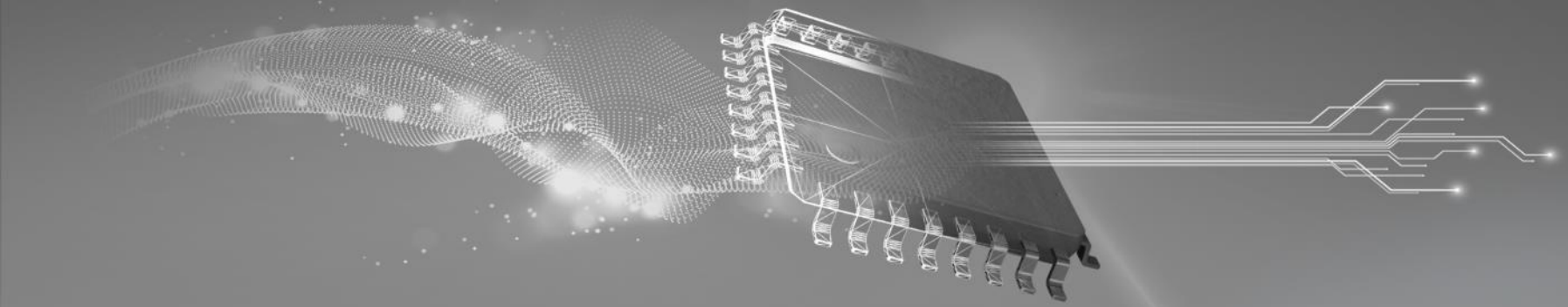
TI TECH DAYS



New TI Smart AFE and Smart DAC for adding intelligence to analog without software at low cost

Uttama Sahu

Systems Engineer - Data Converters (DAC products)

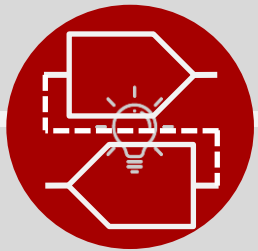
Texas Instruments

Abstract

- Automotive system designers often need simple software (SW) solutions to attain predictable system power up and tunable set points
- Innovative Smart AFE and Smart DAC portfolio provides simple intelligence to an analog system designer without the need for MCUs
- TI's Smart Analog products, have NVM and factory programmable state machines, internal ADCs, DACs, PWM generators, custom waveform generators
- Analog and SW engineers can save cost, remove tiny MCUs, expedite design cycles, and improve quality

Smart DACs

Control w/o software



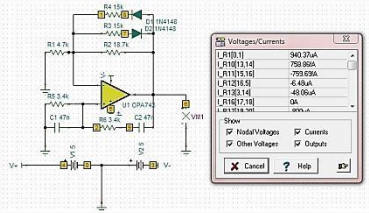
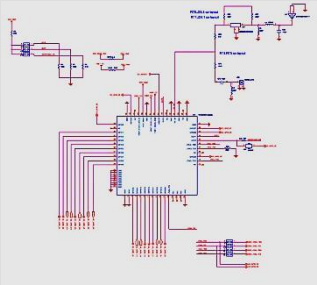
Smart AFEs

Sensing and control w/o software

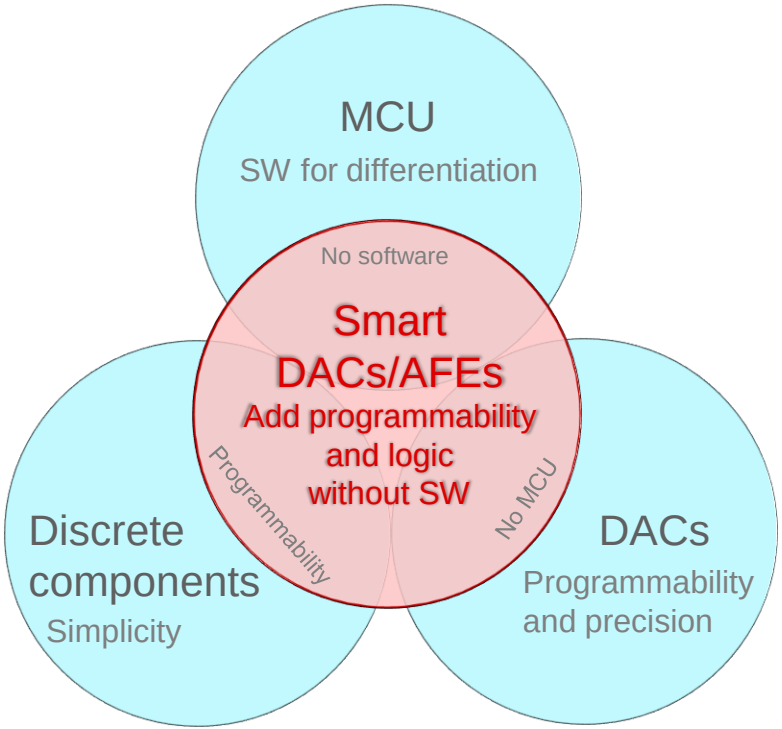
Agenda

- Current day challenges in automotive electronics
- What is Smart Analog
- Automotive applications
  - Stop tail lighting
  - Single slope thermal foldback
  - Multi slope thermal foldback
  - License plate fade-in fade-out lighting
  - Custom lighting animations
- Conclusions

Challenges in automotive lighting electronics

	Design	Pros	Cons
Discrete circuit		• Low Cost • Optimized design	• Difficult to design • Difficult to scale / reuse • Needs strong analog design expertise • Many components
MCU-based circuit		• Manages complexity • Easy to reuse	• Software dependence for simple logic and configuration • Higher R&D time and cost • Software maintenance and certification overhead

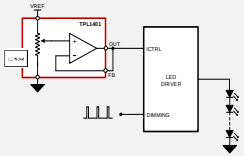
Why Smart DACs and Smart AFEs



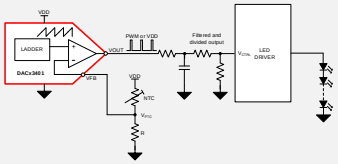
Analog design is fun. Adding programmability is not … **Now you have Smart DACs and Smart AFEs**

What is a Smart DAC? - control w/o software

TPL1401



Programmable current limit



DAC53401

LED dimming

PWM

NVM

Comparator

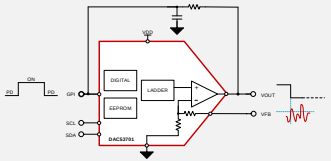
DAC

(Ultra Low-Power)

