TI Cluster EE Solution

Maka Luo (FAE) & Peter Li (FAE)
Analog Cluster

VBAT_RPD, 5V or 3.3V

Tell-Tale LED Driver

Ambient backlight driver allows the gauges to be seen at night. Must be dimmable.

GPIO/ I2C

5V Stepper Motors drive the gauge's position. Motor Driver is typically built into the Cluster MCU

ESD

Reset Button

5V Stepper Motors drive the gauge’s position. Motor Driver is typically built into the Cluster MCU
Hybrid Cluster with Informational Graphics Support

- Fuel Gauge (Stepper Motors)
- Speedometer (Stepper Motors)
- Tachometer (Stepper Motors)
- Ambient Backlights
- Tell-tale LEDs
- Temperature Gauge (Stepper Motors)
- LCD (Mileage, Trip)
- Ambient Backlights
Hybrid Cluster with Informational Graphics Support

Ambient Backlights

Stepper Motors

TFT Display
(720p or lower)

PRNDL / Tell Tale

Ambient Backlights

Stepper Motors
Hybrid Cluster with Active Graphics Support

- Ambient Backlights
- Stepper Motors
- TFT Display (Hi Resolution)
Full Display Digital Cluster

FULL TFT Display
Remote HUD Interface
- Wired Interface
- Signal Input/Output Protection
- Power Stage

Integrated Display
- Wired Interface
- Signal Input/Output Protection
- Input User Interface
- Output User Interface

Applications Processor
- Digital Processing
- Clocking
- Non-isolated DC/DC
- Memory
- Wired Interface

Driver Notification
- Power Stage
- Signal Input/Output Protection
- Output User Interface

Off-Battery Power
- Input Power Protection
- Non-isolated DC/DC
- Current/Voltage Sense

Vehicle Interface Processor
- Digital Processing
- Self-diagnostics/Monitoring
- Wired Interface

Vehicle CAN/LIN/E-NET Bus

• About same as High end Hybrid
• Remove Analog Gauge Motors and Drivers.
Typical Digital Cluster Block Diagram
J6 entry digital cluster

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High性价比，高成熟度，高可靠的数字仪表解决方案
TI AUTOMOTIVE PROCESSOR SOLUTION FOR CLUSTER

HIGH PERFORMANCE
• High-performance graphics and display (HD→ 4K)
• Industry-leading HMI development tool kits supported on Jacinto platform

SAFETY & SECURITY
• Robust HW and SW architecture, AMPU
• Early boot functions, security features
• Ecosystem for Safety OS
• Hypervisor

SYSTEM COST
• Integration with numerous BOM-savings supported by hardware architecture
• Cost-optimized / automotive qualified 28nm

SCALABILITY & RE-USE
• Platform span across all market segments
• Software re-use, R&D efficiency
• Prepare for ECU integration
Choose the right core for the right job

- **Flexibility**
  - MPU: Microprocessor
  - GPU: Graphics Processor
  - DSP: Digital Signal Processor
  - AMPU: Auxiliary Microprocessor
  - HWA: Hardware Accelerator

- **Efficiency**
  - Offload the majority of “work” to specialized processors. Provide tools & SW to manage complexity
  - Optimize entire platform around programmer productivity on the MPUs

- **Key Points**
  - Single to multi-cores MPU enable performance scalability and **concurrency**
  - Separate MPU clusters facilitates multi-OS and multi-domain software architecture
  - Greater power efficiency than solution using general-purpose processors
  - Auxiliary MPUs support real-time, safety OS and/or interrupt-intensive tasks
  - Image, signal and vision co-processors for simultaneous IVI and InfoADAS features

