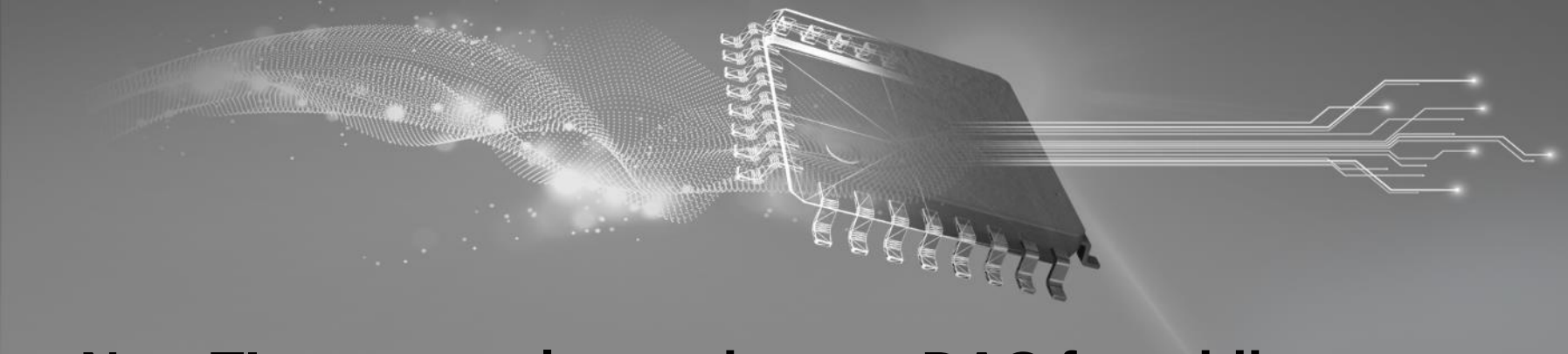
TI TECH DAYS



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

Uttama Sahu

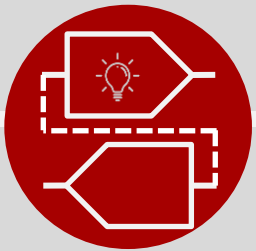
Data Converters - DAC

Texas Instruments

Abstract

- System designers often need simple software solutions to attain predictable system power up and tunable set points
- TI’s 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 software engineers can reduce system costs, remove tiny MCUs, and expedite design cycles

Smart DACs
Control w/o software

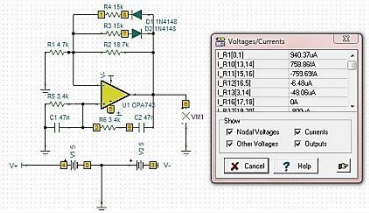
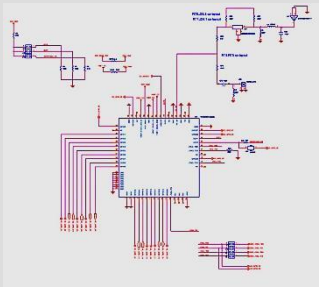


Smart AFEs
Sensing and control w/o software

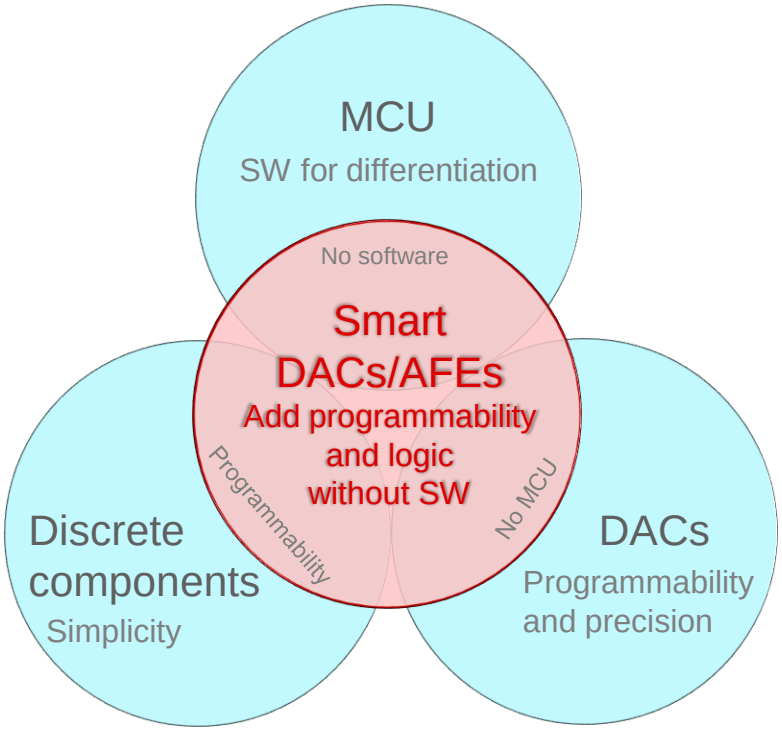
Agenda

- Current day challenges in system design
- What are smart DACs and smart analog
- Example smart DACs
- Smart DAC applications
- Example smart analog
- Smart analog applications
- Summary

Current-day challenges in system design

	Design	Pros	Cons
Discrete circuit		• Low Cost • Optimized design	• Difficult to design • Difficult to scale / reuse • Needs strong analog design expertise • Many components need bigger area
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

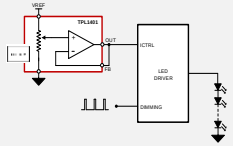
Why smart DACs and smart AFEs



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

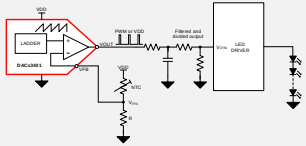
What is a smart DAC? - control w/o software

TPL1401



Programmable current limit

DAC53701



PWM output

PWM

NVM

Comparator

DAC

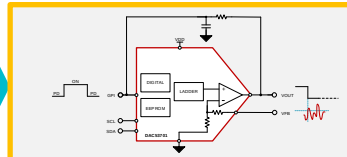
(Ultra Low-Power)