GPI Trigger

Hi-Z

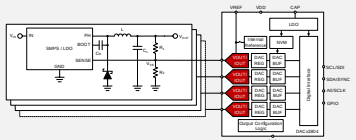
Alarm



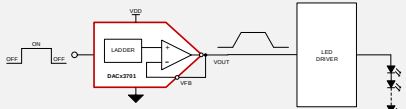
DAC53701

Latching comparator

DAC53204



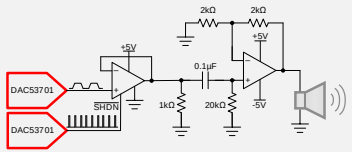
Hassle-free voltage margining



Change output with GPI trigger

DAC53701

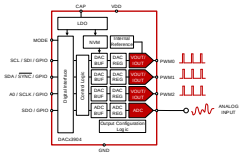
DAC53701



Alarm when MCU fails

Texas Instruments

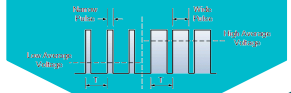
What is Smart AFE? - sensing and control (w/o software)



Analog to PWM

AFE53904B-Q1

PWM

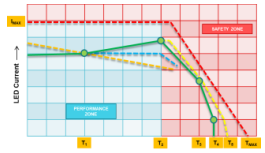


NVM

DAC

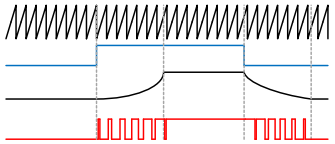
ADC

AFE53902-Q1



IF-THIS-THEN-THAT control

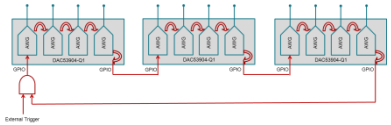
DAC53902-Q1



Logarithmic fade-in fade-out

GPI Trigger

State Machine



Cascaded animation

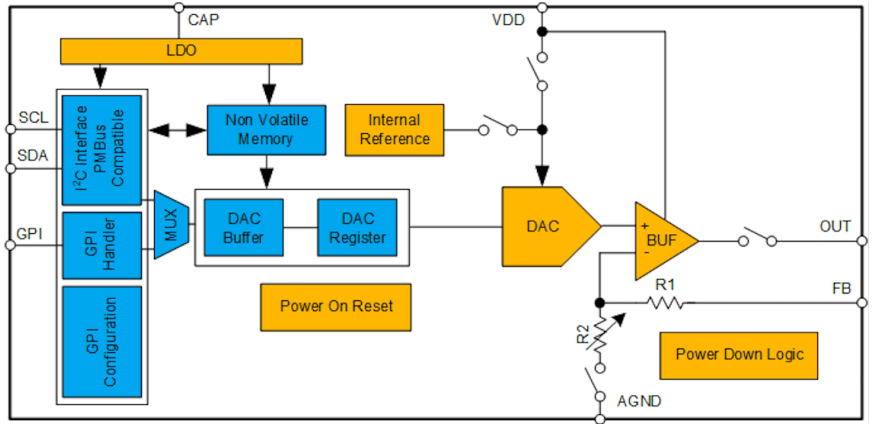
DAC53904-Q1

An example Smart DAC

- GPIO configurable as power-down, PWM input, function trigger, or fade-in fade-out trigger
- User programmable Nonvolatile memory
- PWM output using free-running triangular waveform and FB pin
- I2C interface

- Wide Temperature range: -40°C to +125°C
- Small package WQFN-8 (2x2)

DAC53701-Q1

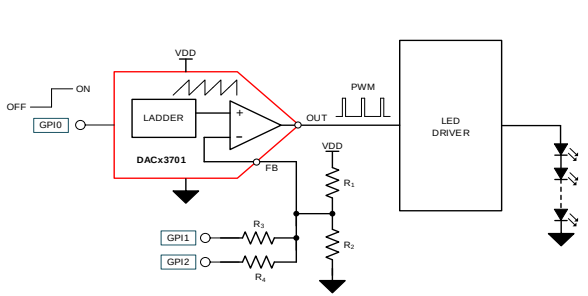


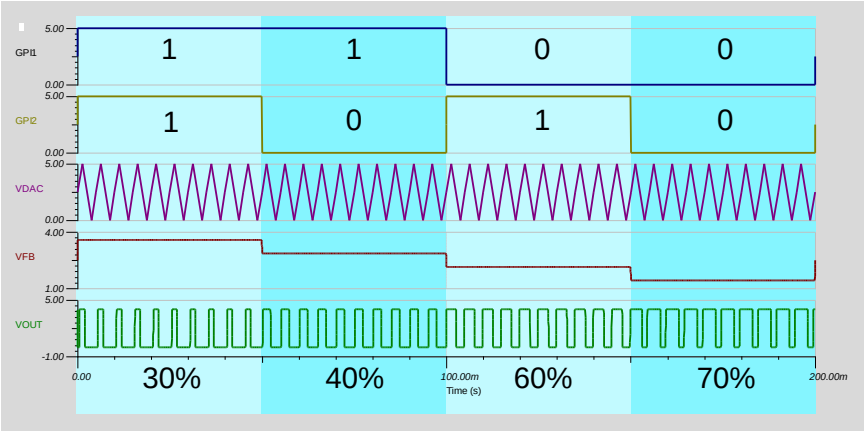
STOP tail lighting

- PWM (~200 Hz) with constant duty cycle
- GPI based dimming when trunk is opened or closed
- Software programmability of PWM frequency through triangular / sawtooth waveform
- Better intensity matching between the trunk and fender lights (< 1% duty cycle accuracy) as compared to 555 timers

$$f_{TRIANGLE-WAVE} = \frac{1}{2 \times SLEW\_RATE \times \left(\frac{MARGIN\_HIGH - MARGIN\_LOW + 1}{CODE\_STEP} \right)}$$