**Heterogeneous Multicore Architecture**

**Texas Instruments**
# Jacinto 6 Processors for Digital Cluster

<table>
<thead>
<tr>
<th>Feature</th>
<th>Jacinto 6 Entry (DRA71x)</th>
<th>Jacinto 6 Eco (DRA72x)</th>
<th>Jacinto 6 (DRA74x)</th>
<th>Jacinto 6 Plus (DRA76x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster Display Resolution</td>
<td>1920x720 @60fps</td>
<td>2880x1080 @60fps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPU (DMIPs)</td>
<td>Up to 3.5K</td>
<td>Up to 5.25K</td>
<td>Up to 10.6K</td>
<td>Up to 12.7K</td>
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<tr>
<td>Aux MPU (Mhz)</td>
<td>2x Dual-M4 (212)</td>
<td>2x Dual-M4 (212)</td>
<td>2x Dual-M4 (212)</td>
<td>2x Dual-M4 (212)</td>
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<tr>
<td>3D GPU (GFLOPS)</td>
<td>SGX544 (Up to 13.6)</td>
<td>SGX544 (Up to 17)</td>
<td>SGX544-MP2 (Up to 34)</td>
<td>SGX544-MP2 (Up to 42.5)</td>
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<tr>
<td>2D GPU (Mhz)</td>
<td>GC320 (354)</td>
<td>GC320 (354)</td>
<td>GC320 (354)</td>
<td>GC320 (354)</td>
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<tr>
<td>Memory BW (GB/s)</td>
<td>Up to 5.3</td>
<td>Up to 5.3</td>
<td>Up to 8.5</td>
<td>Up to 10.7</td>
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<tr>
<td>Optional cores</td>
<td>IVA-HD (Multimedia HD video decode and encode for infotainment content integration)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Power Management</td>
<td>TPS65919</td>
<td>TPS65917</td>
<td>TPS65917 or TPS659039</td>
<td>TPS659039</td>
</tr>
<tr>
<td>Software Compatibility</td>
<td>Software Compatible</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Digital Cluster Automotive Reference Design (DCARD)

DCARD Features:
- Based on DRA71x (J6 Entry) SoC
- 1920x720@60fps OpenLDI cluster display
- Single zone audio output, wake-up from CAN, Ethernet
- **Optional**: Camera input for RVC, DMS and HUD output
- 6-layer PCB Design

**Total System BOM optimized**
Excludes external components: display, camera, etc.

Availability
- Hardware & design files on ti.com
- Demonstration w/ various UI engine

Digital Instrumentation
- Digital Cluster
- HUD
- DMS Integration
TIDEP-01002 Digital Cluster Automotive Reference Design (DCARD)

Features

- Based on J6Entry SoC
- Support for 1920x720@60fps OpenLDI cluster display
- Single zone audio output,
- DMS support
- Fast boot (early telltales/audio, full system boot)
- ASIL-B safety support
- Auto network (CAN/Ethernet)
- No wake-up micro

Applications

- Digital Cluster
- Driver Monitoring
- Heads up display
- Remote Display

Tools & Resources

- TIDEP-01002 and/or Tools Folder
- Design Guide
- Design Files: Schematics, BOM, Gerbers, Software, etc.
- Device Datasheets:
  - J6 Entry

Benefits

1. Low-cost automotive reference board
2. Customers Tier1’s to build their own boards easily and quickly.
JACINTO 6 DISPLAY SUBSYSTEM ARCHITECTURE

- 4-input-pipeline architecture
  - 1 GFX (RGB only)
  - 3 VID (YUV or RGB with scaling & CSC)

- Outputs
  - 3 DPI Outputs
  - 1 HDMI 1.4 TX
  - up to 1080p60 output

- 1 WB (writeback) path for Frame Monitoring
JACINTO SOFTWARE ARCHITECTURE – CLUSTER

- **Graphics Subsystem**
  - **Imagination**
    - 3D Graphics
  - **Vivante**
    - 2D Graphics

- **ARM® MPU**
  - HMI / Applications
  - Cluster Rendering
  - Automotive Stack
  - Tell-Tales Rendering (optional)
  - Safety Checker (optional)
  - Connectivity
  - Display Driver
  - Graphics
  - Kernel, Filesystem, Peripheral Drivers, Power Management

- **ARM® IPU**
  - Video Decode / Encode
  - Driver Minoring System
  - HUD Warping
  - Safety Checker
  - SysBIOS

- **Video Subsystem (optional)**
  - Video Decode
  - Video Encode
  - Video HWA

- **DSP (optional)**
  - Driver Minoring System Application

- **Display Subsystem**
  - Tell-Tales Pipeline
  - DMS Pipeline
  - WriteBack Pipeline

- **Safety Domain**

---

**HLOS SDKs supported**
- Linux SDK
- Mentor Connected OS GENIVI Linux
- Android SDK
- QNX SDKs
  - Both on QNX 6.5 SP1 & QNX 6.6 kernels
  - QNX 6.5 SP1 is ASIL-D (ISO 26262) certifiable

**RTOS SDKs supported**
- TI SysBIOS on Cortex-M4s & C66x DSP
- Green Hills INTEGRITY
  - BSP options available ASIL-A thru ASIL-D (ISO 26262) certifiable
- Mentor Nucleus
  - BSP options available ASIL-A thru ASIL-B (ISO 26262) certifiable
OTHER SOFTWARE SUPPORT

• Code Composer Studio (CCS)
  – Supports multi-core development & debug
  – CCSv6.1 uses an unmodified Eclipse Version 4.4.1 and CDT 8.3
  – Flexible licensing; download trial now; online training

• System Analyzer
  – Real-time tool for analyzing, visualizing and profiling applications running on single or multi core systems