GPI Trigger

Hi-Z

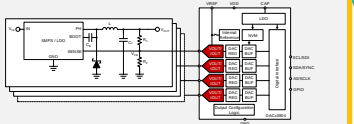
Alarm

DAC53701

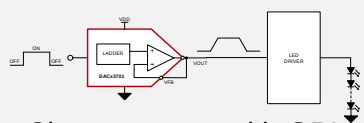


Latching comparator

DAC53204



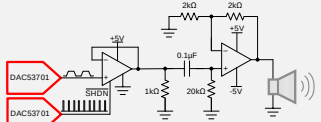
Hassle-free voltage margining



Change output with GPI trigger

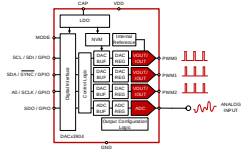
DAC53701

DAC53701



Alarm when MCU fails

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



Analog to PWM

AFE539B4-Q1

PWM

NVM

1100
1010
0101

DAC

101001

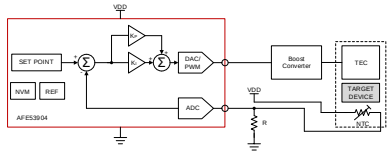
DAC

ADC

101001

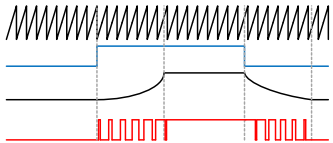
ADC

AFE53902-Q1



Closed-loop control

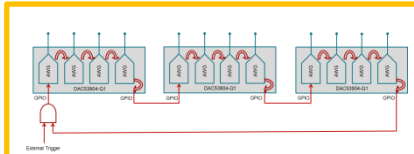
DAC53902-Q1



Logarithmic fade-in fade-out

GPI Trigger

State Machine



Cascaded animation

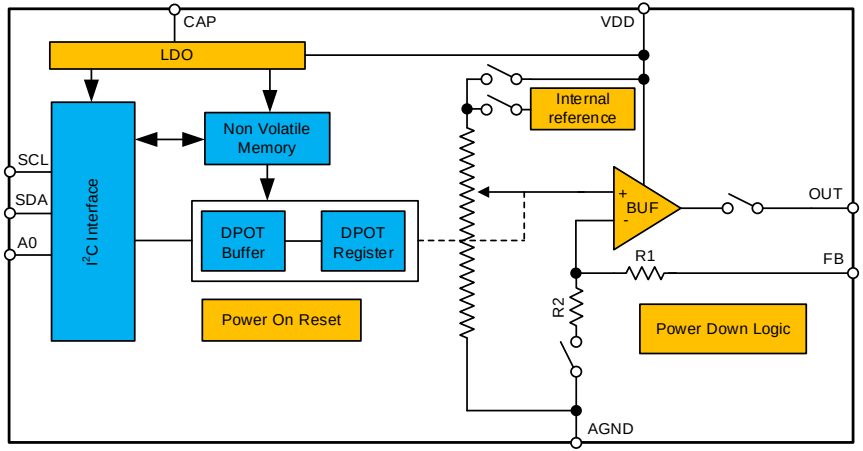
DAC539x4-Q1

An example smart DAC

- Internal reference with 1% accuracy
- User programmable Nonvolatile memory
- Buffered wiper for improved load regulation
- Hi-Z or programmable start-up using NVM
- Lock bit to protect accidental writes to register or NVM
- I2C interface

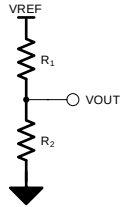
- Wide temperature range: -40°C to +125°C
- Small package WQFN-8 (2x2)

TPL1401



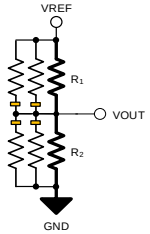
Generating a DC set-point

Resistor divider



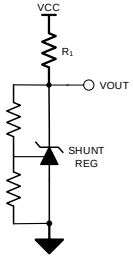
- Simple circuit
- No programmability
- No load regulation
- External reference

LASER trimming



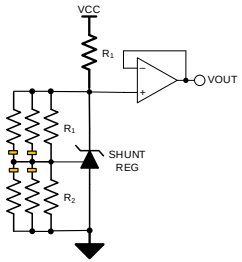
- Limited programmability
- No load regulation
- External reference

Shunt regulator



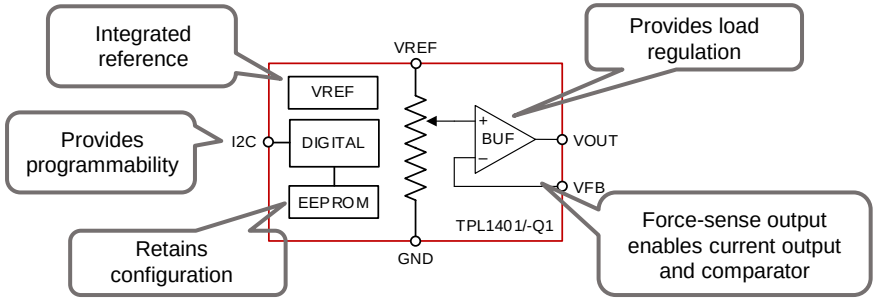
- No programmability
- No load regulation

Load regulation

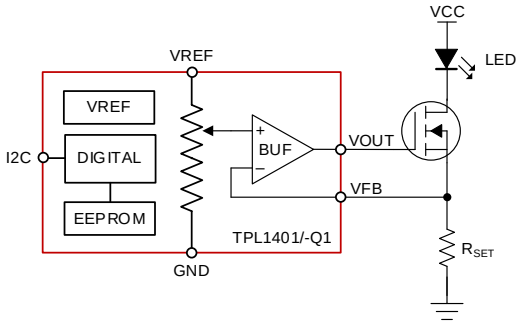


- Large area
- Limited programmability

TPL1401 differentiation

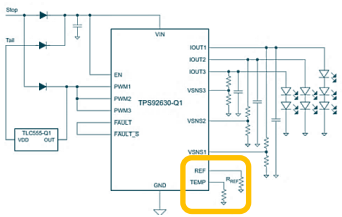


Example application

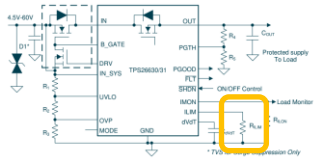


Adjustable current limit

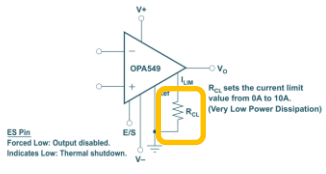
LED driver, DC-DC converter



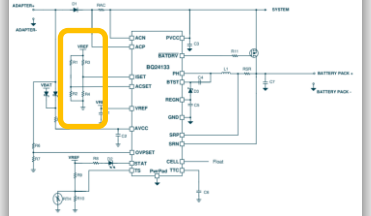
E-fuse, High-side switch



Power amplifier

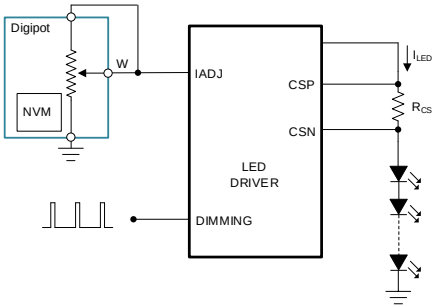


Standalone battery charger



Standard digipot

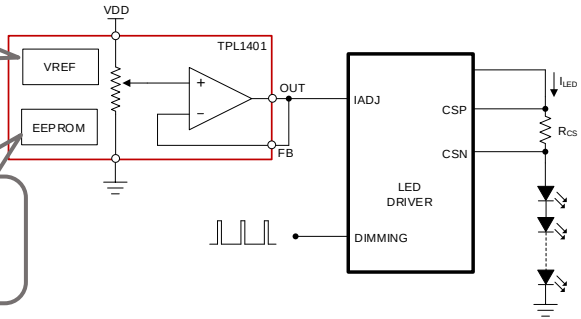
- Digipots are commonly available in 20% tolerance
- Higher accuracy digipots are expensive



