

EE-334

Digital System Design

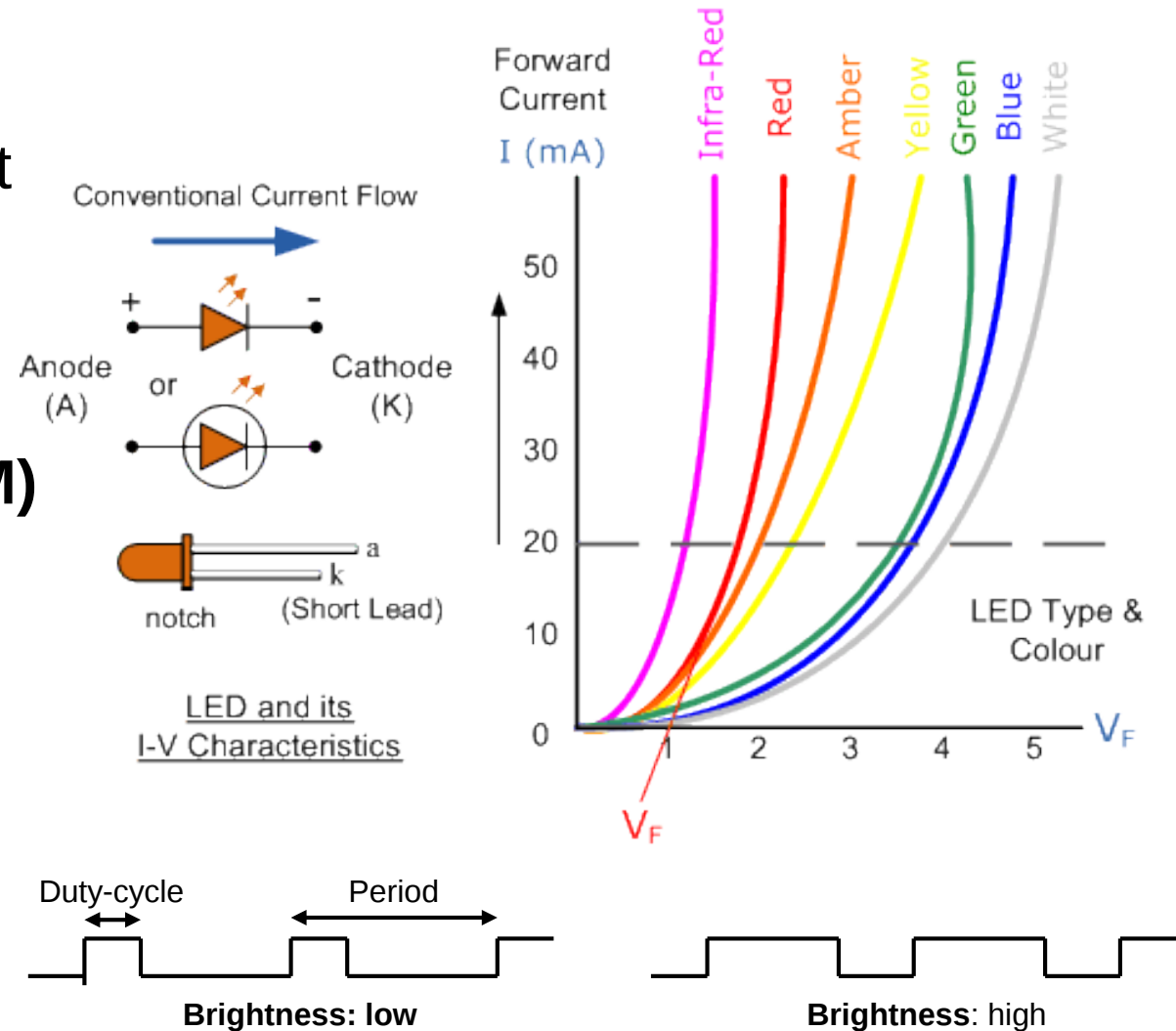
Discussion for Exercise 2
PWM for Color LEDs

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Pulse Width Modulation (PWM)

