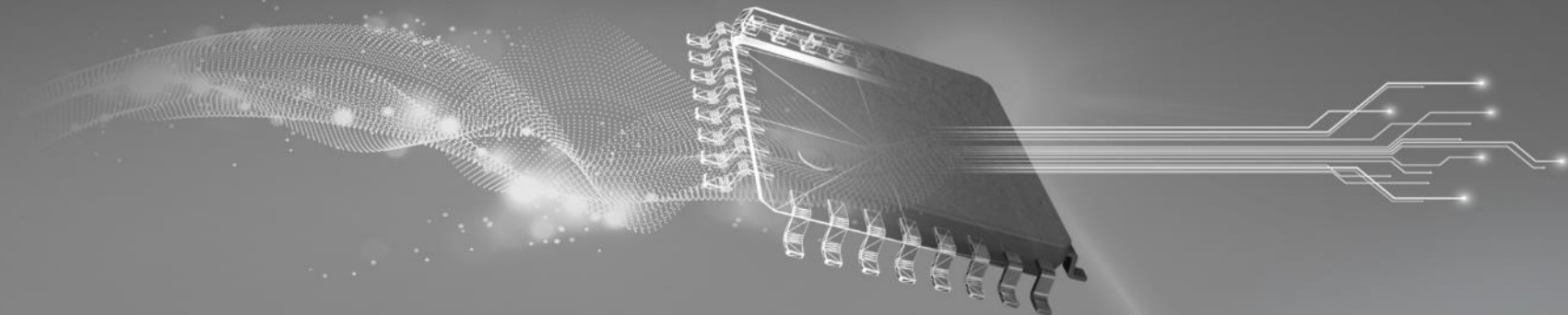# TI TECH DAYS

# TI's intelligent LED drivers in automotive cluster systems
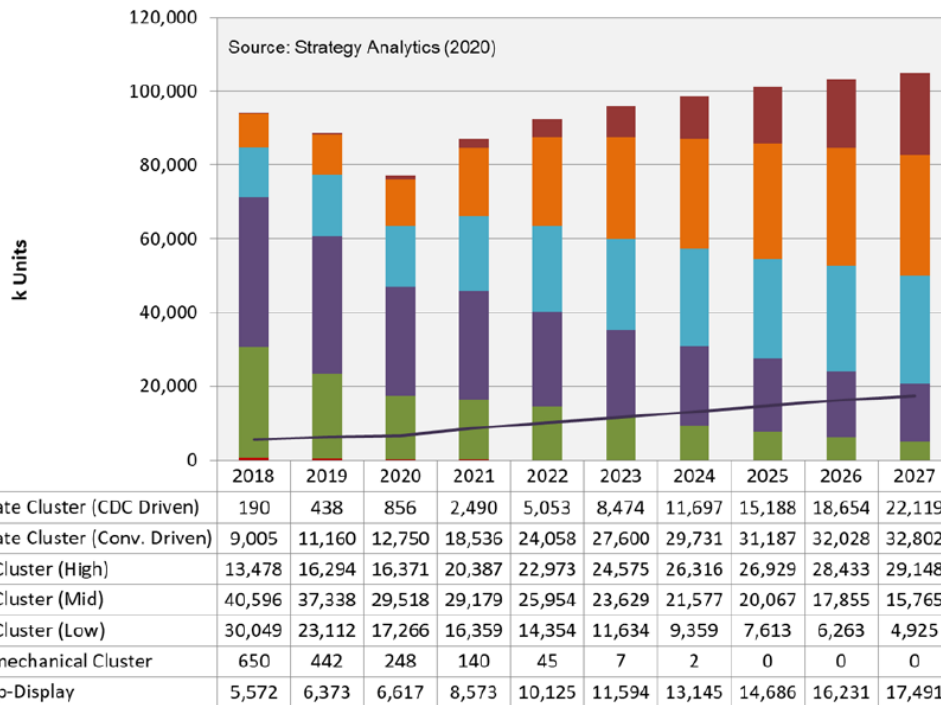
**Shirley He**

**LED Drivers**

# Outline

- Automotive instrument cluster system trends

- Automotive LED indicator

- Global dimming backlight LED driver

- Local dimming backlight architecture and LED driver

- Aid functional safety cluster system design

- Q&A

**TEXAS INSTRUMENTS**

# Automotive instrument cluster system demand volume



Source: Strategy Analytics (2020)

| k Units | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 |
|---|---|---|---|---|---|---|---|---|---|---|
| Solid State Cluster (CDC Driven) | 190 | 438 | 856 | 2,490 | 5,053 | 8,474 | 11,697 | 15,188 | 18,654 | 22,119 |
| Solid State Cluster (Conv. Driven) | 9,005 | 11,160 | 12,750 | 18,536 | 24,058 | 27,600 | 29,731 | 31,187 | 32,028 | 32,802 |
| Hybrid Cluster (High) | 13,478 | 16,294 | 16,371 | 20,387 | 22,973 | 24,575 | 26,316 | 26,929 | 28,433 | 29,148 |
| Hybrid Cluster (Mid) | 40,596 | 37,338 | 29,518 | 29,179 | 25,954 | 23,629 | 21,577 | 20,067 | 17,855 | 15,765 |
| Hybrid Cluster (Low) | 30,049 | 23,112 | 17,266 | 16,359 | 14,354 | 11,634 | 9,359 | 7,613 | 6,263 | 4,925 |
| Electromechanical Cluster | 650 | 442 | 248 | 140 | 45 | 7 | 2 | 0 | 0 | 0 |
| Head-Up-Display | 5,572 | 6,373 | 6,617 | 8,573 | 10,125 | 11,594 | 13,145 | 14,686 | 16,231 | 17,491 |

- Hybrid cluster: consists of both analog gauges and a display panel

- Solid state cluster: consists of a single display panel, containing no analog gauges

*Source: Strategy Analytics, Automotive Instrument Clusters: Moving Towards Cockpit Integration and 3D Displays, May 2020*

**TEXAS INSTRUMENTS**

# LED drivers in instrument clusters



Source: Ford



Source: Audi

- Hybrid cluster:
  - backlight LED driver (low/mid power)
  - LED indicator

- Solid state cluster:
  - backlight LED driver (mid/high power)
  - LED indicator for tell-tales (optional)

TEXAS INSTRUMENTS

# Multi-channel automotive LED indicator family

| | New Generation | | | |
|---|---|---|---|---|
| **TLC6C598/12-Q1** | **TLC6C5816-Q1** ★ | **TLC6C5712-Q1** ★ | **TLC6C5716/24-Q1** ★ |

**TLC6C598/12-Q1**
- Shift Register Power Logic
- 40V Breakdown Voltage
- Vcc = 3 ~ 5.5V
- Cont. <50mA per channel (8/12 ch)
- Thermal Shutdown Protection

**TLC6C5816-Q1** ★
- Shift Register Power Logic
- 40V Breakdown Voltage
- Vcc = 3 ~ 5.5V
- Cont. <50mA per channel (16 ch)
- 2 PWM Input
- LED Open & Short Diagnostic