TPL1401 differentiation

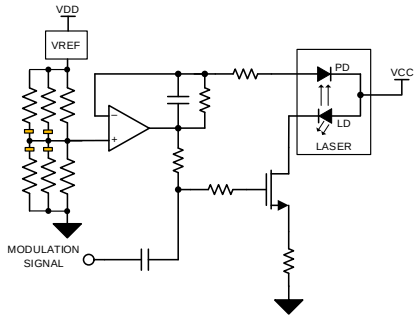
Integrated reference provides 1% accuracy

EEPROM with > 40 years usable life at 125 °C



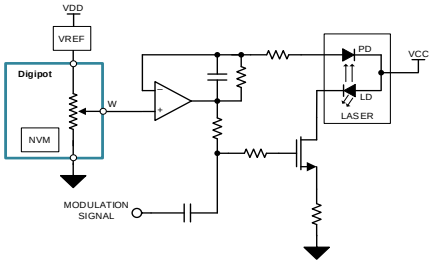
LASER diode analog power control (APC)

Resistor divider



- External reference
- Limited programming steps
- Larger area

Standard digipot

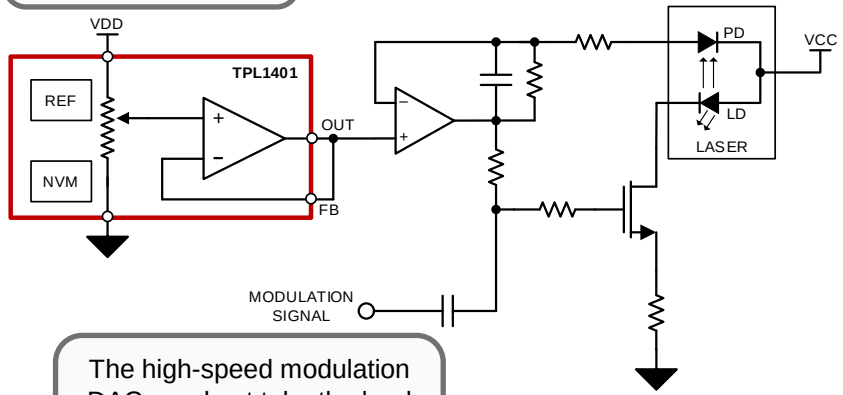


- External reference
- Digital programmability
- Larger area

TPL1401 differentiation

Program at factory and eliminate run-time programming

Simple way to set an accurate bias point for the LASER



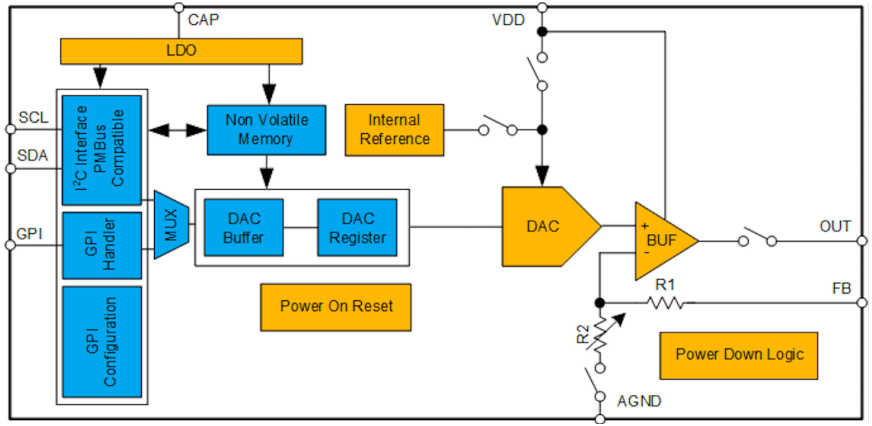
The high-speed modulation DAC need not take the load of controlling the biasing dynamically

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

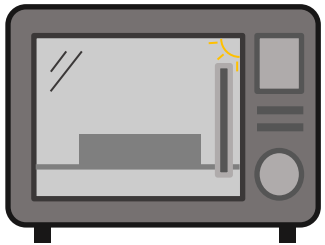
- Wide temperature range: -40°C to +125°C
- Small package WQFN-8 (2x2)