Modulating the brightness of an LED:

- Brightness is a function of the current, but
 - Current modulation with voltage is difficult
 - No ADC easily available on the board
- Solution: **Pulse Width Modulation (PWM)**
 - Duty-cycling of the LED (On/Off)
 - **Duty-cycle (%)** determines **brightness**
 - Pulse **frequency (period)**:
 - Avoid flickering: $> 100 \text{ Hz}$
 - Below low-pass characteristic of the LED and the IO circuitry/drivers: $\sim < \text{MHz}$

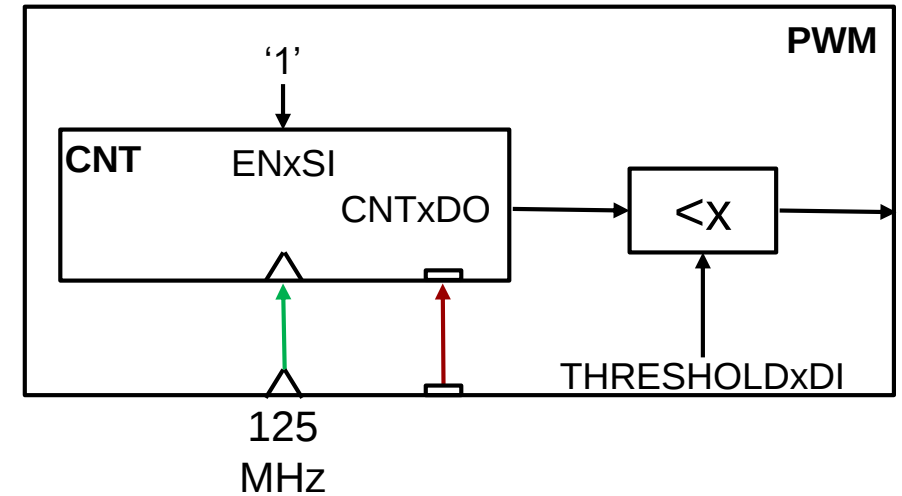
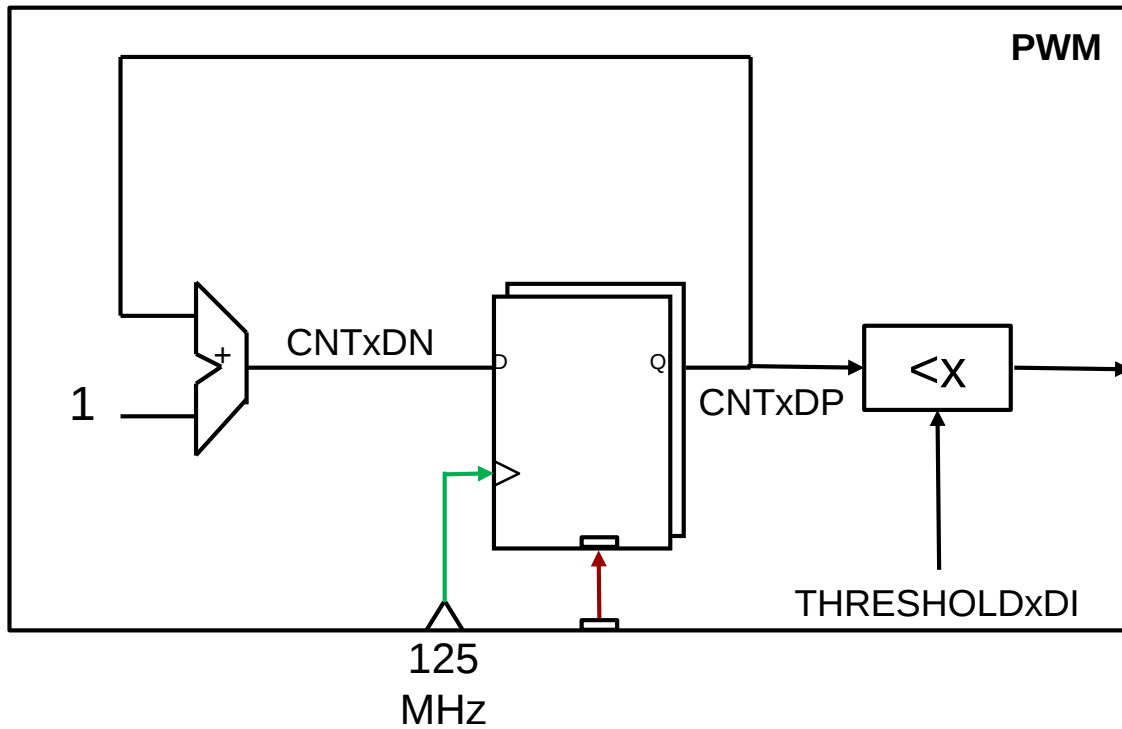