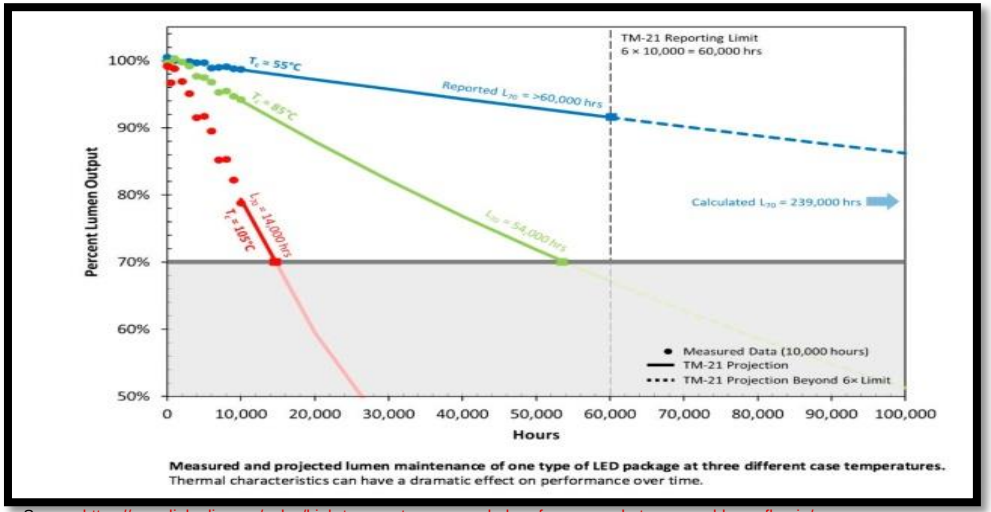
$$f_{SAWTOOTH-WAVE} = \frac{1}{SLEW\_RATE \times \left(\frac{MARGIN\_HIGH - MARGIN\_LOW + 1}{CODE\_STEP} \right)}$$





LED and temperature

LED reliability



Source: https://www.linkedin.com/pulse/high-temperature-enemy-led-performance-what-you-need-know-floroiu/

Daytime running light (DRL)

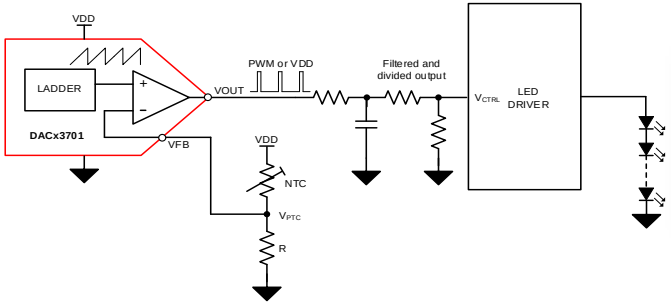
- LED reliability is significantly determined by the operating temperature
- LEDs in DRLs are heated by both self-heating and sunlight

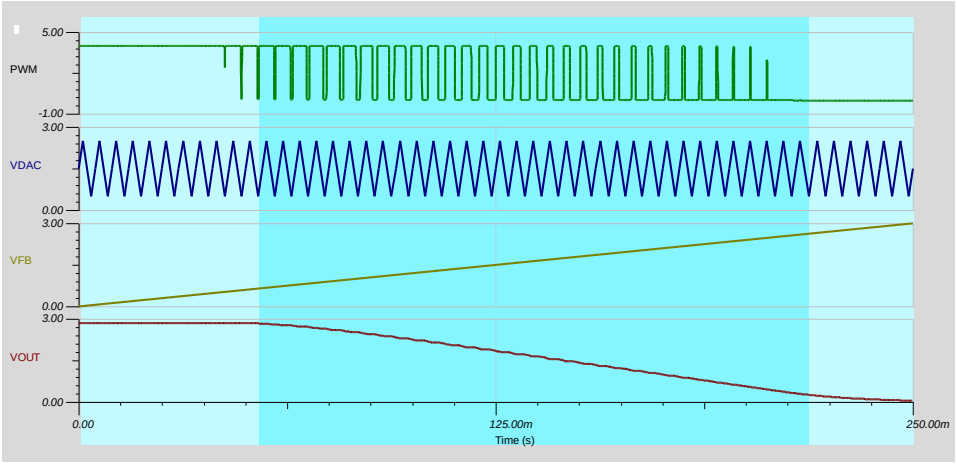
Single-slope thermal foldback

- Processor-less single-slope thermal foldback for DRL
- Software programmable knee point and slope
- PWM with duty cycle following foldback curve
- Software programmability of PWM frequency through triangular / sawtooth waveform
- Optional voltage output with RC filter

$$f_{TRIANGLE-WAVE} = \frac{1}{2 \times SLEW\_RATE \times \left(\frac{MARGIN\_HIGH - MARGIN\_LOW + 1}{CODE\_STEP} \right)}$$

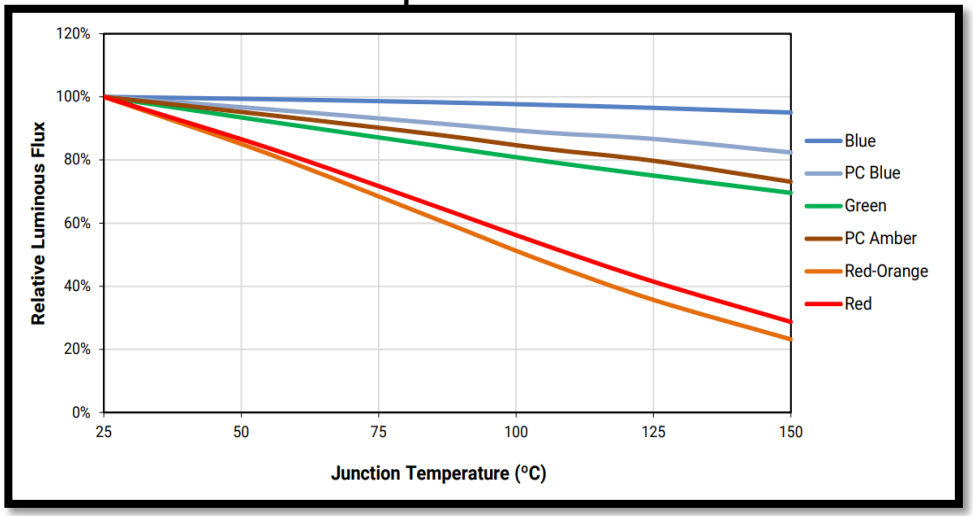
$$f_{SAWTOOTH-WAVE} = \frac{1}{SLEW\_RATE \times \left(\frac{MARGIN\_HIGH - MARGIN\_LOW + 1}{CODE\_STEP} \right)}$$