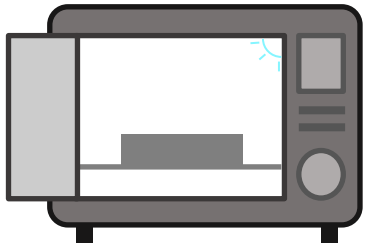
DAC53701-Q1

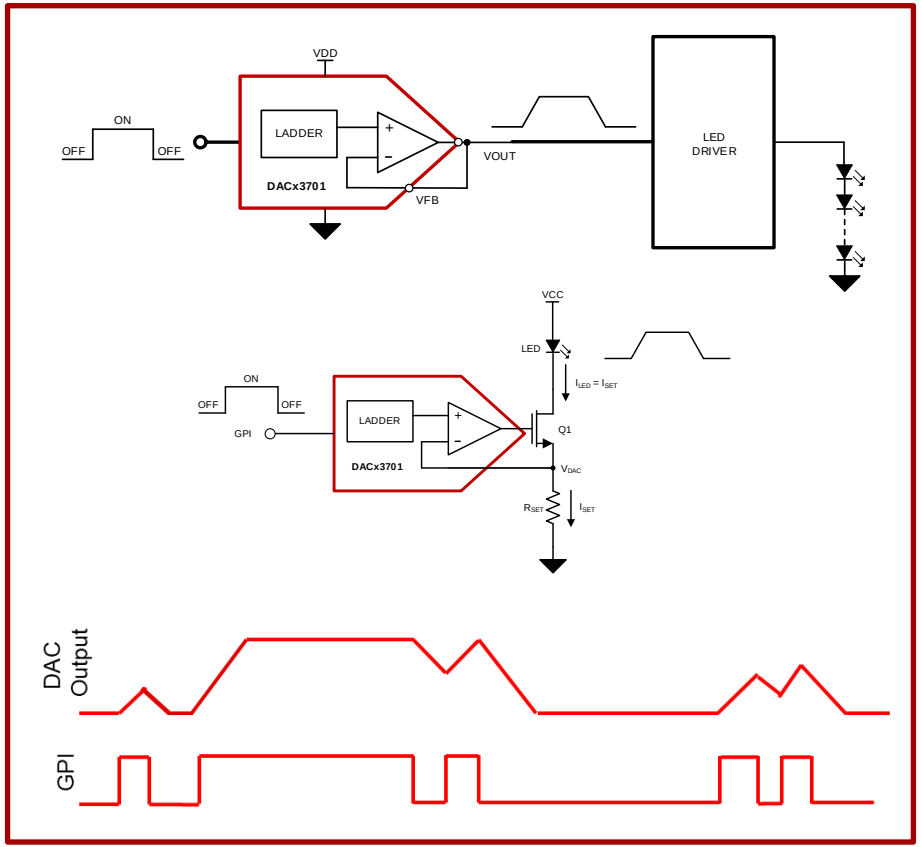


Appliance light fade-in fade-out

- GPI based fade-in fade-out
- Programmable slew rates from milliseconds to 5 seconds
- Programmable min and max output levels
- GPI can be directly connected to mechanical switch without MCU/software
- DAC can drive either an LED driver or directly drive LEDs using a MOSFET





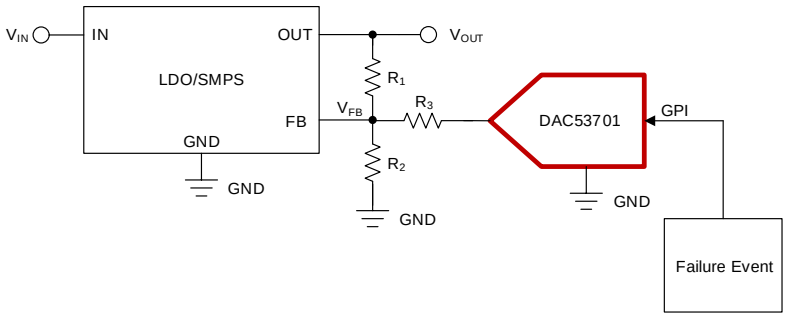


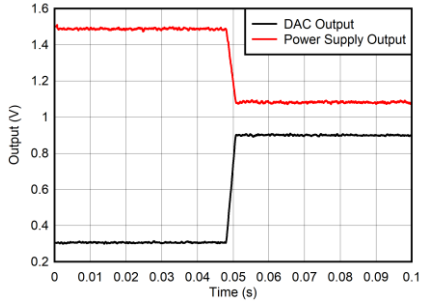
Voltage margining and scaling

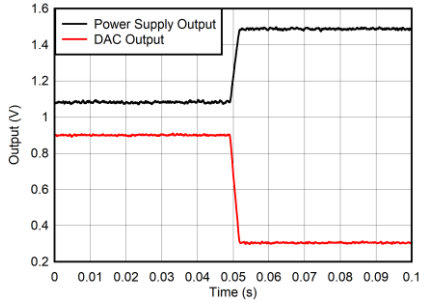
- Hi-Z power-down by default
- Digital slew rate control for glitch-free voltage scaling
- GPI to take the output to Hi-Z or other safe level when software crashes or during brown-out
- I2C and PMBus compatible interface
- NVM for predictable power-up

$$I_{MARGIN} = \left(\frac{V_{OUT} \times (1 + MARGIN) - V_{FB}}{R_1} \right) - I_{NOMINAL}$$

$$R_3 = \frac{|V_{DAC} - V_{FB}|}{I_{MARGIN}}$$

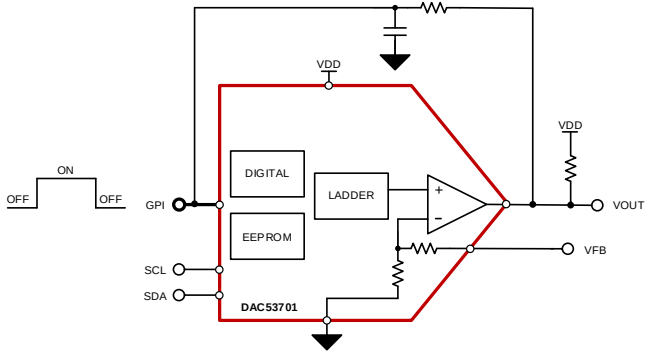






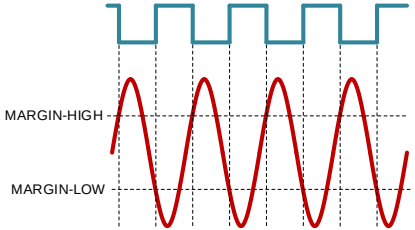
Programmable comparator

- Programmable hysteresis and latching functions independent of MCU
- 10-bit comparator threshold
- 10-bit hysteresis programmed using margin-high and margin-low registers
- Latching comparator function
- EEPROM retention > 40 years at 125 ºC operating temperature, suitable for industrial applications

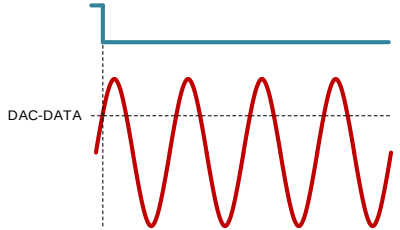


Programmable comparator	Programmable hysteresis	Latching comparator
• Comparator threshold is programmed in DAC-DATA register • GPI is unmapped	• GPI mapped to margin-high (GPI HIGH) and margin-low (GPI LOW) • DAC-DATA is same as either margin-high or margin-low • DAC output is pulled up by a resistor to VDD	• GPI mapped to power-up (GPI HIGH) and power-down to 10K (GPI LOW) • DAC-DATA is the comparator threshold • DAC output is pulled up by a resistor to VDD

Programmable hysteresis
(GPI mapped to margin-high/low)