• Optimizing C Compiler for C66x DSP and Cortex-M4
  – with Runtime Support Library (RTS); download now

• Real-Time Operating System (Sys/BIOS 6.x)
  – Open source (BSD license); download now

• Inter-Processor Communication (IPC 3.x)
  – Provides message passing & notification, shared memory; optimized to use available hardware support
  – Open source, online documentation & training; download now

• DMA Low-Level Driver (EDMA3 LLD)
  – Supports transfers between memory and/or device peripherals; full source code; download now

• EVM Board Support Package (BIOS BSP)
  – Includes Audio-Loopback example; contact TI for download

• StarterWare
  – OS-agnostic low-level software; contact TI for download

• XDAIS (eXpress DSP Algorithm Interoperability Standard) Developer’s Kit
  – Algorithm interface utilized by TI and 3rd-party software; download now

• Optimized DSP Software Library (DSPLib)
  – FIR & IIR filtering, FFT, vector processing, incl. source code; download now

All of the above software is royalty free
# Jacinto 6 Digital Cluster Ecosystem Support

<table>
<thead>
<tr>
<th>Features/Functions</th>
<th>Partner Names</th>
<th>Partners Logo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphics / HMI partners</td>
<td>Altia</td>
<td>Crank</td>
</tr>
<tr>
<td>Industry-leading HMI development tool kits</td>
<td>GlobalLogic</td>
<td>Green Hills Software</td>
</tr>
<tr>
<td>Hypervisor partners</td>
<td>QNX</td>
<td>Mentor Embedded Green Hills Software Texas Instruments</td>
</tr>
<tr>
<td>RTOS / Early features</td>
<td>Cetitec</td>
<td>Excelfore Mentor Embedded Elektrobit Vector Software</td>
</tr>
<tr>
<td>Automotive Stack</td>
<td>mentors.com</td>
<td>vector.com</td>
</tr>
</tbody>
</table>

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*Texas Instruments*
Unique Features & Benefits

• Robust Architecture (enable robust Linux Cluster)
  ASIL-B SOC
  Frame monitoring framework
  HW feature support FFI

• Heterogeneous Backup UI
  Independent Telltale/Safety UI on M4

• High efficient Hybrid Composition
  (Saving of 30% - 50% GPU bandwidth by offloading composition)

• <1s telltale fastboot (<2s Cluster UI)
• Support CAN wakeup on internal M4
• DMS/SRV integration
• No Fan
Integration w/ DMS & HUD
Display resolutions up to 2880x1080

- DMS和HUD的处理不占用仪表的graphic资源
- 异构的M4核直接控制视频的采集通过硬件DMA输出，无需主核参与
- 多硬件图层高效合成，互不影响 （telltale/ADAS/HUD/3D仪表）
- 成熟的软硬件框架， production ready
- 可方便移植其他视觉处理功能
Integration w/ IVI features

Jacinto Family of Devices can drive a single fully reconfigurable LCD display to support a fusion between traditional infotainment (radio, Nav., smartphone replication, HVAC, etc.) & digital cluster features (see configuration examples of single reconfigurable display to left)

QNX, Linux, Android, Mentor Nucleus, GHS INTEGRITY RTOS support
Integration w/ vision features

- Heterogeneous Arch Isolation
  - 3D Cluster UI on A15+GPU
  - Telltale backup UI on IPU2
  - Vision Processing on IPU1+DSP

“Jacinto 6” DRA74/5x (DRA7x ASIL-B Certified)

- Digital Cluster integrate
  - DMS(Driver Monitoring)
  - Face Identification
  - AR-Driver

DMS/FaceID ➔ In-Cabin Sensing (TOF/Radar)
Typical Demo

1. Jacinto 6 Entry stand-alone cluster based on Linux running on a Cortex-A15 and Mentor Nucleus RTOS on a Cortex-M4
   
   https://www.youtube.com/watch?v=TvLnC-IJeQ8&list=PLISmVLHAZbTSLiyH-Pz71QFh_6wLJiizV&index=19
   
   Demonstrating 60fps cluster performance on a 1920 by 720 display and safety architecture based on auxiliary MPU core. A similar concept was also demonstrated on Jacinto 6 Eco showing >70fps cluster performance on a 1920 by 720 display.

2. Jacinto 6 stand-alone cluster based on Green Hills Integrity running on a Cortex-A15
   
   
   demonstrating safety architecture.