LED and temperature

LED performance

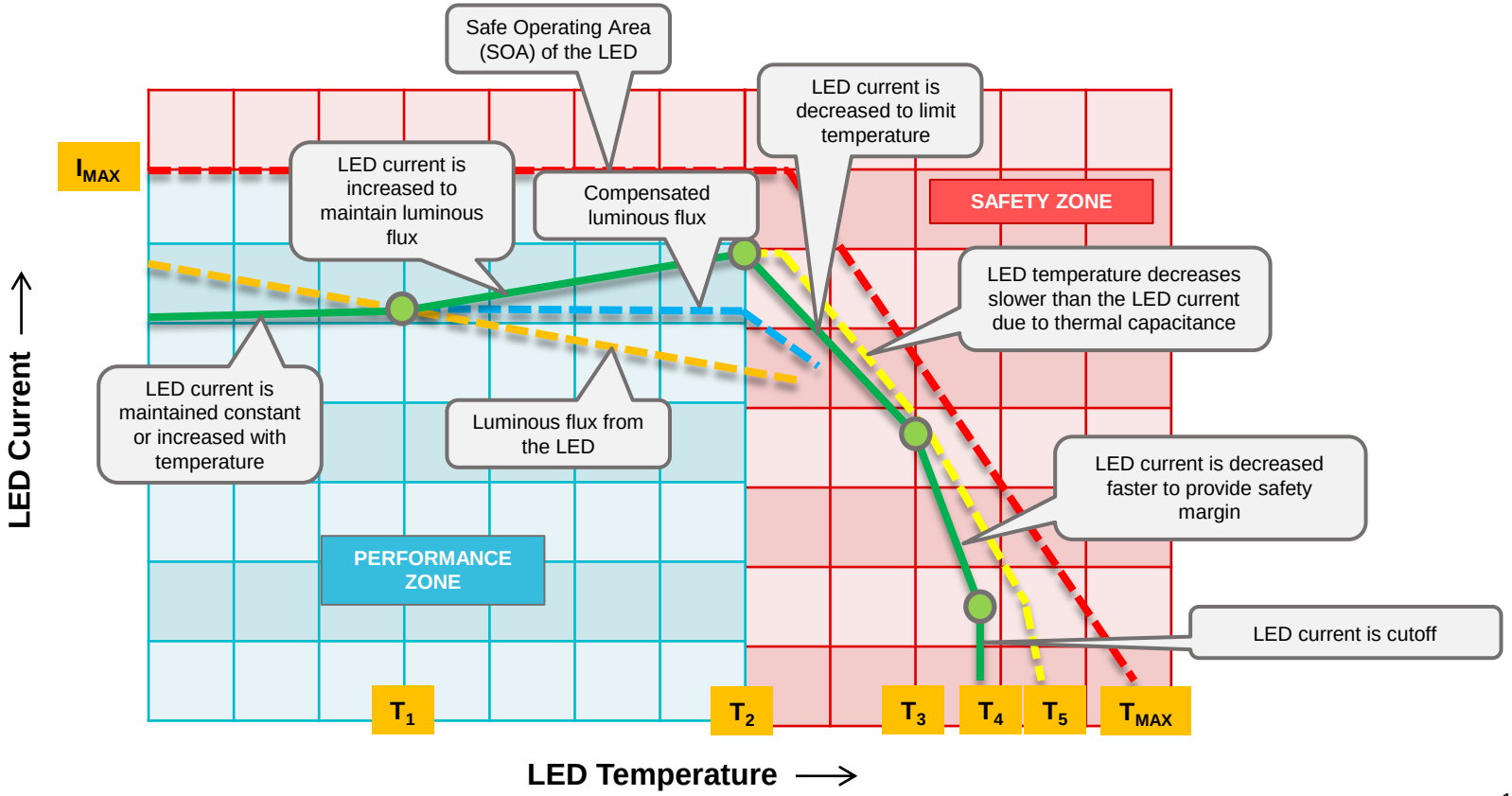


Source: https://www.cree.com/led-components/

Tail light

- The LED luminous flux output reduces with temperature. For example, at 75°C the performance of a LED can be 5%-70% less than the specified value
- This phenomena is more pronounced with RED LEDs as compared to other colors

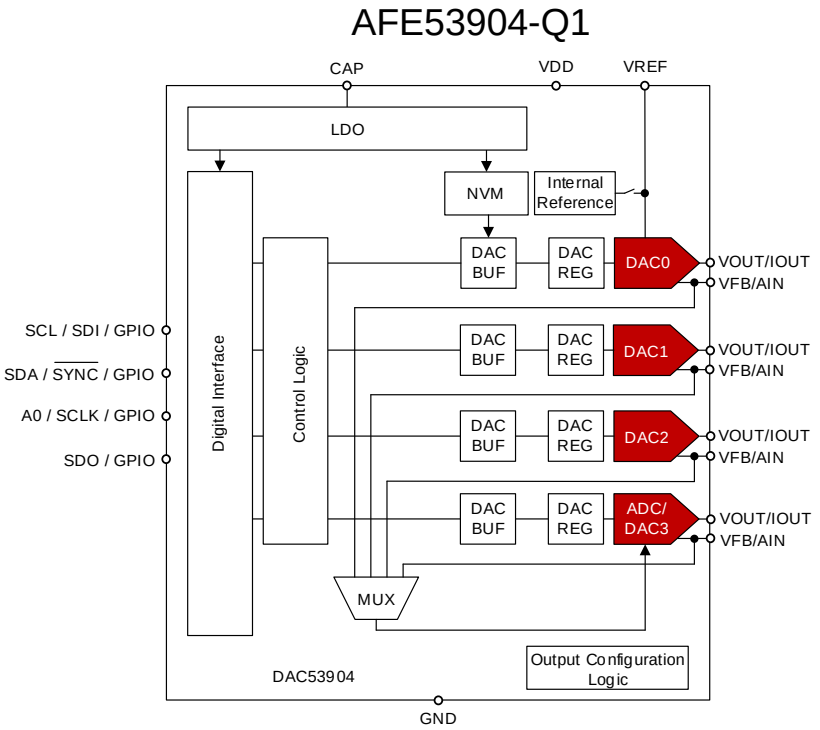
Multi-slope thermal foldback



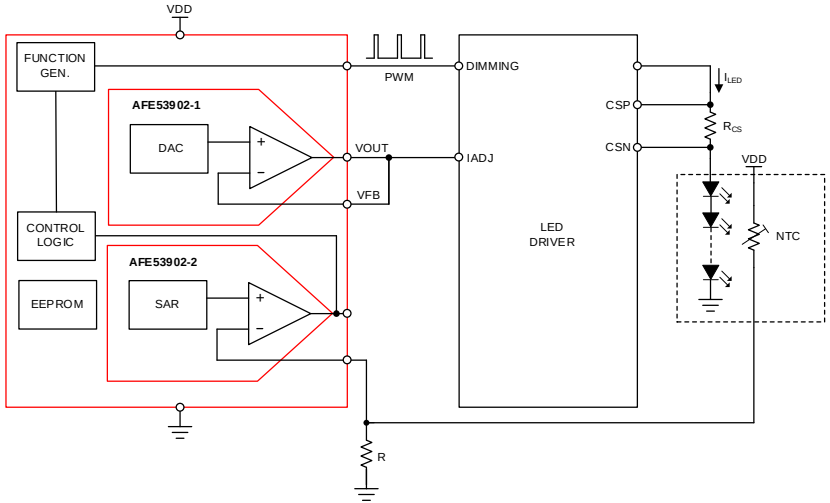
An example Smart analog frond end (AFE)