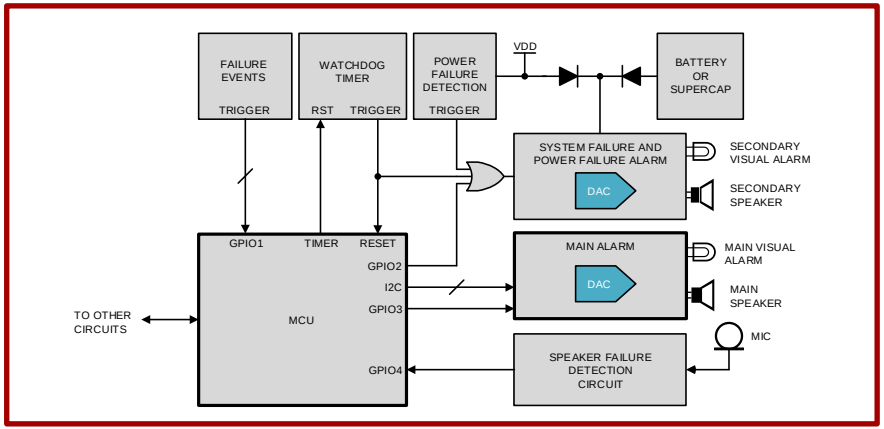


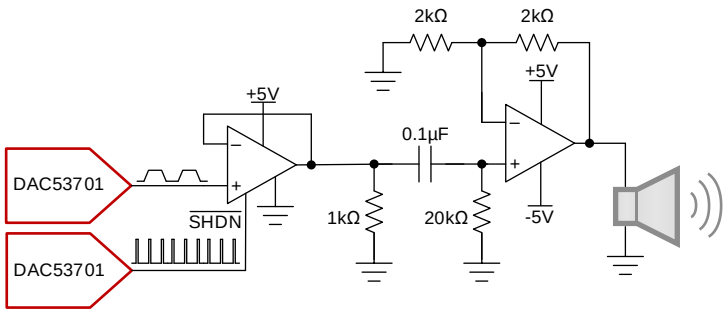
Latching comparator
(GPI mapped to power-up/down)



Medical alarm

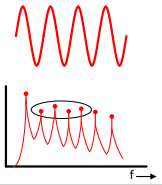
- In-built alarm timings as per IEC60601-1-8 standard – register based configuration
- One DAC is used for generating the trapezoid with timing and gain control
- Another DAC is used to generate the alarm tone
- Directly trigger high-priority alarm using GPI
- Low-power consumption enables smaller battery back-up for power failure alarm





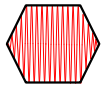
Pulse

- Pulse frequency shall be between 150 Hz and 1 kHz
- There shall be 4 harmonics between 300 Hz and 4 kHz
- These 4 harmonics shall be within ±15 dB of each other
- The harmonics shall be measured in the acoustic domain



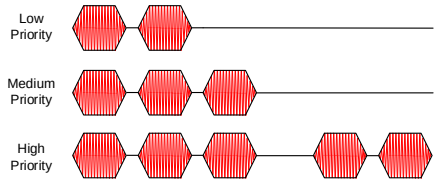
Pulse Envelope

- Specifies the rise and fall times (7.5 ms to 100 ms)
- Measured in the acoustic domain
- This signal block repeats within an alarm burst



Burst

- The pattern of the burst varies based on the alarm priority
- There are 3 alarm priorities
- Medical equipment manufacturers choose different timings and frequency as per their preference

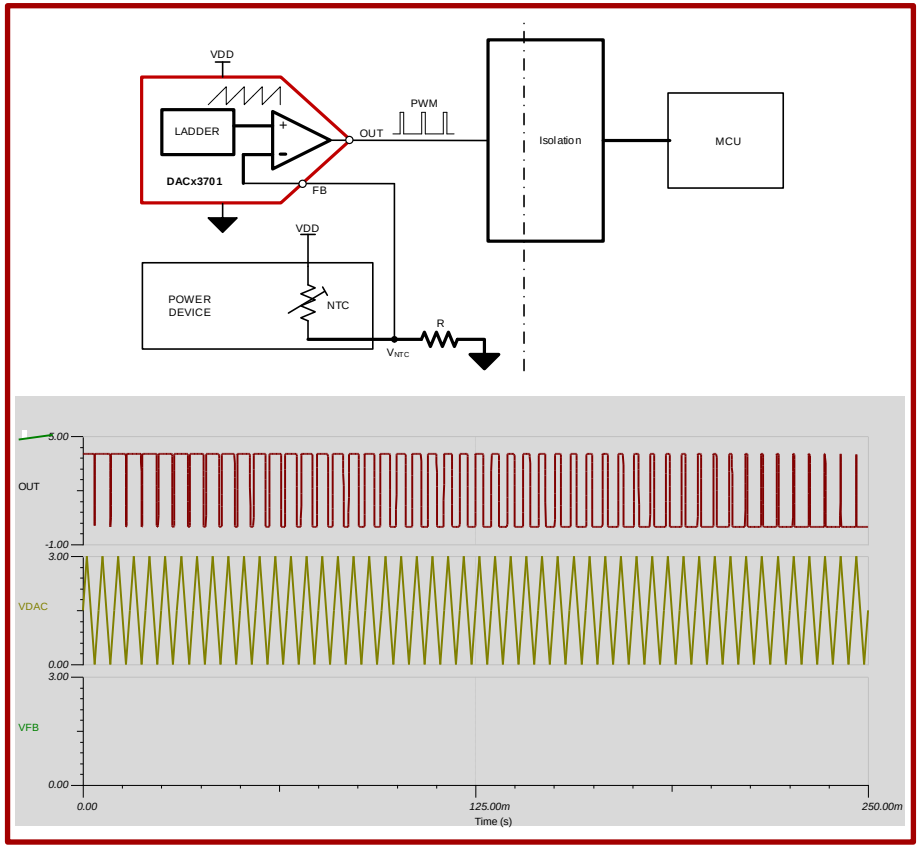


Temperature to PWM converter

- NTC resistance to PWM conversion
- PWM interfaces needs only single-wire – suitable for isolation barriers
- PWM duty cycle proportional to NTC resistance
- Factory programming of PWM frequency through triangular / sawtooth waveform in NVM
- No run-time software required