For more details, see http://www.ti.com/jacinto.
Find millions of questions and answers at https://e2e.ti.com/support/processors/f/791.
Digital Cluster Block Diagram - Power

System Power

- High-Side Switch
- Mid/Low Vin Boost
- Mid/Low Vin Buck/Boost
- MID/LO Vin LDO
- MID/LO Vin Multi-Rail DC/DC
- MID/LO Vin Buck
- PMIC

Cluster System Power

- Reverse Battery Protection
- Over Voltage/Over Current Protection
- Off-Battery Power

Camera Interface and Driver Monitoring
- Camera Module
- Serializer
- Deserializer
- Video MUX
- Analog Video Decoder
- LVDS
- ESD Protection
- (IR) LED Driver

Applications Processor
- CAN
- CAN Transceiver
- RS232 Transceiver
- LIN Transceiver
- RS485 Transceiver
- Analog MUX
- ESD Protection
- Current Sense Amplifier
- Analog Switch
- Comparator
- Temperature Sensor
- IO Expander

Display Support and Backlight Control
- Display Module
- LCD Panel
- Gamma Buffer
- LCD Bias Supply
- Ambient Light Sensor
- ESD Protection
- Backlight LED Driver

Engine Monitoring
- OPAMP
- SAR ADC
- Voltage Reference

Driver Notification
- Audio DAC
- Class AB or Class D Audio Amplifier
- OPAMP
- Tell-Tale Drivers
- E2C Level Translator
- Bidirectional Voltage Translation
- Digital Logic and Voltage Translation
- Non-Inverting Buffer/Driver
- Voltage Translator
Cluster System Power – MCU Wake on CAN Support

- Input filter aids in CISPR 25 Conducted Emission compliance
- Full Range: 3 V to 42 V
- Normal Operation: 6 V to 18 V
- Start-Stop: 4.5 V to 6 V
- Reverse Battery Protection required. Can be accomplished with a diode:
  - 0.3 V to 1 V drop across
  - Typically 1 W to 2 W
- 10 – 14V used to Power 10W chimes and Ambient Backlight LEDs in some systems
- Low VIN DC/DC or LDO to power MCU 3.3V section. MCU may have this function built in. For DC/DC, must have Low I_o for always on operation
- Low I_o Power System required to power Vehicle Interface Processor and CAN bus during sleep (120 µA System Power Budget)
Innovation for Packaging

Hotrod packaging

Hotrod is a flip chip on lead frame QFN package

- Major performance enhancements
  - Lower Rds_on
    - Higher Efficiency @ 2.1MHz
    - 91% at VIN=13.5V, Vout=5V, Iout=3A
  - Smaller solution size
  - Lower inductance => dramatically lower switch node ringing (see bottom image)
  - Package footprint from 2x2mm to 4x5mm
Innovation for EMI Performance

EMI Optimized Buck Converters

Minimize EMI through:
1. Spread Spectrum Feature
2. Hot-rod Packaging
3. Symmetric Pinout

Spread Spectrum makes it easier to design and meet OEM standards for conducted and radiated EMI such as CISPR 25 Class 5

Hot-rod packaging eliminates switch node ringing

Symmetrical pin out optimizes EMI performance
Innovation for Packaging
Wettable flank packages and high switching frequency

Wettable Flanks
- Wettable flanks guarantees visible side-wetting at good solder joints
- Enables 100% automotive visual inspection assembly processes
- Dual plated punched process with notch on underside of the package

2.1 MHz Operation
- True 2.1 MHz operation to avoid AM band

Switching Frequency vs. VIN

- Maintains 5V, 3A output with 2.1MHz switching for VIN=6V
- Test Conditions: Force-PWM mode Temp = 25degC
- No Load
- Iload=3A

Holding frequency means no sweeping through AM Band when in Cold Crank

Standard QFN

Wettable Flanks
**LMR33630/20-Q1**

36V 2A/3A, Simple Switcher ® Synchronous Buck Regulators

### Features
- 85/55mOhm Internal HS&LS RDS\(_{on}\)
- 50 ns minimum on time (typical)
- <25\(\mu\)A quiescent current at no load
- Vin range 3.8V - 36V
- Vout Range 1.0V to 95%Vin
- Switching frequency = 410 kHz, 1.4MHz, 2.1 MHz +15%
- Minimum Off-Time = 75ns (typ)
- QFN-12, Q Grade available
- Vfb =1V + -2% over temperature
- Soft-start time = 5 ms
- Soft starts into pre-biased load
- Cycle by cycle current limiting
- Hiccup Short Circuit Protection
- Internal Compensation
- SOIC-8 and QFN-12 3x2mm package
- P2P compatible with 65V and 85V versions

### Benefits
- High frequency and tight current limit to lower inductor size
- Wide vin operation to accommodate industrial and automotive line variation
- High efficiency with good thermal performance to withstand high ambient temperatures found in automotive electronics
- Compact solution size with high switching frequency

