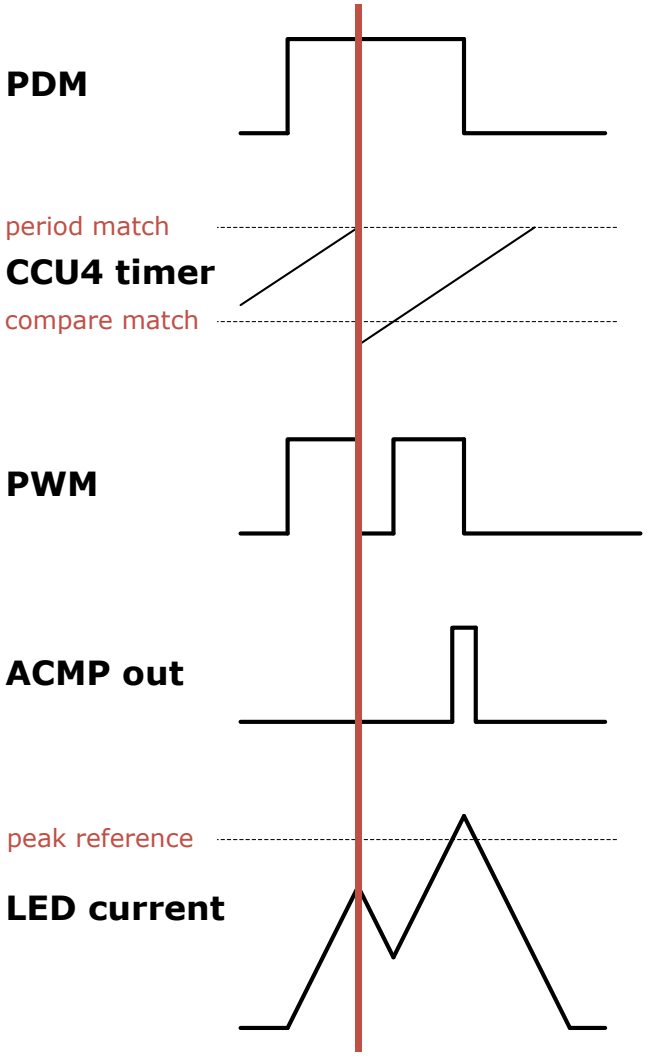


Modulation Dimming – Dimmable Current Control with XMC1 (5/8)