**TLC6C5712-Q1** ★
- Const. Current Sink
- 7V Breakdown Voltage
- Vcc = 3 ~ 5.5V, SPI
- Cont. <75mA/ch (12 ch)
- 8 bit Dot Correction
- 6 Ext. PWM arbitrary mapping
- Full Diagnostic & Protection
- Deactivated LED Fault Detection

**TLC6C5716/24-Q1** ★
- Const. Current Sink
- 7V Breakdown Voltage
- Vcc = 3 ~ 5.5V, Serial I/F
- Cont. <50mA/ch (24/16 ch)
- 7 bit Dot Correction, 8 bit BC
- 12/10/8 bit Int. Ind. PWM
- Full Diagnostic & Protection
- Deactivated LED Fault Detection

## Old Generation

**TPIC6C596**
- Shift Register Power Logic
- 33V Breakdown Voltage
- Vcc = 4.5 ~ 5.5V
- Cont. <100mA per channel (8 ch)

**TPIC2810**
- I2C Power Logic
- 40V Breakdown Voltage
- Vcc = 3 ~ 5.5V
- Cont. <100mA per channel (8 ch)

**TLC5916/17-Q1 TLC5926/27-Q1**
- Const. Current Sink
- 17V Breakdown Voltage
- Vcc = 3 ~ 5.5V, Serial I/F
- Cont. <120mA/ch (8/16 ch)
- 8 bit Global Dot Correction
- OT, LED Open
- LED Short (7 only)

**TLC5941-Q1**
- Const. Current Sink
- 17V Breakdown Voltage
- Vcc = 3 ~ 5.5V, Serial I/F
- Cont. <90mA/ch (16 ch)
- 6 bit Ind. Dot Correction
- 12 bit Int. Ind. PWM
- OT, LED Open

**TLC59116-Q1**
- Const. Current Sink
- 17V Breakdown Voltage
- Vcc = 3 ~ 5.5V, FM+ I2C
- Cont. <120mA/ch (16 ch)
- 8 bit Global Dot Correction
- 8 bit Int. Ind. PWM
- OT, LED Open

## Topology
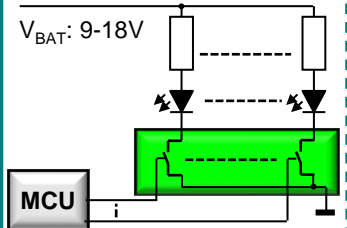


- No Diagnostic
- Simple ON/OFF
- Requires Parallel wires from MCU
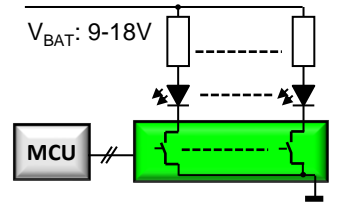
- No Diagnostic or Simple Diagnostic
- Simple ON/OFF
- MCU Serial I/F & Daisy Chain Option
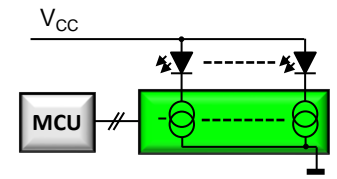
- Diagnostic
- Constant Current w/ Rsense
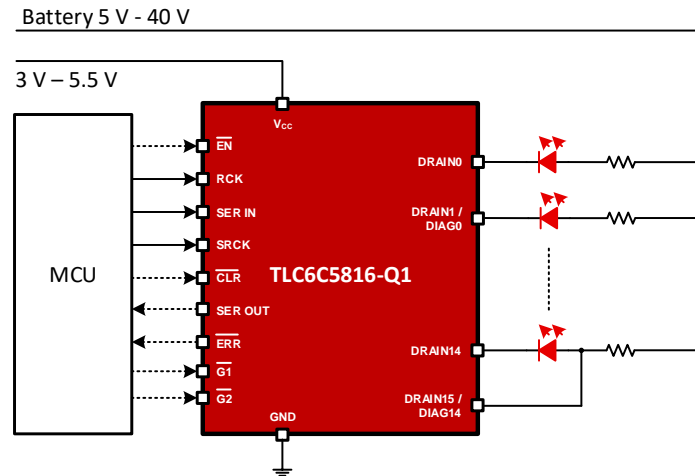- MCU Serial I/F & Daisy Chain Option

**TEXAS INSTRUMENTS**

# TLC6C5816-Q1

## Features

- AEC-Q100 Qualified for Automotive Applications
- **16 Channel Power DMOS Transistor Outputs**
  - Open drain output up to 50mA/channel
  - Rdson 6.2 Ohm (25C Junction, typ)
  - Rdson 13.5 Ohm (150C Junction, worst case)
  - 40V Output for load dump, support load directly connect to battery
  - Optimized slow slew rate helps reduce EMI
- **Serial Interface & PWM inputs**
  - Shift register compatible with 596/598/5912
  - Fault register readback with RCK high
  - 2 PWM inputs, each control 8 outputs.
- **Diagnostic & Protection**
  - Over Temperature Protection
  - 8 Channel On-demand LED Open / Short Diagnostics
  - **Serial Interface Communication Error Detection**
  - **Open-drain error output for MCU interruption**
- **Package**
  - HTSSOP-28

## Benefits

- 16 channels in one chip for more cost efficient to power each LED
- On-demand LED Short & Open Detection to easy fulfill diagnostics and save system cost
- Optimized Slew Rate helps reduce EMI
- Dual PWM input to support two different dimming scenarios
- SPI Checksum readback to enhance SPI communication reliability



## Applications

- Instrumentation Cluster
- HVAC / Head-unit Faceplate
- Center Stack HMI
- Electronic Gear Shifter

## Key Parameter Overview

| | | |
|---|---|---|
| Vcc operating voltage | 3 ~ 5.5 | V |
| Output voltage maximum rating | 40 | V |
| Channel output maximum current | 50 | mA |
| Rds(on) typical | 6.2 | Ω |

TEXAS INSTRUMENTS

# TLC6C5712-Q1

## Features

- **AEC-Q100 Qualified for Automotive Applications**
- **12 Channel Power DMOS Transistor Outputs**
  - Constant current up to 75mA, set via external resistor
  - Breakdown voltage up to 7V
  - Max drop-out voltage: 0.75V @ 50mA/ch, 1.2V @ 75mA/ch
  - Configurable slew rate for optimized EMI performance
- **Precision Constant Current**
  - Channel-Channel difference   < ±3%
  - Device-Device difference       < ±3%
  - 8-bit, 256-step linear dot correction for each channel
- **Serial Interface & PWM inputs**
  - 6 PWM Inputs with frequency supervision
  - Programmable PWM mapping capability via SPI interface
- **Diagnostic & Protection**
  - Open-load, Short-to-GND, Shorted-LED detection for both activated and deactivated states
  - LED Weak Supply Detection
  - Adjacent Pin Short Detection
  - Reference Resistor Open/Short Detection & Protection
  - Thermal Prewarning and Shutdown
  - Input PWM Timeout Monitoring
  - Open-drain Error reporting
  - Force Error for SPI Integrity Diagnostics
  - SPI register lock for content protection
- **Small & thermal effective package**
  - 28 HTSSOP (PowerPAD)