### Applications
- Media USB PD
- Industrial distributed power applications
- Space constrained industrial applications
- Space constrained automotive applications
## LMR33630 Efficiency Data

<table>
<thead>
<tr>
<th>Key Specifications</th>
<th>Silicon (SOIC)</th>
<th>Silicon (HR QFN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency (12V to 5V, 3A, 2.1 MHz)</td>
<td>89.2%</td>
<td>91.6%</td>
</tr>
<tr>
<td>Efficiency (12V to 5V, 3A, 400 kHz)</td>
<td>91.3%</td>
<td>92.1%</td>
</tr>
<tr>
<td>$R_{ds_{on}}$ (HS)</td>
<td>95mΩ</td>
<td>75mΩ</td>
</tr>
<tr>
<td>$R_{ds_{on}}$ (LS)</td>
<td>66mΩ</td>
<td>50mΩ</td>
</tr>
<tr>
<td>Quiescent Current ($I_q$)</td>
<td>31µA</td>
<td>30µA</td>
</tr>
<tr>
<td>Minimum On-time</td>
<td>34ns</td>
<td>33ns</td>
</tr>
<tr>
<td>Abs Maximum $Vin$</td>
<td>40V</td>
<td>40V</td>
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<tr>
<td>Minimum $Vin$</td>
<td>3.71V</td>
<td>3.70V</td>
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</tbody>
</table>

![Graph showing efficiency vs output current](image)
400kHz and 2MHz size comparison QFN Hotrod

LMR33630
3A @ 400kHz

306mm²

LMR33630
3A @ 2MHz

168mm²
LMR33630/20-Q1 : HR vs SOIC Footprint
LMR33620/30-Q1 Overview

The LMR33620/30-Q1 is the latest device wide vin 2/3A, 36V device on the latest LBC9 process node

• Wide input voltage range from 3.8-36V (42V transients) helps reduce input protection circuitry for 12V automotive and 24V industrial systems
• Low <25uA Iq for better light load performance and for always on applications
• 3 frequency options of 400kHz, 1.4MHz, or 2.1MHz to optimize for efficiency or solution size
• 94.5% peak efficiency at 400kHz with leaded (SOIC8) or HR QFN package
• Highest energy density on the market for QFN HR12 package
LMR14020/30/50
4 - 40V 2A/3.5A/5A, High performance/ cost ratio, Buck Converter

Features
- Wide Vin range: 4V to 40V
- Standby current: 40 µA(typ)
- High duty cycle supported (>97%)
- Switching Freq: 200KHz - 2.5MHz
- 75ns minimum on time – typical
- Internal compensation for ease of use
- Frequency foldback over current protection
- Spread spectrum for low EMI (optional)
- Synchronize to external clock
- Power Good option by request
- Stable with ceramic output cap

Benefits
- Start stop supported
- Improved light load efficiency
- Track input for low drop out operation
- Avoid AM band noise and compact solution size

Applications
- Industrial and Communications – PLC, 12V/24V Rail POL Regulators
- Automotive - Charger Adapter, Infotainment
- Battery Powered Medical, Communications, Audio, Negative Voltage Sources

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Iout (A)</th>
<th>Soft Start</th>
<th>Enable</th>
<th>Fsync / Fadj</th>
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<td>LMR14030</td>
<td>3.5</td>
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<tr>
<td>LMR14050</td>
<td>5</td>
<td>✓</td>
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</tr>
</tbody>
</table>
# LM73605Q1 and LM73606Q1 Overview

High-Performance Synchronous DC-DC Converter Family

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
<th>Applications</th>
</tr>
</thead>
</table>
| • LM73605/5: 36V, 5A/6A  
• LM76002/3: 60V, 2.5A/3.5A  
• > 90% full load efficiency  
• 15µA operating quiescent current  
• Internal Compensation  
• \( f_{sw} \): 350kHz to 2.2MHz  
• Wettable Flank QFN  
• AECQ100 qualification | • 36V and 60V family handles high voltage transients common in Industrial/Automotive/Comms  
• Easy to manage thermal design  
• Wettable flank allows visual inspection in leadless package  
• Small Solution Size: High integration yields low BOM count | • Industrial:  
• Factory & Building Automation  
• Medical/Health  
• Automotive:  
• Connectivity (USB)  
• ADAS  
• Communications:  
• Remote Radio Head (RRH) |

## Value Proposition

- **Thermal Performance**
- **Efficiency Performance**
- **Small Total Solution Size**
LM73605Q1 & LM73606Q1
36V, 5A/6A Synchronous Buck Converter for AECQ1