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

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

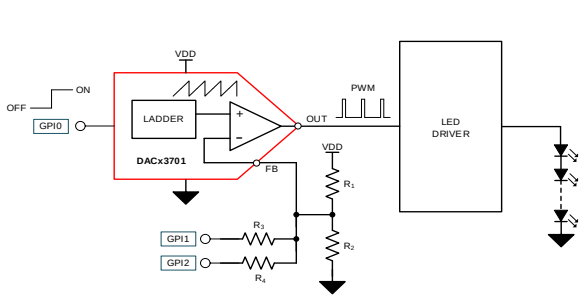


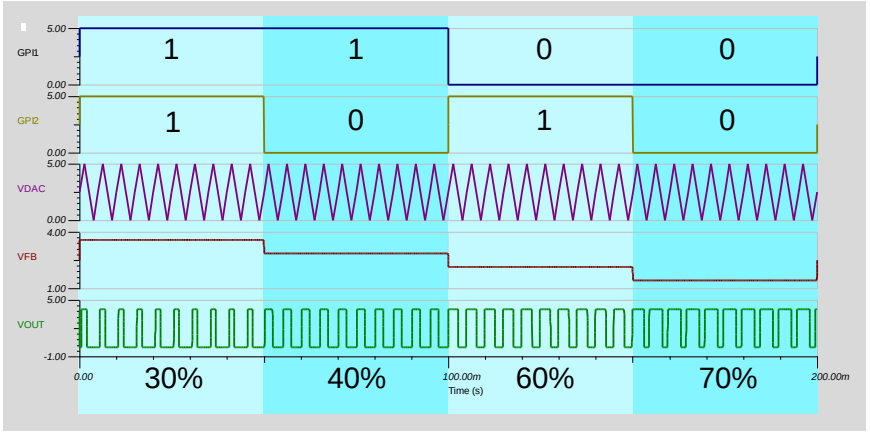
STOP tail lighting

- 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

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

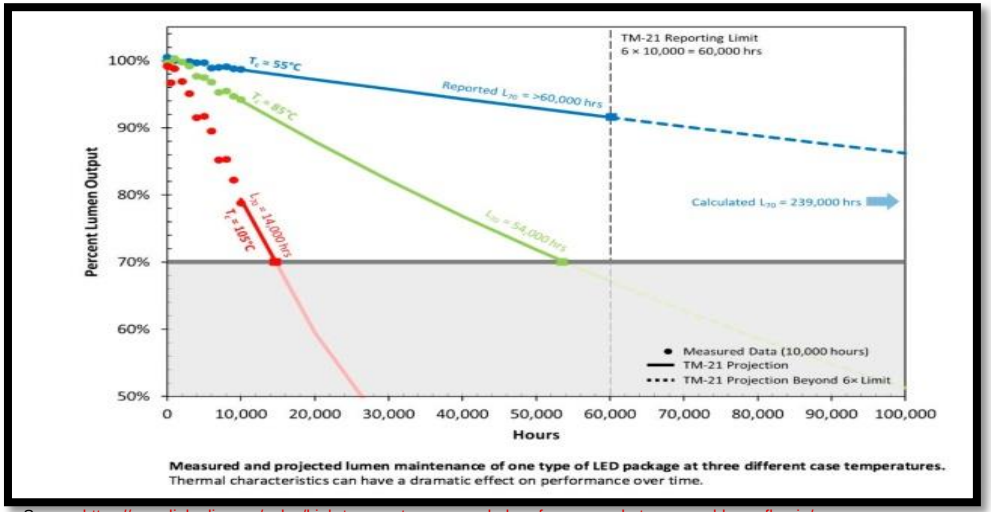
$$f_{SAWTOOTH-WAVE} = \frac{1}{SLEW\_RATE \times \left(\frac{MARGIN\_HIGH - MARGIN\_LOW + 1}{CODE\_STEP} \right)}$$





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)

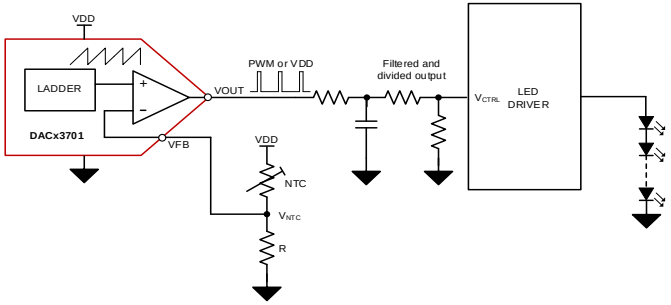
- LED reliability is significantly determined by the operating temperature
- LEDs in DRLs are heated by both self-heating and sunlight