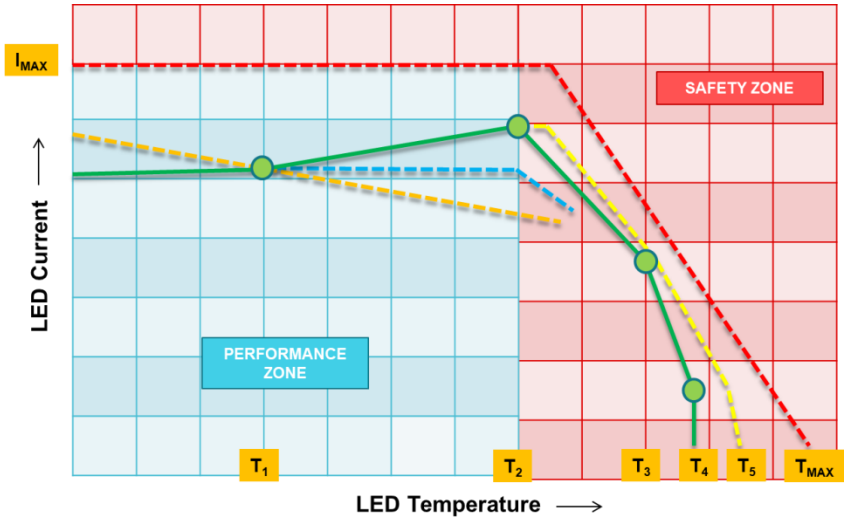
- User programmable Nonvolatile Memory (NVM/EEPROM)
- I2C and SPI mode auto-detection
- GPIO interface
- PWM output
- Hi-Z output during power-off condition
- 10-bit ADC mode for all channels
- Control logic that supports look-up table and closed-loop control

- Wide Temperature range: -40°C to +125°C
- Small package WQFN-16 (3x3)



Multi-slope thermal foldback using AFE53902-Q1

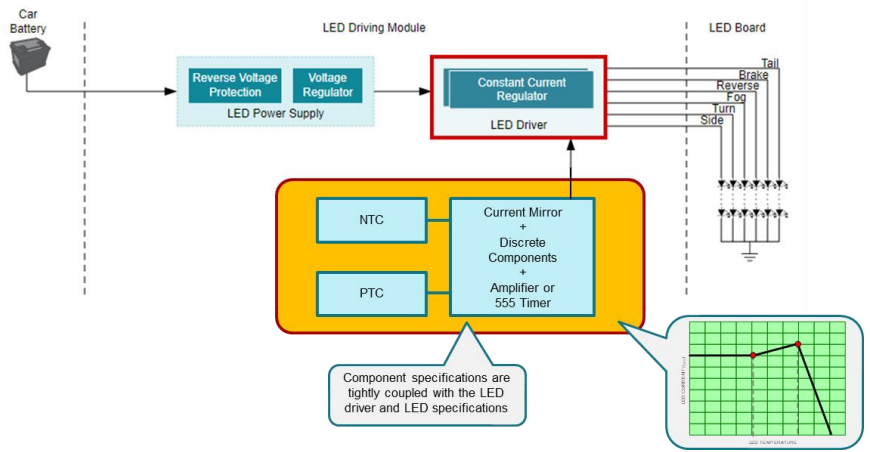




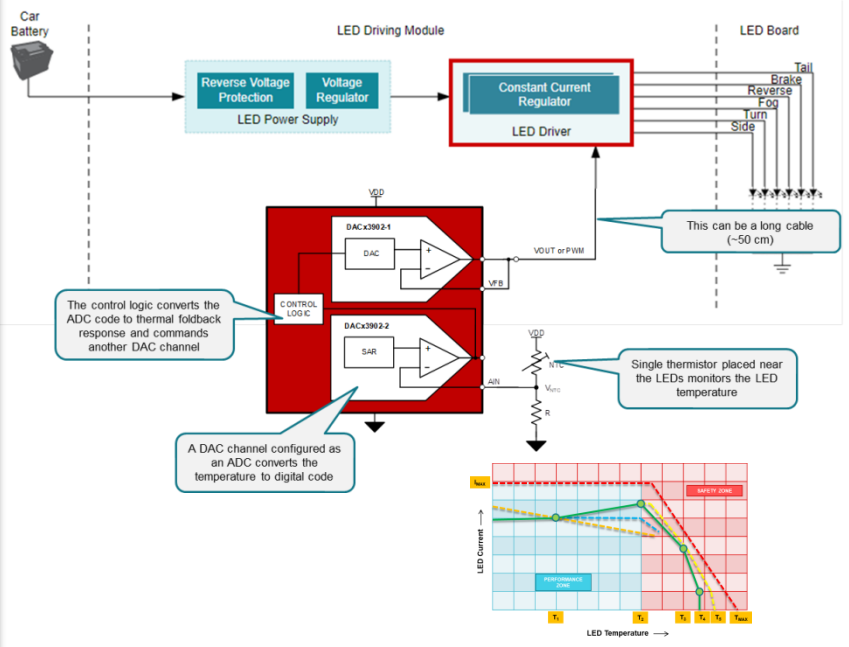
- One DAC channel and one ADC channel
- NTC is directly interfaced to ADC
- In-built linearizer for NTC output
- Look-up table to program the foldback points and slopes
- PWM or voltage output option

Thermal foldback: Smart AFE differentiation

Existing solution (dual-slope)