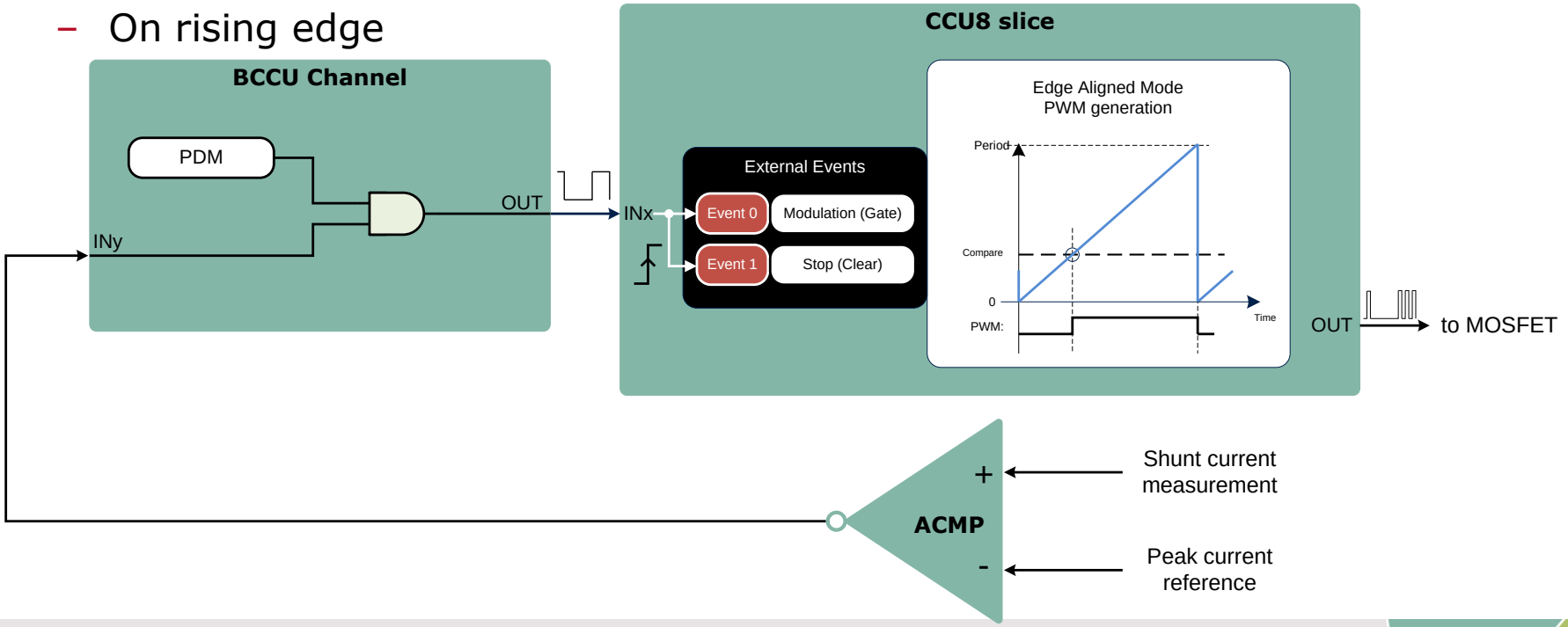
Modulation Dimming – Dimmable Current Control with XMC1 (6/8)

- CCU4 timer period match reached before LED current reaches peak reference value
- Effect
  - A momentary drop in average LED current value
  - Noticed as shimmer at low brightness levels
- Workaround
  1. Set CCU4 period value to max to minimize occurrence
  2. Use CCU8 instead of CCU4