## Benefits

- Output current high accuracy ensure whole system close to zero deviation in LED Display
- Full Programmable via SPI to offer the flexibility for various applications
- Complete Diagnostic and Protection to meet high functional safety requirements
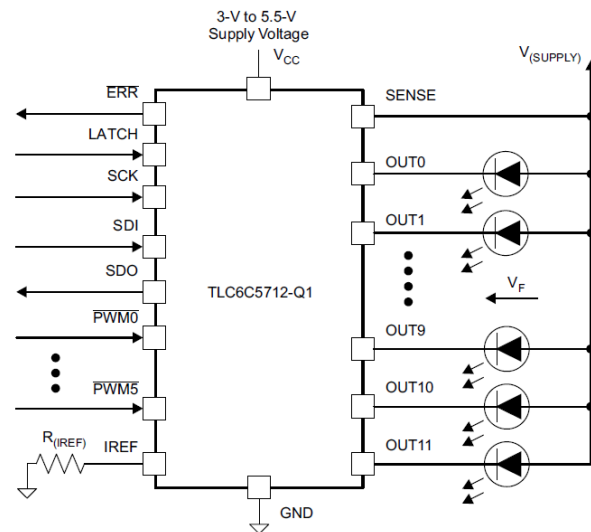


## Applications

- Instrumentation Cluster
- HVAC / Head-unit Faceplate, Center Stack HMI, Electronic Gear Shifter
- Local Dimming Display
- RGB Ambient Lighting

## Key Parameter Overview

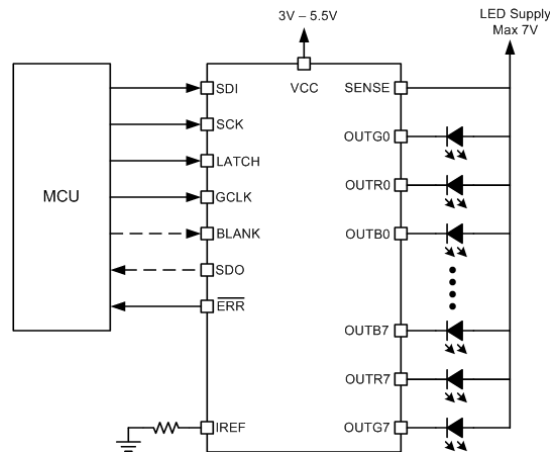| | | |
|---|---|---|
| Vcc operating voltage | 3 ~ 5.5 | V |
| Output voltage maximum rating | 7 | V |
| Full range output current | 75 | mA |
| Output current accuracy | ±3 | % |

**TEXAS INSTRUMENTS**

# TLC6C5716/24-Q1

## Features

- **AEC-Q100 Qualified for Automotive Applications**
- **24/16 Channel Outputs**
  - Constant current up to 50mA, set via external resistor
  - Breakdown voltage up to 7V
- **Precision Constant Current**
  - Channel to Channel: ±8%
  - Device to Device: ±2%
  - 7-bit, 128-step Dot correction for each channel
  - 8-bit, 256-step Brightness Control for each color group
- **Serial Interface & PWM Dimming**
  - up to 4MHz SCK and 8MHz GCLK frequency, optimized for Automotive application
  - 12/10/8 Bits internal PWM dimming configurable by each channel
  - EMI friendly with programmable Output Channel Turn On/Off Slew Rate
  - Grouped Delay to Prevent Inrush Current
- **Diagnostic & Protection**
  - LED open error (LOD), LED short error (LSD), Output pin short to GND error (OSD)
  - LOD/LSD detection circuit failure, LOD/LSD register failure
  - PWM operation error, GCLK signal missing error
  - Adjacent pin short error (APS)
  - Thermal Prewarning (TPW), Thermal error and Shutdown (TEF)
  - IREF resistor open failure (IOF), IREF resistor short failure (ISF)
- **Small & thermal effective package**
  - 38 HTSSOP (PowerPAD)

## Benefits

- High system reliability by fault detection and readback, including PWM error, GCLK missing, etc
- Suitable to drive eight RGB color mixing LED lamps
- Mixed LED Binning with DC/BC compensation and high accuracy of constant current
- EMI friendly with low inrush current and group delay



## Applications

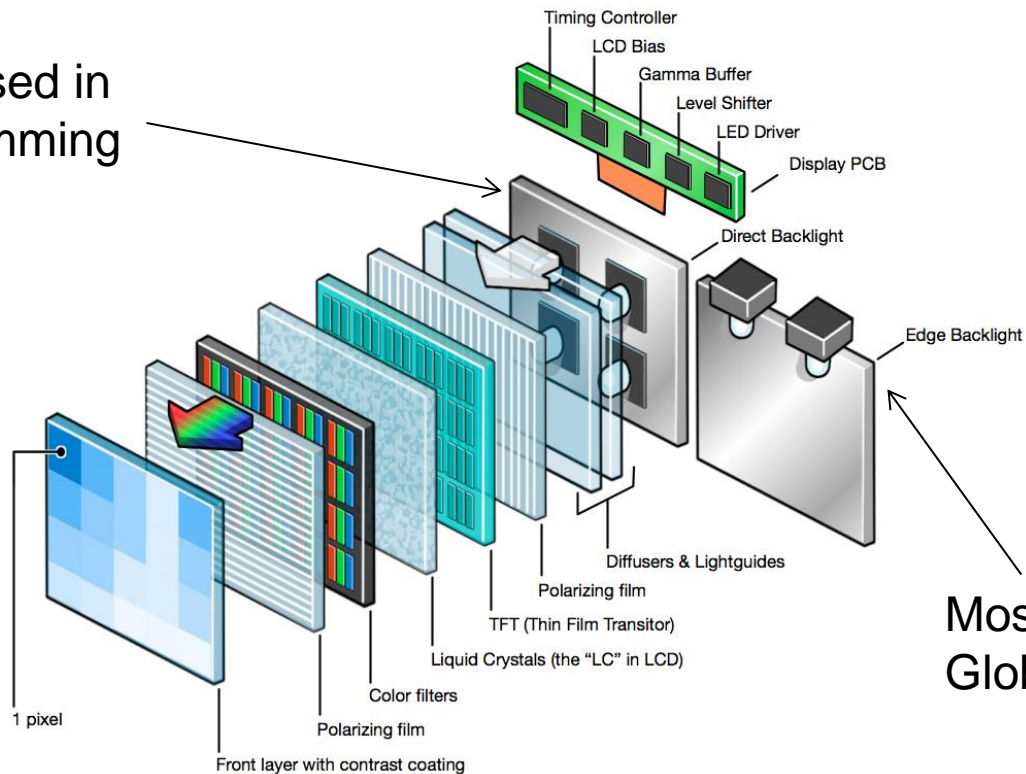- Instrumentation Cluster
- HVAC / Head-unit Faceplate, Center Stack HMI, Electronic Gear Shifter
- Local Dimming Display
- RGB Ambient Lighting