**Features**

- **Wide Vin range**: 3.5V - 36V, Vout range 1.0V to 95%Vin
- **Min ON time**: 60ns (typ), min OFF time = 80 ns (typ)
- **Fully Synchronous Rectifier**
- **Internal Compensation**
- **Default operation when feature pins floating**
- **Wettable Flank QFN 4x6mm package**
- **51/30 mOhm Internal HS&LS Rdson**
- **15 µA standby current**, PFM operation at light load
- **External bias input to improve efficiency**
- **Adjustable / synchronizable switching frequency range**: 350kHz – 2.2MHz (default 500kHz when RT pin floating)
- **Pin selectable FPWM or Auto mode**
- **Internal soft start / Prebias SS / extendable SS time / Tracking**
- **PGood flag**
- **Cycle by cycle current limiting**
- **Hiccup Short Circuit Protection**

**Benefits**

- **Easy to use**: no external power diode, minimum BOM count, visual inspection, small solution size ➔ save design time, save board space / cost, visual inspection
- **High Performance**: high efficiency at heavy load and light load, good thermal, long standby time
- **Wide Range of Vin/Vout/fsw**: easy system optimization, current scaling, easy reuse, and single stage step down from high Vin
- **Flexible** system optimization options, monitoring and protections features

**Applications**

- **Automotive ADAS**
- **Automotive Body Control & Lighting**
- **Automotive Connectivity**
- **Automotive Infotainment**

**Diagram**

- **Efficiency @ V_out=5V, 500kHz**

**Efficiency (%)**

- **LOAD (A)**
  - **12VIN**
  - **24VIN**

**Texas Instruments**
LDO for cluster
TLV702-Q1: 300mA High PSRR LDO in 1.5x1.5 QFN and SOT23

Features
- High PSRR: 48dB at 1MHz
- Available in small 1.5 x 1.5 SON; SOT23-5
- 2% Accuracy over full temperature range
- Stable with effective capacitance of 0.1μF
- Thermal Shutdown & Over current protection
- Without or with active pull-down
- Low I_Q: 35μA

Benefits
- Suited for cost effective RF/Audio Applications
- Smaller / cost effective power solution
- Stable output for low power applications
- Smaller / Cost effective power solution
- Avoid large fault currents / thermal shutdown
- Quick discharge to control logic
- Longer battery life

Applications
- Automotive Camera Modules
- Automotive Infotainment
- Microcontroller Power
- SoC I/O Power
- Voltage Reference for FPGAs

---

### Device Specifications

<table>
<thead>
<tr>
<th>Device</th>
<th>V_IN</th>
<th>I_OUT</th>
<th>V_DO</th>
<th>I_Q</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLV702-Q1</td>
<td>2.0 - 5.5 V (6V max)</td>
<td>300mA</td>
<td>260mV</td>
<td>35μA</td>
<td>DSE, DBV</td>
</tr>
</tbody>
</table>
TLV710-Q1: Dual 200mA, Low I_Q, Low Noise, High PSRR LDO

Features
- Dual channel LDO with 2x200mA load capability
- Independent ENABLE pins
- Low power I_Q=31uA per LDO 62uA total
- 2% Accuracy
- Low Output Noise/ High PSRR
  - 48mVRMS (No Bypass Cap Required)
  - PSRR 70dB @ 1kHz
- Tiny 1.5 x 1.5mm, SON6 Package
- 3.3V/1.8V and 2.8V/1.8V versions released to market as AEC-Q100 Grade 1

Applications
- Automotive ADAS systems
- Automotive Infotainment systems
- Image sensor power
- MCU Power
- Powering DACs, ADCs and OPAMPS

Benefits
- High Power density with flexibility
- Enables use of cheap caps
- Low Power Applications
- Stable Output Voltage
- Good for noise sensitive applications
- 56% Smaller than SC 70 Package

Applications
- Automotive ADAS systems
- Automotive Infotainment systems
- Image sensor power
- MCU Power
- Powering DACs, ADCs and OPAMPS

Low V_IN Roadmap
Application Roadmap
Backlight for cluster
Backlight Driver Features

Wide Operating Voltage
- Operate during transient battery conditions, incl. 3V cold crank & 40V load dump
- Boost & SEPIC operation modes with int or ext FET

Low Noise/EMI Performance
- Programmable switching frequency from 100kHz to 2.2MHz
- Avoid interference by operating around AM radio band
- Built-in spread spectrum, phase shift, hybrid dimming option

Efficient Brightness Control
- Individual string control with PWM, I2C, SPI brightness control options
- Up to 32000:1 dimming ratio to achieve ultra low to high brightness range
- Adaptive output voltage control to improve power and thermal efficiency
- Advanced “sloper” response for smooth brightness transition