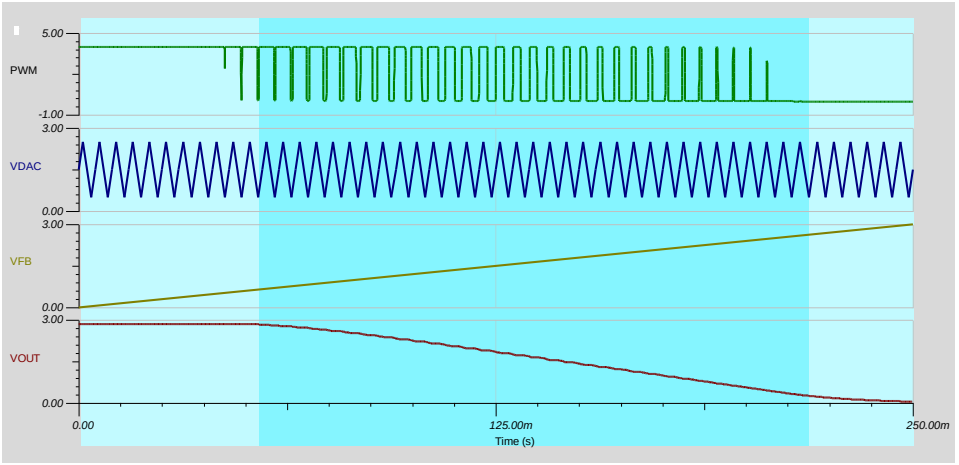
Single-slope thermal foldback

- 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

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

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

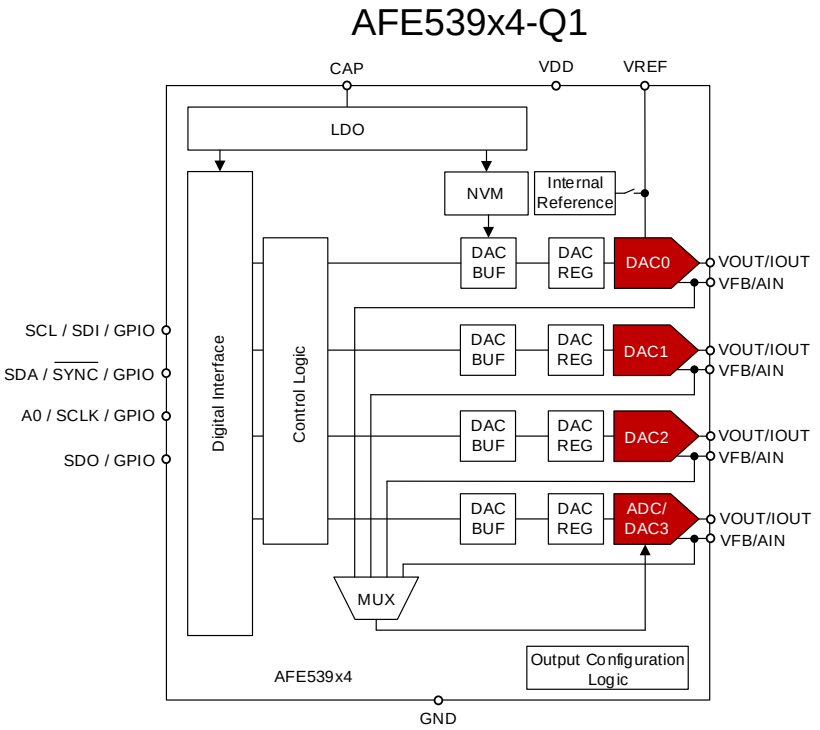




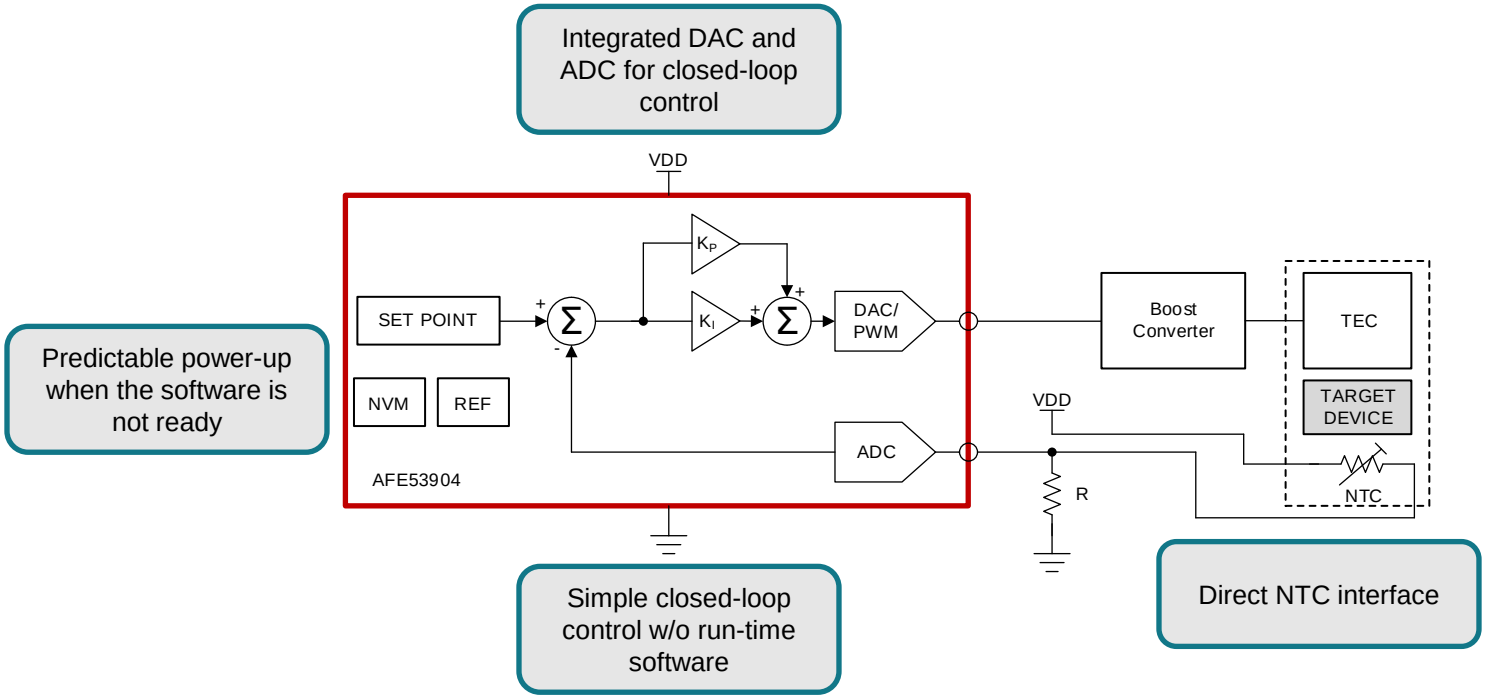
An example Smart analog frond end (AFE)

- 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)



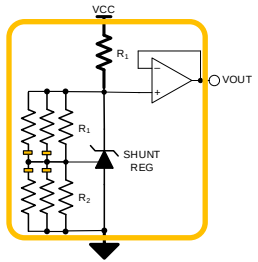
TEC control


Integrated DAC and ADC for closed-loop control
VDD
K_P
K_I
SET POINT
NVM
REF
DAC/ PWM
ADC
AFE53904
Boost Converter
TEC
TARGET DEVICE
NTC
R
VDD
Predictable power-up when the software is not ready
Simple closed-loop control w/o run-time software
Direct NTC interface

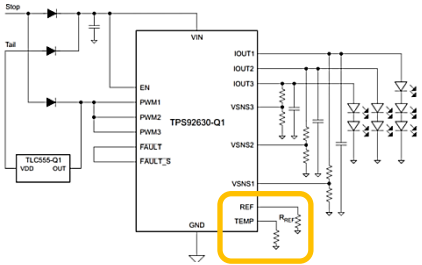
TPL1401 application summary

- Losing yield at factory? Does the voltage need tuning at factory or at the field?
- Does the PCB need HW change for every new revision?
- Are you struggling to find the right way to generate a DC set-point?

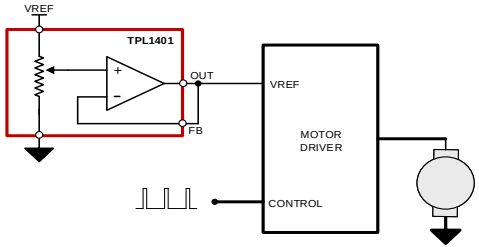
Voltage divider, Adjustable shunt regulator



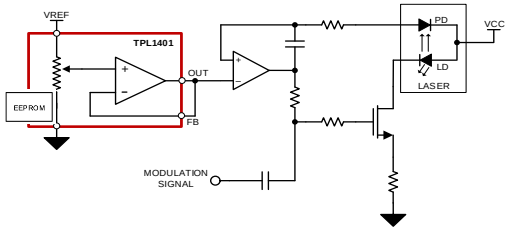
Adjustable current limit



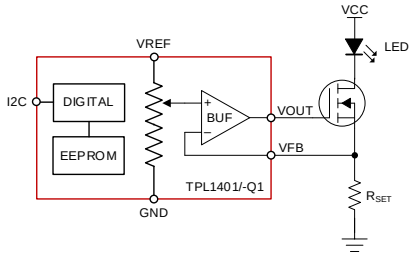
Adjustable reference



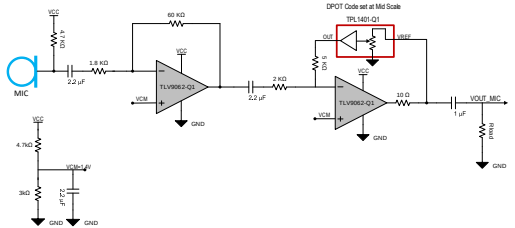
LASER diode



LEDs



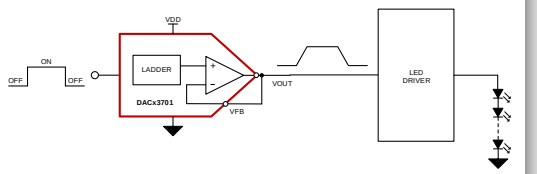
Microphone tuning



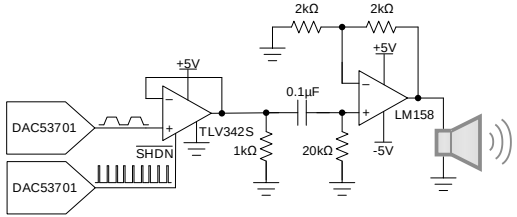
DAC53701 application summary

- Are you using an MCU just to create an adjustable PWM? Are you stuck with a 555 timer?
- Are you avoiding simple fade-in fade-out effects in lighting because of cost?
- Do you often notice fault management designs to be tricky?