## Key Parameter Overview

| Vcc operating voltage | 3 ~ 5.5 | V |
|---|---|---|
| Output voltage maximum rating | 7 | V |
| Full range output current | 50 | mA |
| Output current accuracy | ±8 | % |

**TEXAS INSTRUMENTS**

# TFT LCD architecture



Mostly used in Local Dimming

Mostly used in Global Dimming

Timing Controller
LCD Bias
Gamma Buffer
Level Shifter
LED Driver
Display PCB

Direct Backlight

Edge Backlight

Diffusers & Lightguides

Polarizing film

TFT (Thin Film Transitor)

Liquid Crystals (the "LC" in LCD)

Color filters

Polarizing film

Front layer with contrast coating

1 pixel

**TEXAS INSTRUMENTS**

# Global dimming LED backlight driver roadmap

**Diagnostic Level** (vertical axis)

Size 10", Brightness 1000nit

**3 CH** — **4 CH** — **6 CH** (horizontal axis)

**LP8864S-Q1**
- 3V to 48V $V_{IN}$
- 4 x 150mA LED Current
- Dimming Ratio > 32,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

**LP8864-Q1**
- 3V to 48V $V_{IN}$
- 4 x 200mA LED Current
- Dimming Ratio > 32,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

**LP8866S-Q1**
- 3V to 48V $V_{IN}$
- 6 x 150mA LED Current
- Dimming Ratio > 32,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

**LP8866-Q1**
- 3V to 48V $V_{IN}$
- 6 x 200mA LED Current
- Dimming Ratio > 32,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

**LP8863-Q1**
- 3V to 48V $V_{IN}$
- 6 x 150mA LED Current
- Dimming Ratio > 32,000:1
- Ch. Current Ind. Control
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Advanced Diagnostics w/ I2C

Ext. FET

Int. FET

Bigger, Higher Brightness

Smaller, Lower Brightness

**LP8869-Q1** *3A*
- 4.5V to 40V $V_{IN}$
- 3 x 120mA LED Current
- Dimming Ratio 10,000:1
- Power Line FET Driver
- Current De-rating w/ Ext NTC

**LP8867-Q1** *3A*
- 4.5V to 40V $V_{IN}$
- 4 x 120mA LED Current
- Dimming Ratio 10,000:1
- Power Line FET Driver
- Current De-rating w/ Ext NTC

**LP8869C-Q1** *3A*
- 4.5V to 40V $V_{IN}$
- 3 x 120mA LED Current
- Dimming Ratio 10,000:1

**LP8867C-Q1** *3A*
- 4.5V to 40V $V_{IN}$
- 4 x 120mA LED Current
- Dimming Ratio 10,000:1

*xxA* **Power FET Current**

Texas Instruments

# LP8866-Q1 / LP8866S-Q1

## Features

- **AEC-Q100 Qualified for Automotive Applications (Grade 1: $T_A$ -40C to +125C)**
- **Six High-Precision Current Sinks**
  - Output Current up to 200/150 mA/Channel
  - Current Matching 1% (typical)
  - Up to 16-bit LED Dimming Resolution
  - Individual LED String Brightness Control
  - Dimming Ratio 32,000:1 @ 152Hz PWM
  - I2C, PWM Brightness Control Modes
  - 8 configurable LED strings configuration
  - Automatically adjusts phase shift for number of LED strings
- **Boost Controller for LED String Power**
  - Input Voltage Operating Range 3 V to 48 V
  - Switching Frequency 100 kHz to 2.2 MHz
  - Boost SYNC input to set boost switching frequency from an external clock
  - Spread Spectrum for lower EMI
  - Adaptive Voltage Control for Power Optimization
  - Output voltage automatically discharged when boost is disabled
- **Full Protection and Diagnostic Features**
  - Open, Shorted, Short-to-GND LED Fault Detection
  - Boost Output OVP and OCP
  - Boost Input UVLO, OVP and OCP
  - External Resistor Fault/Charge Pump Fault/CRC Errors
  - VDD UVLO and Thermal Shutdown
- **HTSSOP-38 Package (DCP)**

## Applications

- **Backlight for:**
  - Automotive Infotainment
  - Automotive Instrument Clusters
  - Smart Mirrors
  - Heads-Up Displays (HUD)
  - Central Information Displays (CID)
  - Audio-Video Navigation (AVN)

## Benefits

- **High brightness and big size LCD panel support with**
  - 6 * 200/150 mA  LED output
- **Good Cold cranking behavior with**
  - Input Voltage Operating Range 3 V to 48 V
- **Good EMI Performance with**
  - Phase shifted LED outputs
  - Boost converter Spread Spectrum
  - Hybrid Dimming  (Linear + PWM)
  - Boost synchronization input
- **Ease Customer design with**
  - Resistor configuration for PWM /Boost frequency/LED configuration/Dimming mode
  - Integrated Discharge function

![Texas Instruments logo]
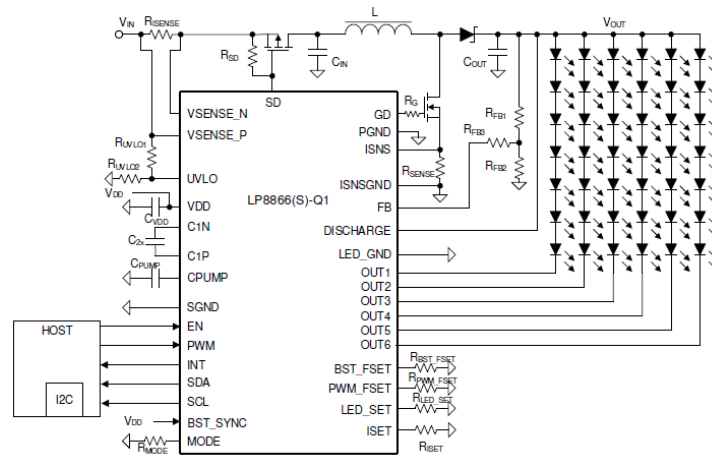
# Full diagnostics

| REGISTER NAME | FUNCTION |
|---|---|
| FSM_LIVE_STATUS | Current state of the functional state machine |
| PWM_INPUT_STATUS | Measured 16-bit duty cycle of the PWM pin input |
| LED_PWM_STATUS | 16-bit LED PWM duty cycle from state machine |
| LED_CURRENT_STATUS | 12-bit LED current DAC value from state machine |
| VBOOST_STATUS | 10-bit value for adaptive boost voltage target — value is linear between VBOOST_MIN and VBOOST_MAX calculations |
| MODE_SEL_CFG | Dimming mode configuration from MODE detection |
| LED_STRING_CFG | LED string phase configuration from LEDSET detection |
| BOOST_FREQ_SEL | Boost switching frequency value from BST_FSET detection |
| PWM_FREQ_SEL | LED PWM frequency value from PWM_FSET detection |

The LP8866-Q1 contains several diagnostic registers that can be read with the I2C interface for debugging or additional device information.