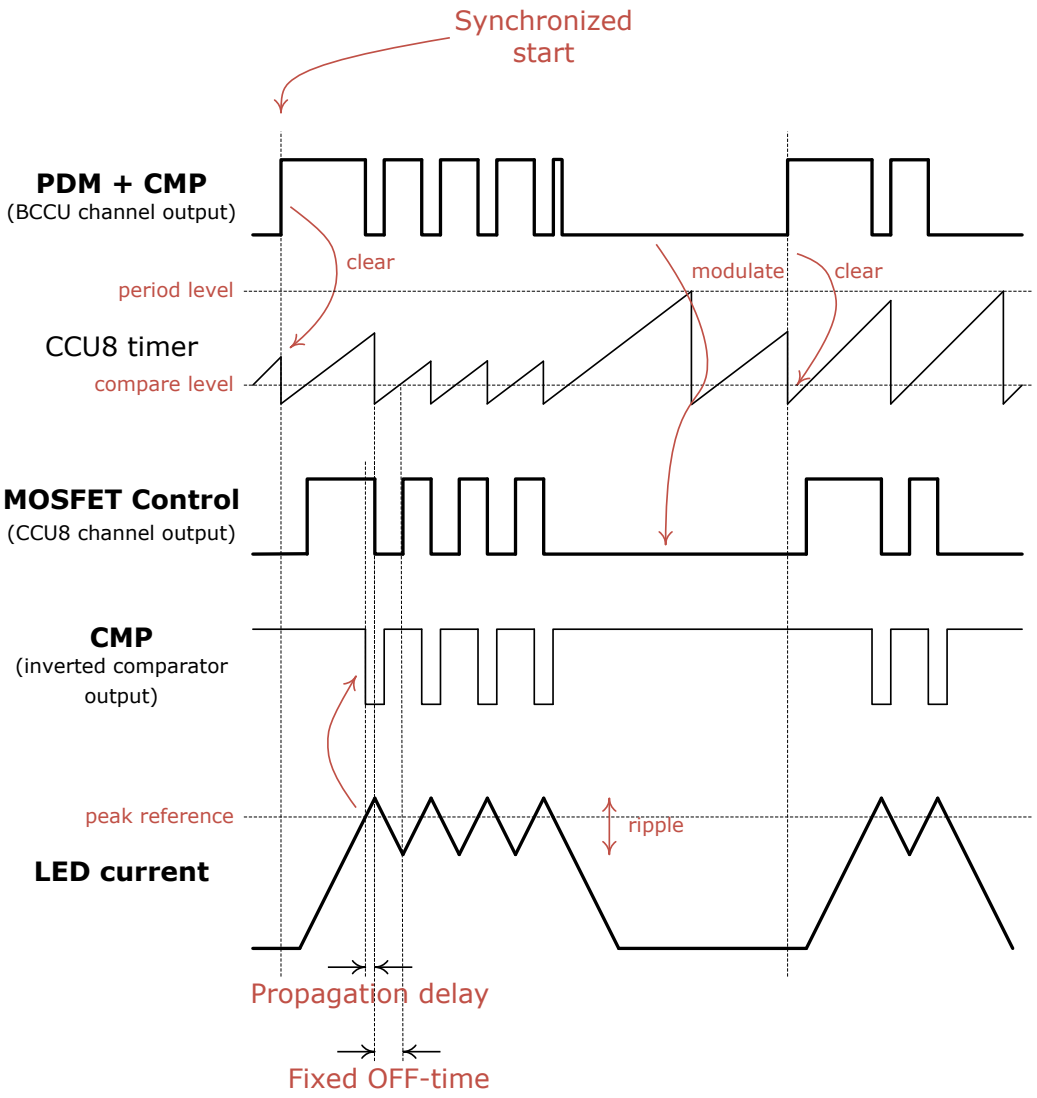


Modulation Dimming – Dimmable Current Control with XMC1 (7/8)

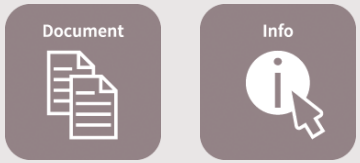
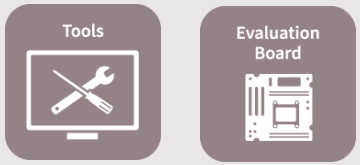
- Inverted ACMP out as gating input to BCCU channel
- BCCU output as input to CCU8 slice for 2 external events
  1. Modulation (gate CCU8 output)
     - Not synchronized
  2. Stop (clear timer)
     - On rising edge



Modulation Dimming – Dimmable Current Control with XMC1 (8/8)



Support material:

Collaterals and Brochures 	› Product Briefs › Selection Guides › Application Brochures › Presentations › Press Releases, Ads	› www.infineon.com/XMC
Technical Material 	› Application Notes › Technical Articles › Simulation Models › Datasheets, MCDS Files › PCB Design Data	› www.infineon.com/XMC › Kits and Boards › DAVE™ › Software and Tool Ecosystem
Videos 	› Technical Videos › Product Information Videos	› Infineon Media Center › XMC Mediathek
Contact 	› Forums › Product Support	› Infineon Forums › Technical Assistance Center (TAC)

Glossary abbreviations

- ACMP Analog Comparator
- BCCU Brightness and Color Control Unit
- CCM Continuous Conduction Mode
- CCU Capture/Compare Unit
- DAVE™ Free development IDE for XMC™
- ERU Event Request Unit
- LED Light Emitting Diode
- MOSFET Metal-oxide-semiconductor field-effect transistor
- PDM Pulse-density Modulation
- PWM Pulse Width Modulation

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