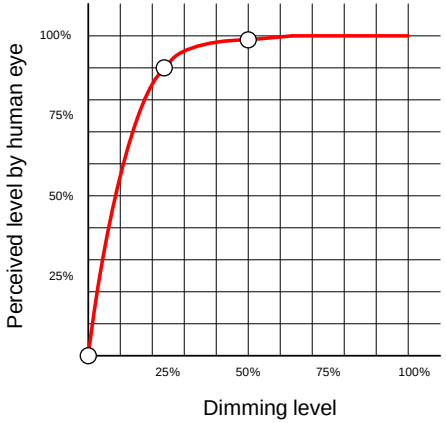


Smart AFE solution (programmable multi-slope)



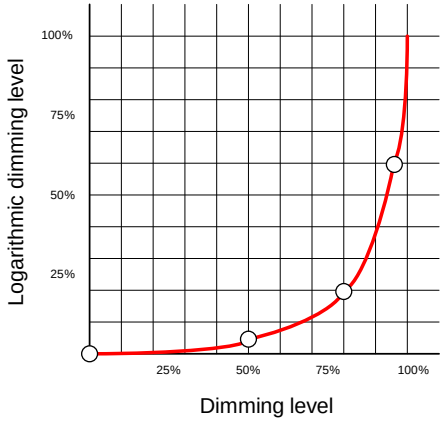
LED dimming and human eye perception

Human eye perception



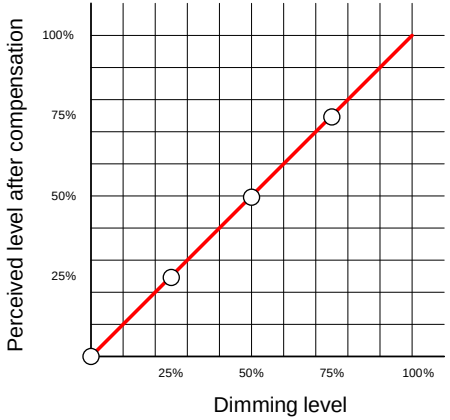
+

Logarithmic dimming

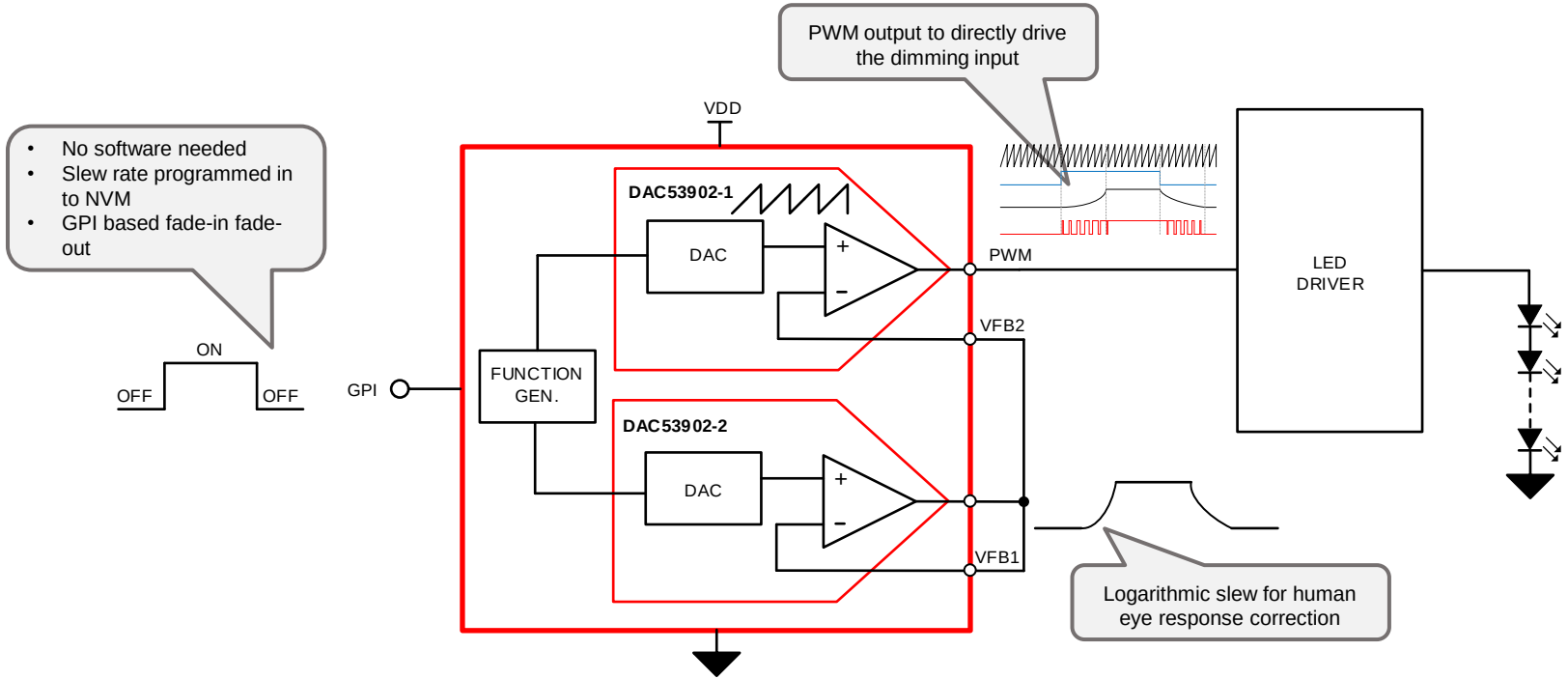


=

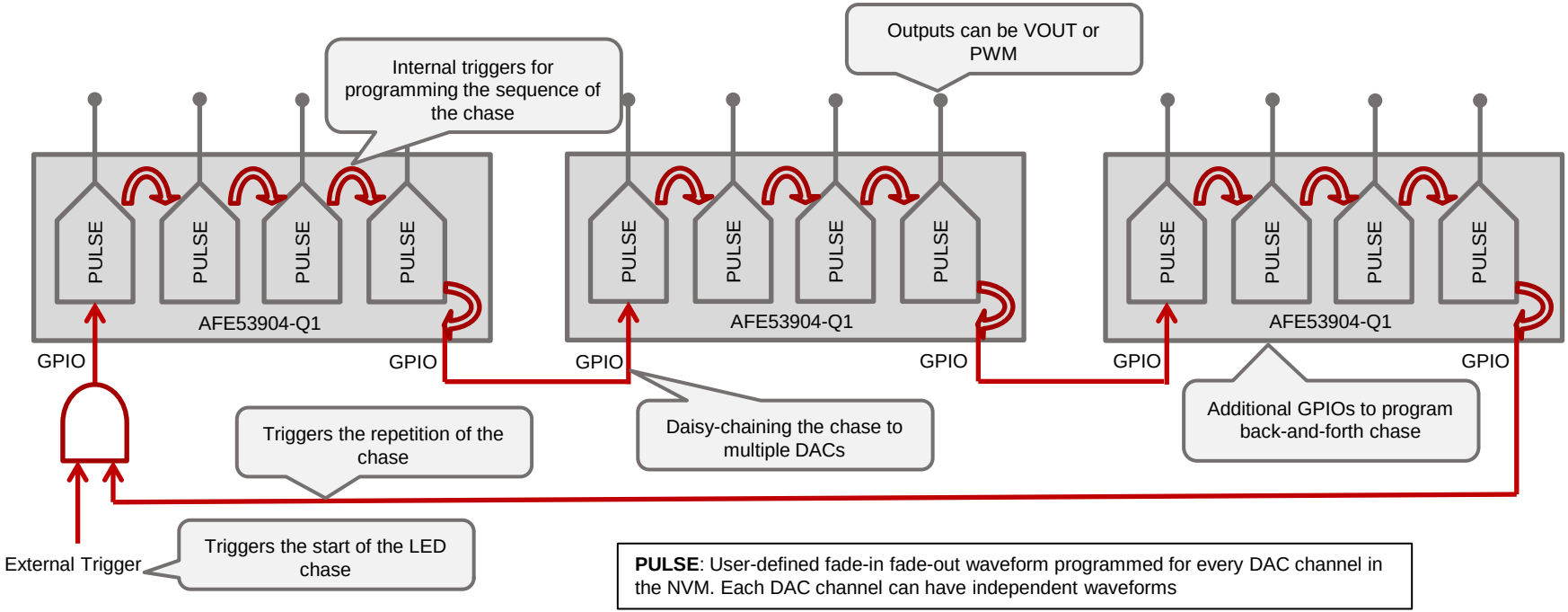
Correct perception



Fade-in fade-out with human eye response

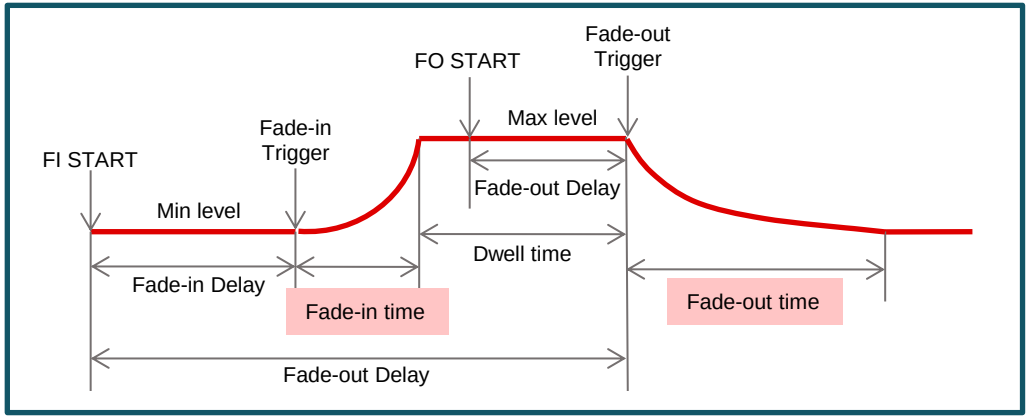


LED animation: DAC53904-Q1

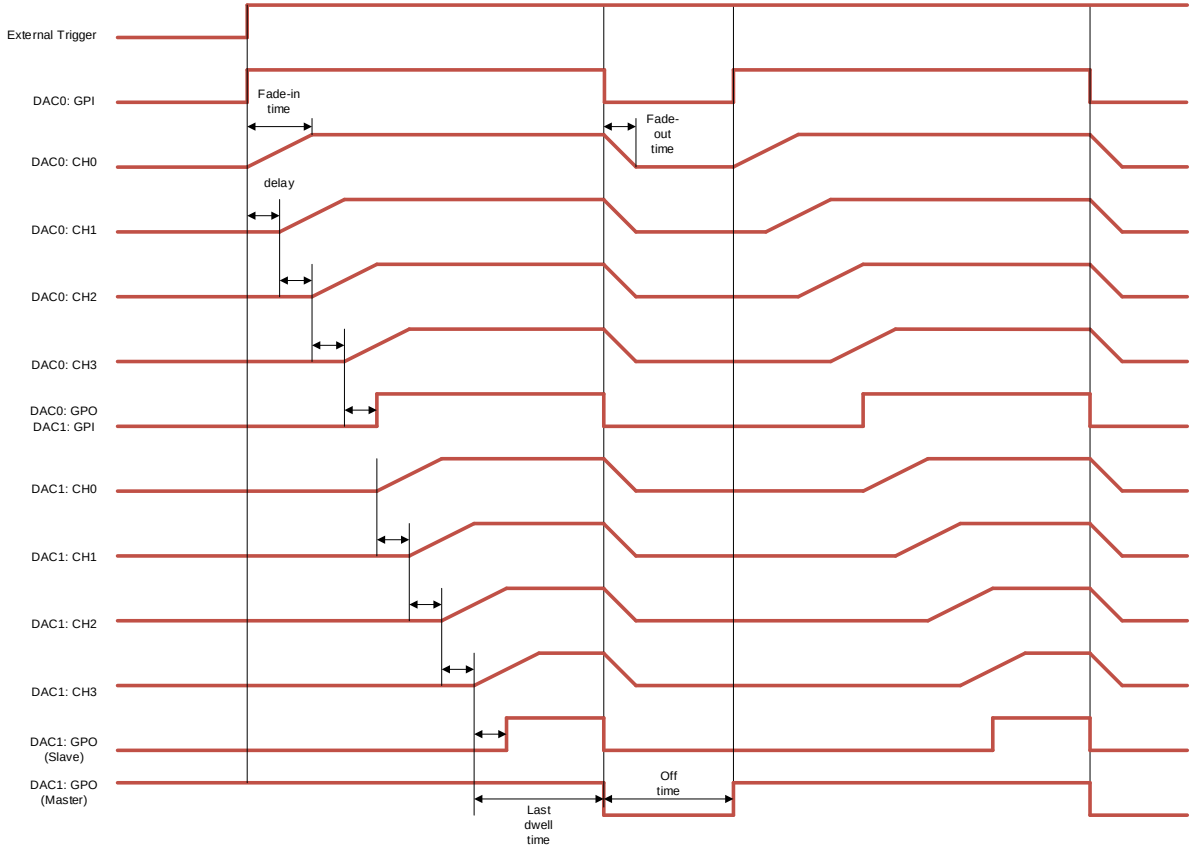


Animation settings

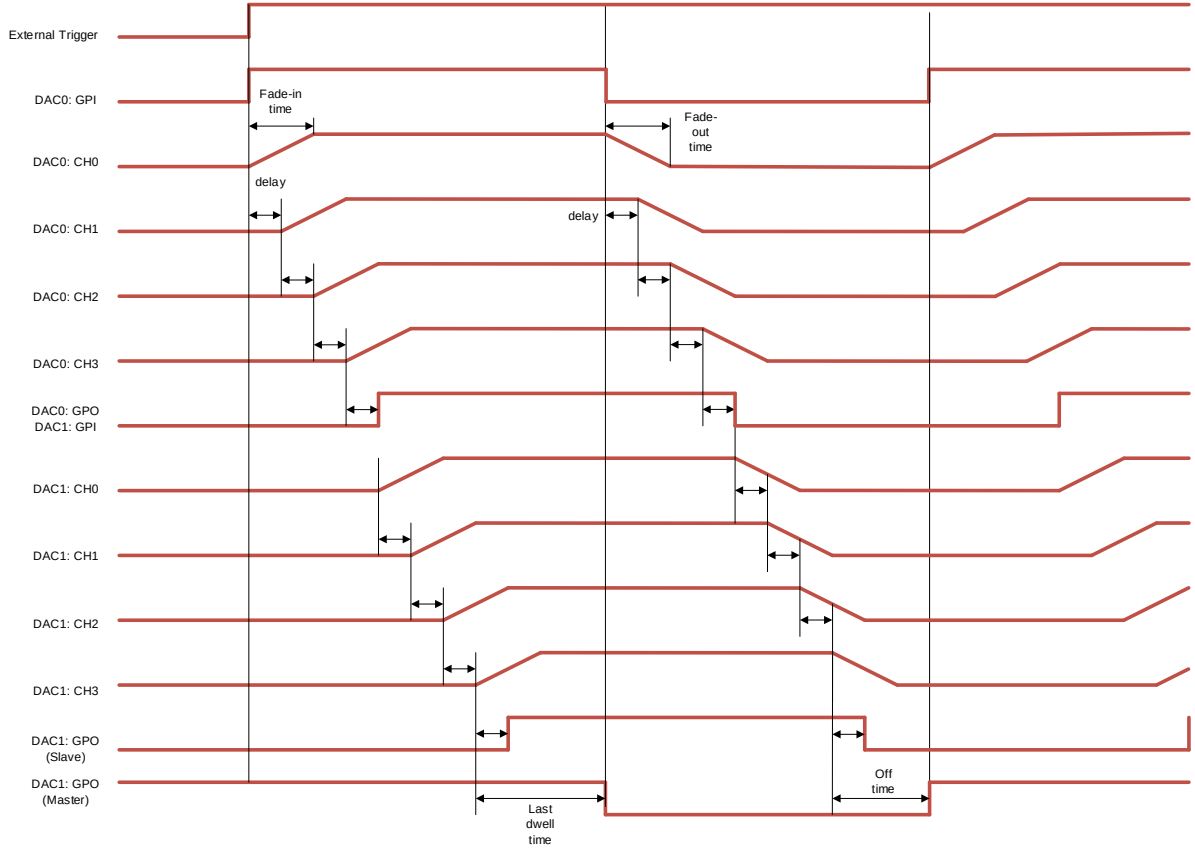
- **Fade-in fade-out**
  - Fade-in time
  - Fade-out time
  - Log/linear fading
  - Min level
  - Max level