# LED SHORT_TO_GND

- Support the industry's quickest detection of LED short to GND fault

- Avoid the glare when LED is short to GND
  - Risk of blinding driver at night
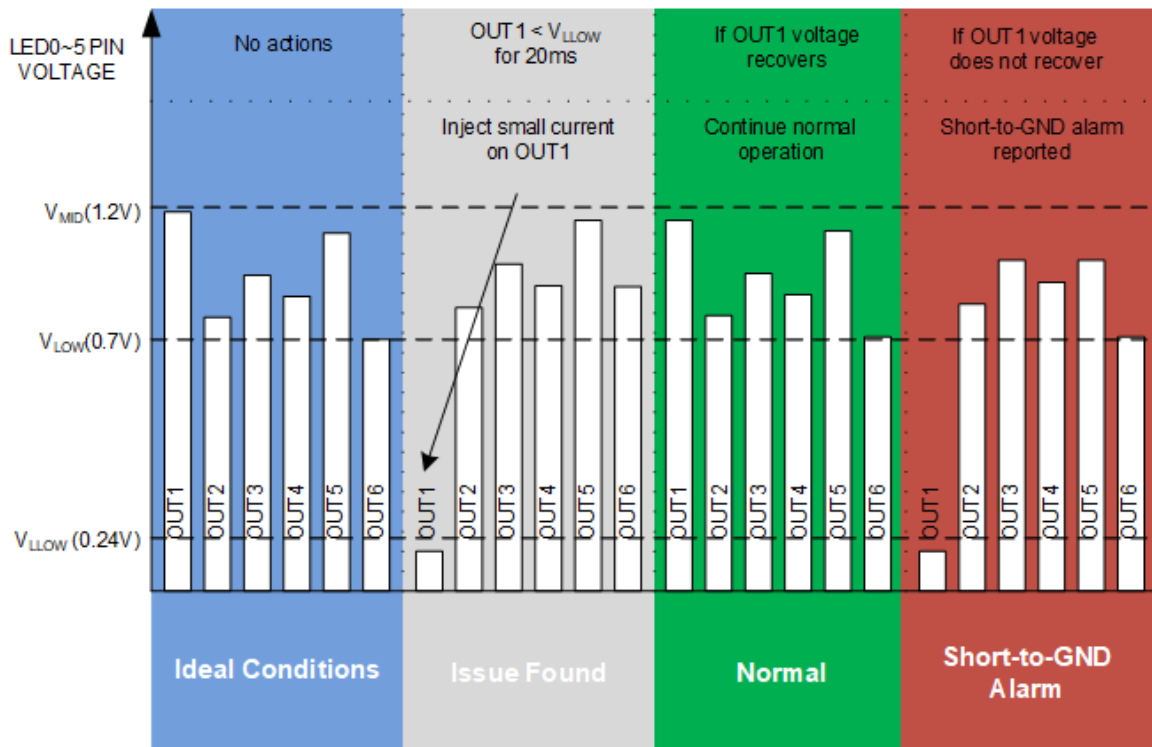
# Full fault detection and handling

| Supply Fault |
|---|
| VIN undervoltage |
| VIN overvoltage |
| VIN overcurrent |
| VDD undervoltage |
| Charge pump fault |
| Charge pump components missing |
| Boost sync clock invalid fault |
| Internal Register CRC Fault |

| Boost Fault |
|---|
| Boost OVP low |
| Boost OVP high |
| Boost overcurrent |
| LEDSET detection fault |
| MODE detection fault |
| FSET detection fault |
| ISET resistor fault |
| Thermal shutdown |

| LED Fault |
|---|
| Open LED string |
| Shorted LED |
| LED short to GND fault |
| Invalid LED string detected |

- The Interrupt Fault Status registers can be read back in three fault registers

- Fault in red means critical fault which will make the chip enter into fault recovery state. It will shutdown all the modules and retry periodically

**TEXAS INSTRUMENTS**

# High reliability & diagnostic coverage

LP8866-Q1 could survive (no damage) when any pin is OPEN/ Short to GND or short with adjacent pin

| Name | Damage? | | |
|---|---|---|---|
| | Open | Short to GND | Adjacent pin Short |
| VDD | No | No | No |
| EN | No | No | No |
| C1N | No | No | No |
| C1P | No | No | No |
| CPUMP | No | No | No |
| CPUMP | No | No | No |
| GD | No | No | No |
| PGND | No | No | No |
| PGND | No | No | No |
| ISNS | No | No | No |
| ISNSGND | No | No | No |
| ISET | No | No | No |
| FB | No | No | No |
| NC | No | No | No |
| DISCHARGE | No | No | No |
| NC | No | No | No |
| OUT6 | No | No | No |
| OUT5 | No | No | No |
| OUT4 | No | No | No |
| OUT3 | No | No | No |
| OUT2 | No | No | No |
| OUT1 | No | No | No |
| NC | No | No | No |
| INT | No | No | No |
| SDA | No | No | No |
| SCL | No | No | No |
| BST_SYNC | No | No | No |
| PWM | No | No | No |
| SGND | No | No | No |
| LED_SET | No | No | No |
| PWM_FSET | No | No | No |
| BST_FSET | No | No | No |
| MODE | No | No | No |
| DGND | No | No | No |
| UVLO | No | No | No |
| VSENSE_P | No | No | No |
| VSENSE_N | No | No | No |
| SD | No | No | No |