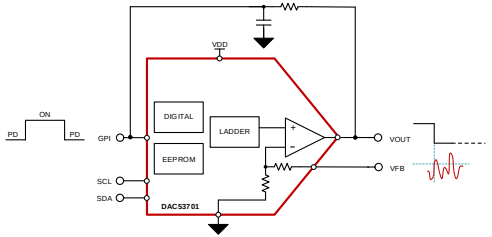
Fade-in fade-out



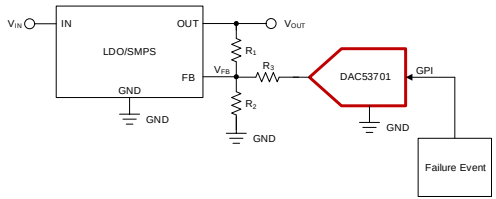
Medical alarm



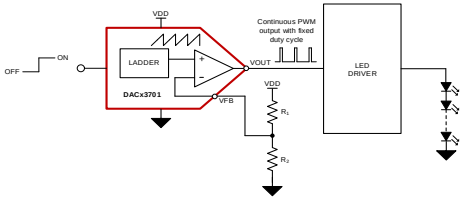
Programmable comparator



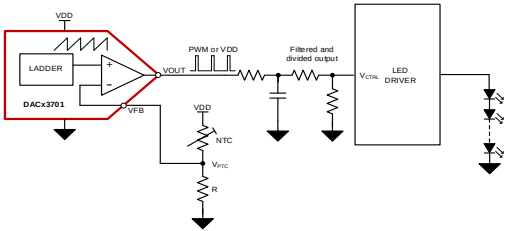
Voltage margining and scaling



PWM output



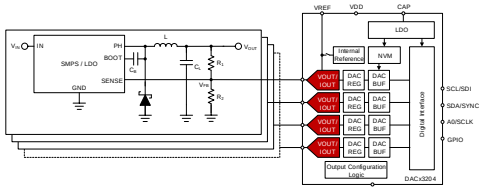
Temperature/Resistance to PWM



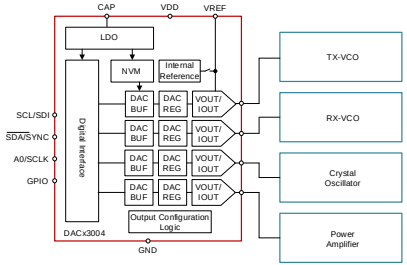
DAC53204 application summary

- Does your system require accurate bias points?
- Does your voltage margining circuit require a DAC that has Hi-Z output even during power-off?
- Do you often notice fault management designs to be tricky?

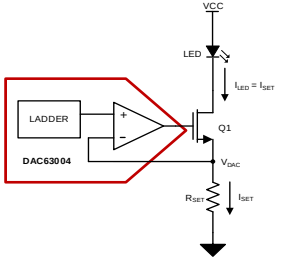
Voltage margining and scaling



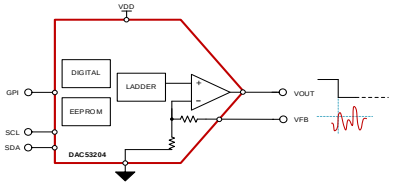
Amplifier and VCO biasing



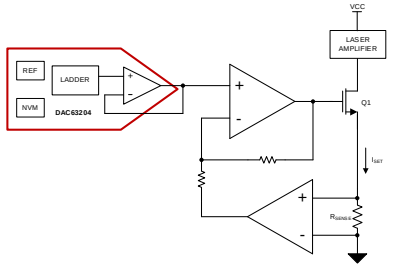
Ultra-low power LED biasing



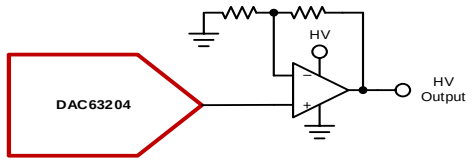
Programmable Comparator



LASER amplifier control



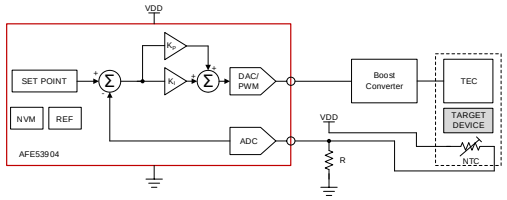
MEMS LIDAR scanning



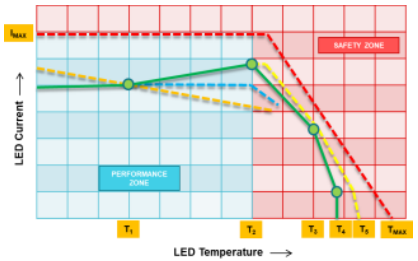
AFE539x4 application summary

- Are you using an MCU to create simple control loops?
- Does your system have shortage of GPIOs or have the need for long-distance control over GPIOs?
- Are you burdened by software to create LED animations?

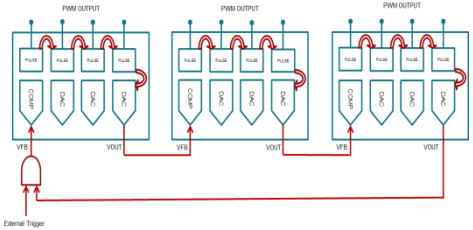
TEC control, PI control



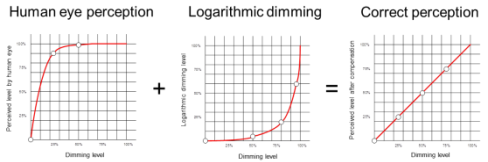
Multi-slope thermal foldback



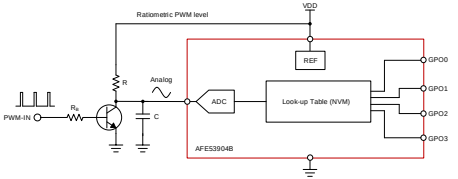
LED animation



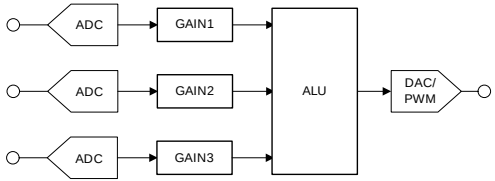
Logarithmic fade-in fade-out



PWM IO expander



Dynamic headroom control



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