- **Trigger source**
  - GPI (voltage output mode)
  - Comparator (PWM output mode)
- **Delay**
  - Starting point
  - Delay from starting point
  - Last dwell time
  - Off time



One-way chaser, common blanking



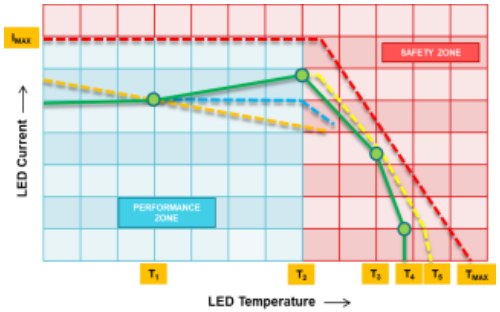
One-way chaser, sequential blanking



LED lighting - recap

Advanced programmable lighting effects without software

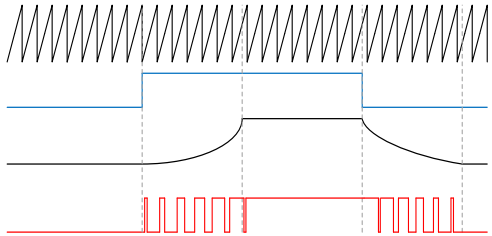
Rear lighting



Maintain luminosity across wider temp - Multi slope thermal fold-back

Key Spec
- GPIO interface for MCU-less operation
- ADC input for thermistor interface
- NVM to save waveforms
- Control logic for closed-loop operation over temp
- PWM output that changes with temperature

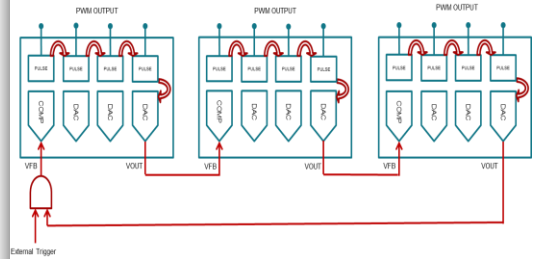
License plate, interior lighting



Fade-in and Fade-out with human eye correction

Key Spec
- GPIO interface for MCU-less operation
- NVM to save waveforms
- 1st DAC ch for Fade in/out, 2nd DAC Ch for PWM
- Slew rate control with logarithmic waveform play
- Small size, Low cost, minimal passives

Turn indicator animation



Create chasing patterns for turn indicator, w/o software

Key Spec
- Cascaded devices for any number of LEDs
- Programmable fade-in fade-out
- NVM to save animation patterns
- PWM output
- I2C interface to program
- MCU-less operation

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265