**TEXAS INSTRUMENTS**

# Local dimming architecture

| | Global Dimming | Local Dimming |
|---|---|---|
| TCON | Process Video stream only | Process both Video stream and backlight control signal |
| LED Backlight Unit | Mostly edge-lit | Direct lit only. Each zone contains at least one LED |
| LED Driver | Channel current output global controlled | Channel current output individually controlled Digital interface cascaded |
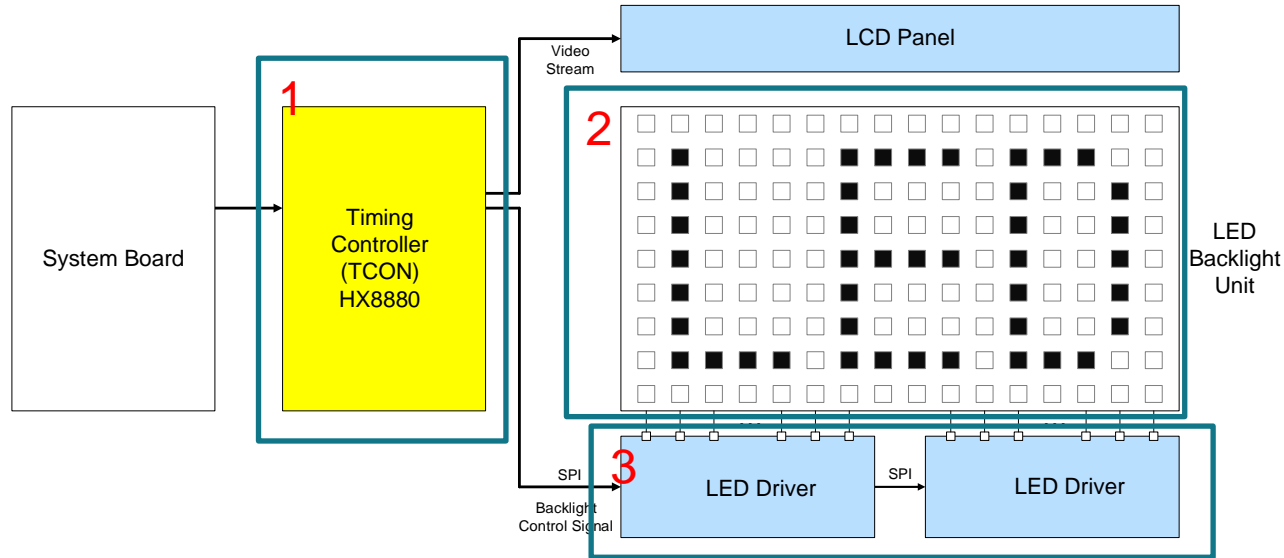
# Channel individual control LED driver (direct)

- All the LEDs are driven at the same time in parallel
- One backlight zone needs one LED driver's channel

TEXAS INSTRUMENTS
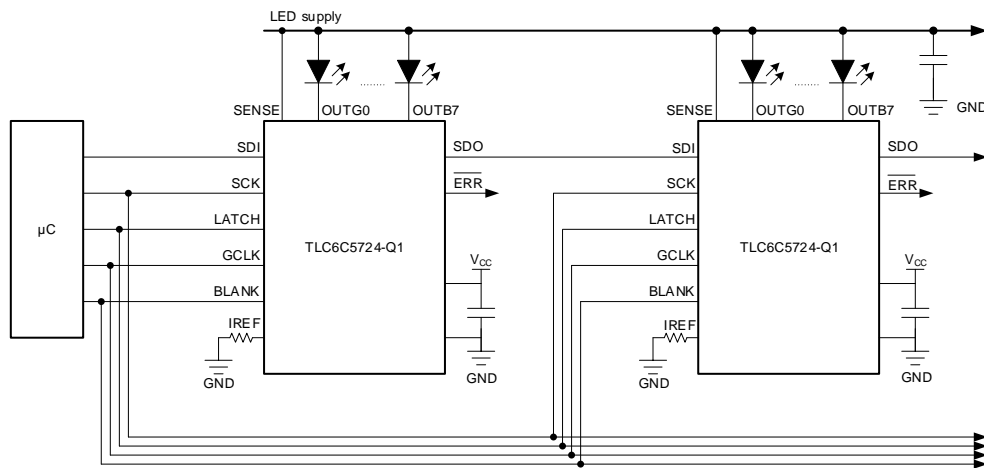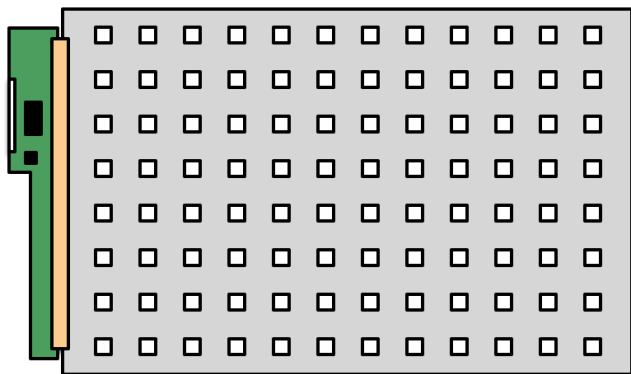
# Channel individual control LED driver (scan)

- The backlight LEDs are driven sequentially in groups.

- One LED driver's channel could cover multiple zones (depending on multiplexing config)

- High peak current for each LED and LED driver's channel since each LED could be only on in a duty cycle (25% in the 4:1 multiplexing example below).

TEXAS INSTRUMENTS
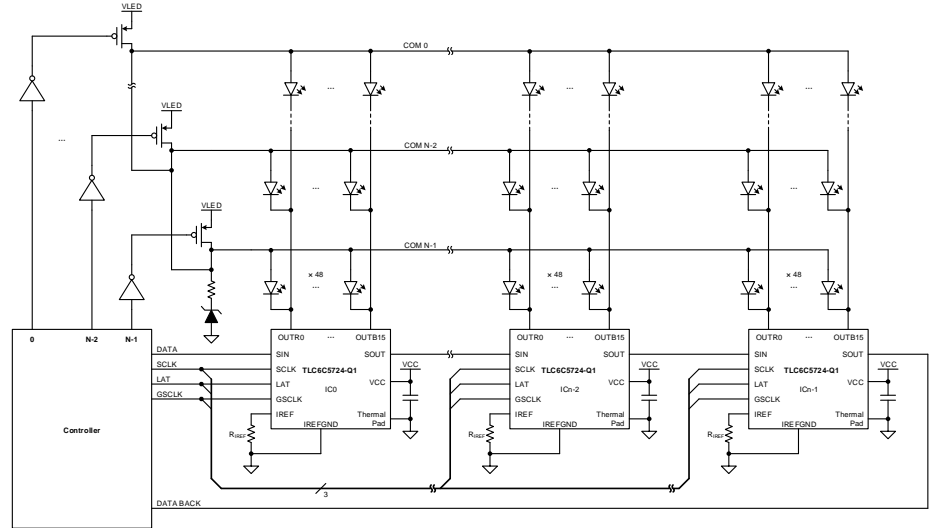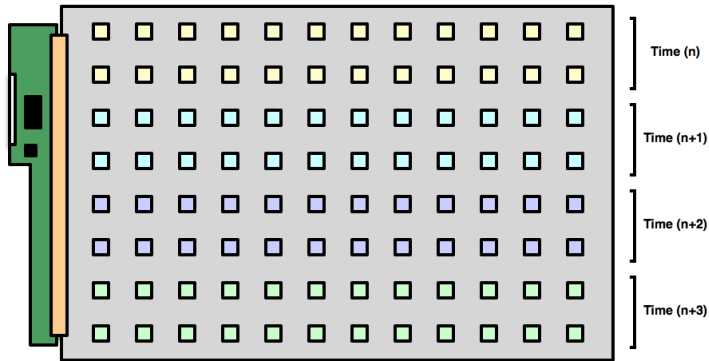
# Thermal dissipation