Protection & Diagnostics
- Under/overvoltage, overcurrent, overtemperature protection
- Open/Short LED detection
- Powerline (V_{bat}) FET option to protect against inrush & reduce Iq_{off} standby
- Fault reporting through I2C, SPI or FAULT pin flag
Automotive Backlighting LED Driver Topology

Internal Switching FET

- Vin
- PLFET
- SD
- SW
- PGND
- FB
- LED0
- LED1
- LED2
- LED3
- AGND
- EN
- PWM
- CIN
- SGND
- VDD
- VOUT
- VOUT

External Switching FET

- Vin
- PLFET
- SD
- SW
- PGND
- GD
- ISNS
- ISNSGND
- FB
- LED0
- LED1
- LED2
- LED3
- AGND
- EN
- PWM
- CIN
- SGND
- VDD
- VOUT
- VOUT

Lower Power Density
Smaller size panel

Brightness 1000 nit LCD
Size 8”

Higher Power Density
Larger size panel
Automotive Backlight Driver Roadmap

- **LP8860-Q1**: 4x150mA, 2.2MHz, PS, Hybrid Dim, 3V $V_{IN}$, 13,000:1, Ext FET
- **LP8861-Q1**: 4x100mA, 2.2MHz, PLFET, 10,000:1, 2A FET, HTSSOP20
- **LP8862-Q1**: 2x160mA, 2.2MHz, PLFET, 10,000:1, 2A FET, HTSSOP20
- **TPS61193-Q1**: 3x100mA, 2.2MHz, 10,000:1, 2A FET, HTSSOP20
- **TPS61194-Q1**: 4x100mA, 2.2MHz, PLFET, 10,000:1, 2A FET, HTSSOP20
- **TPS61195-Q1**: 6x200mA, 200kHz, 5,000:1, Ext FET, HTSSOP28
- **TPS61196-Q1**: 6x150mA, 2.2MHz, PS, Hybrid Dim, 3V $V_{IN}$, 32,000:1, Ext FET
Automotive Backlighting

LP8864S-Q1
- 3V to 48V VIN
- 4 x 120mA LED Current
- Dimming Ratio > 32,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

LP8864-Q1
- 3V to 48V VIN
- 4 x 120mA LED Current
- Dimming Ratio > 32,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

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

LP8869-Q1
- 4.5V to 40V VIN
- 3 x 120mA LED Current
- Dimming Ratio 10,000:1
- Power Line FET Driver
- Current De-rating w/ Ext NTC

LP8869C-Q1
- 4.5V to 40V VIN
- 3 x 120mA LED Current
- Dimming Ratio 10,000:1

LP8863-Q1
- 3V to 48V VIN
- 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

LP8863S-Q1
- 3V to 48V VIN
- 4 x 150mA LED Current
- Dimming Ratio > 32,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

LP8864S-Q1
- 3V to 48V VIN
- 4 x 120mA LED Current
- Dimming Ratio > 32,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

LP8864-Q1
- 3V to 48V VIN
- 4 x 120mA LED Current
- Dimming Ratio > 32,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

LP8866S-Q1
- 3V to 48V VIN
- 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 VIN
- 6 x 200mA LED Current
- Dimming Ratio > 32,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

LP8867-Q1
- 4.5V to 40V VIN
- 4 x 120mA LED Current
- Dimming Ratio 10,000:1
- Power Line FET Driver
- Phase Shift, Hybrid Dimming
- Full Diagnostics w/ I2C