Required Components / Logic Functions

- Track the time within a single period of the PWM → Counter (free running)
- Specify the duration N of the on-phase of the LED in number of cycles. Increase the duration when a button is pressed (by a given offset) → Counter (Enabled)
- Set output to '1' during on-phase (first N cycles) and to '0' during off-phase (remaining PWM period cycles) → Comparator
- Detect when a button is pressed to increment the duration counter (only 1 increment, even when button is pressed for many cycles). → Edge Detector

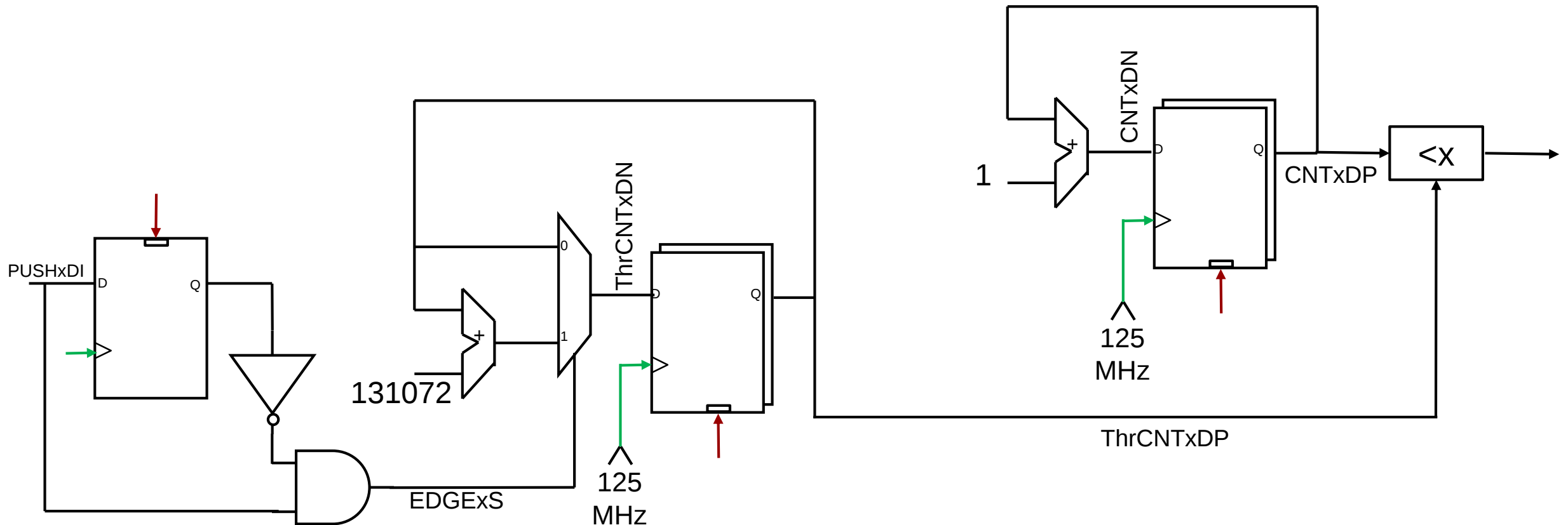
PWM

- Free running counter compared with a threshold



PWM with Tunable Threshold

- PWM threshold defined by incrementable counter
 - Triggered by an edge detector to avoid multiple counts at once



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