## Direct Drive
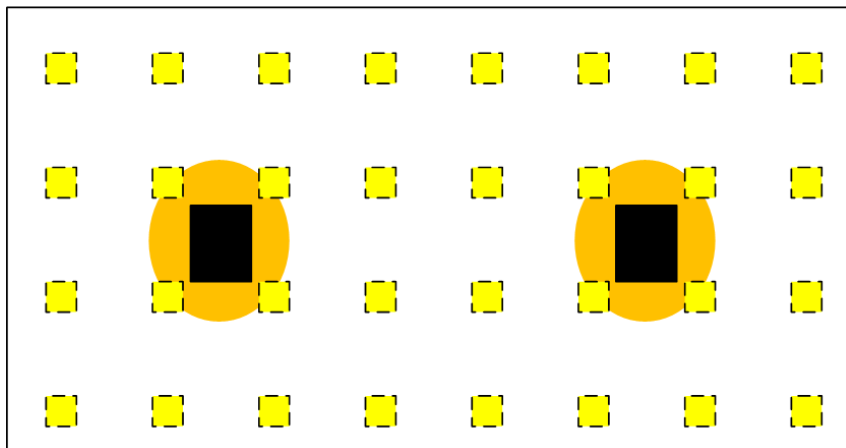
## Scan

- Feasible to put chip on LED board
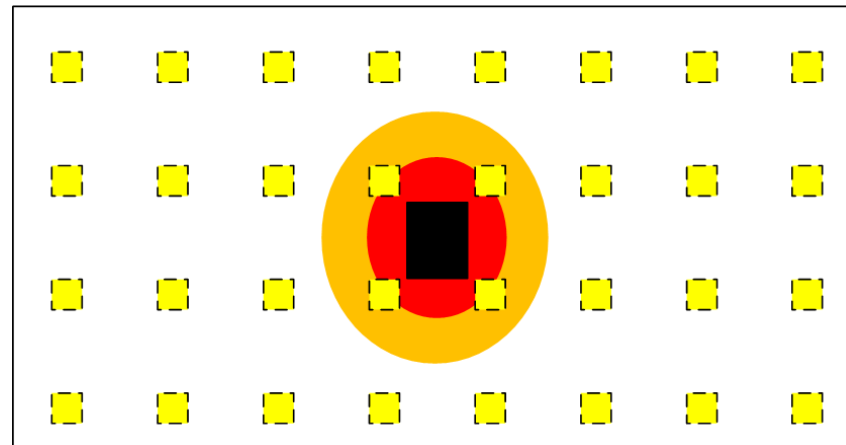
- Higher LED power consumption and higher LED driver power consumption
- Higher PCB thermal peak
- Unfeasible to put chip on LED board

# Direct vs. scanning LED driver placement

**Direct Drive**
*(Drivers on board)*

**Integrated Scanning**
*(Drivers on external board)*

Shell

LCD Panel

LED Board

Control Board

- LED drivers & LEDs

VLED/VDD/SPI(4)/CLK/GND

- TCON/MCU
- Power

- LEDs only

HSx (4) + LEDx (all channel)

- LED Drivers
- TCON/MCU
- Power

Bigger connectors & more PCB space

**TEXAS INSTRUMENTS**
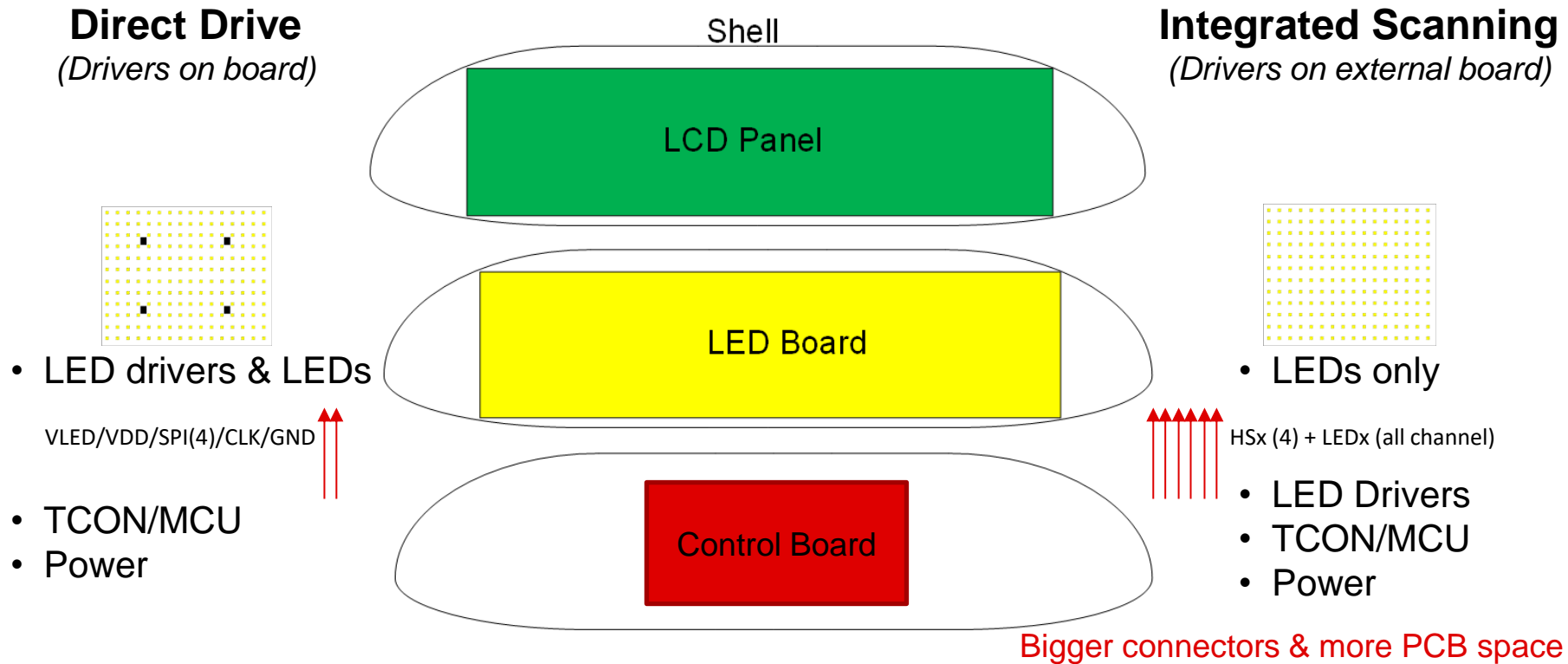
# Local dimming roadmap

**TLC5941-Q1**

- 16 CH Const. Current Sink
- 17V breakdown Voltage
- Vcc = 3 ~ 5.5V, 30MHz Serial I/F
- 60mA/ch
- 6 bit Dot Correction
- 12 bit Int. Ind. PWM
- OT, LED Open
- HTTSOP-28, 4.4 mm* 9.7 mm

**TLC6C5716/24-Q1**

- 16/24 CH Const. Current Sink
- 8V breakdown Voltage
- Vcc = 3 ~ 5.5V, 4MHz Serial I/F
- 50mA/ch
- 7 bit Dot Correction, 8 bit BC
- 12/10/8 bit Int. Ind. PWM
- OT, LED Open/Short/Short-to-GND
- HTTSOP-38, 6.2 mm* 12.5 mm

**TLC6C5748-Q1**

- 48 CH Const. Current Sink
- 11V breakdown Voltage
- Vcc = 3 ~ 5.5V, 25MHz Serial I/F
- 32mA/ch
- 7 bit Dot Correction, 7 bit BC
- 3 bit MC, Integrated IREF
- 16 bit Int. Ind. PWM, ES-PWM
- OT, LED Open/Short
- HTTSOP-56, 6.1 mm * 14 mm

## Lower cost per channel

**TEXAS INSTRUMENTS**

# TLC6C5748-Q1
## 48ch, 16bit PWM LED Driver with low headroom voltage and high output voltage

## Features

- 48 Outputs with 7bit DC for each output
- 16bit PWM Constant-Current with 7bit Brightness Control and 3bit Max Current Control for 31.9mA, no external RIREF resister
- IC Supply Voltage Range:      3.0 – 5.5V
- LED Breakdown Voltage:      11V
- Precise Constant Current Regulation:
  Channel-to-Channel:  ± 2% (typ)
  Device-to-Device:  ± 2% (typ)
- Low Headroom Voltage: 0.25V@19mA
- LED Open/Short Detection
- Over Temperature Detection
- Power Save Mode: 7uA consumption
- HTTSOP-56 Package (DCA)     6.1 mm * 14 mm
- Operating Junction Temperature Range: -40 C to +125C

## Applications

- Automotive Local Dimming Backlight
- Automotive Pixel Lamp
- Automotive RGB display

## Benefits

- Best to drive 48 LED zones with uniformity
- Perfect solution for chip-on-LED-board architecture
- Direct daisy chain interface with TCON controller
- Max 3 single-junction LEDs/ 1 dual-junction LED in series
- Reduces system power consumption
- Reduces system cost
- Unlimited device cascading

TEXAS INSTRUMENTS
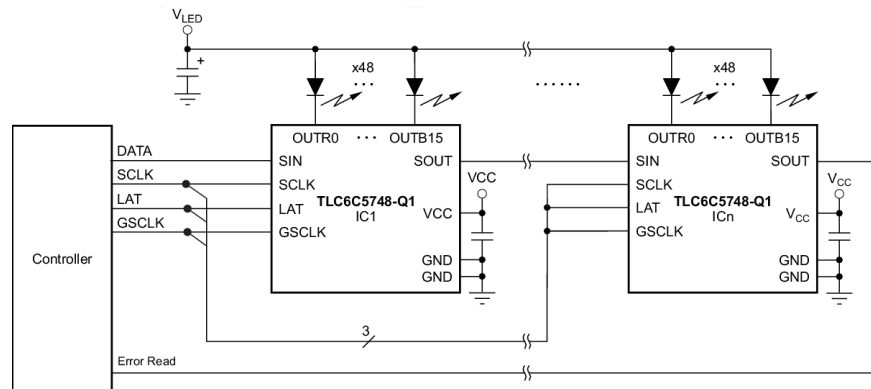
# XTIDA-020036 384-Zone 12" Local Dimming Backlight Reference Design



## Features

- 384 zones & LEDs
  - 12x32 matrix; 1S1P
  - 0.9 cm pitch
- PCB Specifications
  - Direct driver on back of PCB
  - 2 layer PCB
- SPI control for 8x daisy-chain
- 8x 48-ch low-side LED drivers
- Compatible with local dimming TCONs
- LED Specifications
  - OSRAM Mini TOPLED White 120° SMD
  - Size : 2.3mm x 1.9mm (91mil x 75mil)
  - Single junction @ 3.05V forward voltage
  - 20mA per LED
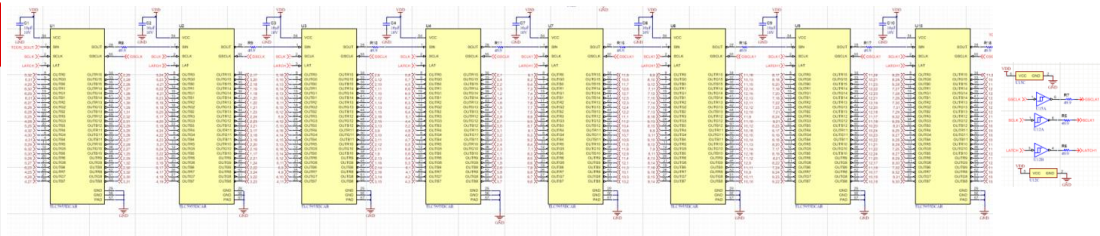
## Tools & Resources

- **TIDA-020036 Folder**
- **Design Guide**
- **Design Files:** Schematics, BOM, Gerbers, Software, etc.
- **Device Datasheets:**
  - TLC6C5748-Q1
  - SN74LVC2G17
  - LCW MVSG.EC-BXCX



~500mV headroom
30C temperature increase



*TOP*

*BOTTOM*
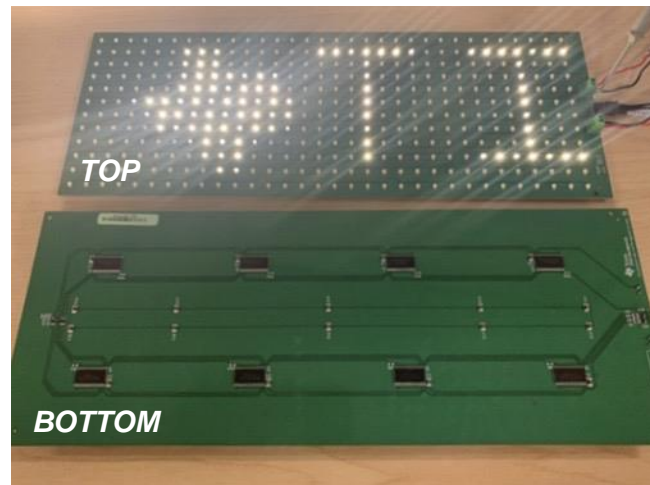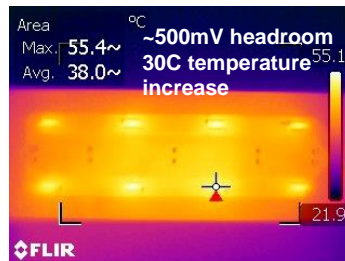
# Aiding Functional Safety cluster system designs

- TI offers **Functional Safety-Capable** LED drivers to aid system-level functional-safety cluster system design

- Documentation we can provide:
  - **Functional safety FIT rate**
    - Based on IEC TR 62380 or SN 29500 standards
    - Calculated at a 90% confidence interval for safety-related rate estimation in compliance with IEC 61508 and ISO 26262
  - **Failure mode distribution (FMD)**
  - Pin FMA *
  - Diagnostic description and fault handling routine *

  *Available for select products*

**TEXAS INSTRUMENTS**

# Q&A