LP8867C-Q1
- 4.5V to 40V VIN
- 4 x 120mA LED Current
- Dimming Ratio 10,000:1

Headunit / CID w/ <8” Display

Hybrid Cluster

Head-up Display

Full-Digi Cluster / Cockpit

Power FET Current

Production
Sampling
Development
Concept

3 CH
4 CH
6 CH

Headunit / CID w/ >8” Display
## Automotive LED Backlight Driver Selector

<table>
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<th>LP8863-Q1</th>
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<th>LP8862-Q1</th>
<th>TPS61193-Q1</th>
<th>TPS61194-Q1</th>
<th>TPS61196-Q1</th>
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<tbody>
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<td></td>
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<td>#LED Strings</td>
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<td>LED Current max per String</td>
<td>150mA</td>
<td>150mA</td>
<td>100mA</td>
<td>160mA</td>
<td>100mA</td>
<td>100mA</td>
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<td>LED Current Matching</td>
<td>+/-0.5% typ</td>
<td>+/-1% typ</td>
<td>+/-1% typ</td>
<td>+/-1% typ</td>
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<td>Dimming Mode</td>
<td>PWM or Hybrid</td>
<td>PWM or Hybrid</td>
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<td>Dimming Ratio</td>
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<td>32,000:1 @ 150Hz</td>
<td>10,000:1 @ 200Hz</td>
<td>10,000:1 @ 200Hz</td>
<td>10,000:1 @ 200Hz</td>
<td>10,000:1 @ 200Hz</td>
<td>500:1 @ 200Hz</td>
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<td>PWM Synchronization</td>
<td>VSYNC, HSYNC</td>
<td>Yes, I2C config</td>
<td>Yes, I2C config</td>
<td>Yes, I2C config</td>
<td>Yes, I2C config</td>
<td>Yes, I2C config</td>
<td>Yes, Automatic</td>
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<td>Phase Shift</td>
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<td>Yes, I2C config</td>
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<td>Yes, I2C config</td>
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<td>VIN</td>
<td>3V to 48V</td>
<td>3V to 48V</td>
<td>4.5V to 40V</td>
<td>4.5V to 40V</td>
<td>4.5V to 40V</td>
<td>4.5V to 40V</td>
<td>8V to 30V</td>
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<td>VOUT</td>
<td>15V to 48V</td>
<td>7V to 47V</td>
<td>Up to 45V</td>
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<td>VIN to 120V</td>
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<td>Internal/240mΩ</td>
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<td>DC/DC Type</td>
<td>Boost</td>
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<td>Boost, SEPIC</td>
<td>Boost, SEPIC</td>
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<td>Switching Frequency</td>
<td>100k to 2.2MHz</td>
<td>300k to 2.2MHz</td>
<td>500k to 2.5MHz</td>
<td>300k to 2.5MHz</td>
<td>300k to 2.5MHz</td>
<td>300k to 2.5MHz</td>
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<td>Switch Current Limit</td>
<td>2A to 9A</td>
<td>Up to 10A</td>
<td>2A/2.5A</td>
<td>2A/2.5A</td>
<td>2A/2.5A</td>
<td>2A/2.5A</td>
<td>4A (w/ 100mΩ Rsense)</td>
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<td>Spread Spectrum Clock</td>
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<td>External SYNC Clock Input</td>
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<td>✓</td>
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<td>✓</td>
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<td>Battery isolation FET</td>
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<td>Boost Discharge Function</td>
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<td>✓</td>
<td>✓</td>
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<td>VIN UVLO</td>
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<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>VIN OVP</td>
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<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>VIN OCP</td>
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<td>✓</td>
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<tr>
<td>Open / Short LED</td>
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<td>✓</td>
<td>✓</td>
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<td>Thermal Shutdown</td>
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<td>✓</td>
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<td>Fault Reporting</td>
<td>I2C, SPI, Pin Flag</td>
<td>I2C, SPI, Pin Flag</td>
<td>Pin Flag</td>
<td>Pin Flag</td>
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<tr>
<td><strong>Control</strong></td>
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<td>Brightness control Methods</td>
<td>PWM Pin, I2C, SPI</td>
<td>PWM Pin, I2C, SPI</td>
<td>PWM Pin</td>
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<td>PWM Pin</td>
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<td>Independent String control</td>
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<td>✓</td>
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<td>Temperature Compensation</td>
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<tr>
<td>Support External NTC</td>
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<tr>
<td>Device Configuration</td>
<td>EEPROM/Pins</td>
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<td>Pins</td>
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<td>VDD</td>
<td>3V to 5.5V External</td>
<td>3V to 5.5V</td>
<td>5V Internal</td>
<td>5V Internal</td>
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<td>5V Internal</td>
<td>6V Internal</td>
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<td>Ambient Temp Range</td>
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<td>-40° to 125°C</td>
<td>-40° to 125°C</td>
<td>-40° to 125°C</td>
<td>-40° to 125°C</td>
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</tbody>
</table>

*Texas Instruments*
**LP8867-Q1 / LP8869-Q1**

### Features
- AEC-Q100 Qualified for Automotive Applications (Grade 1: T_A -40C to +125C)
- 4/3 x 120mA LED Driver for Automotive LCD Display
  - High Dimming Ratio of 10 000:1 at 100 Hz
  - Current Matching 1% (Typical)
  - LED String Current up to 120 mA per Channel
  - Outputs can be Combined Externally for Higher Current per String
- Integrated Boost/SEPIC Converter for LED String Power
  - Integrated SW FET with Up to 3A Switching Current Limit
  - Input Voltage Operating Range 4.5 V to 40 V
  - Output Voltage up to 45 V
  - Switching Frequency 300 kHz to 2.2 MHz
  - Switching Synchronization Input
  - Spread Spectrum for Lower EMI
  - Minimum Number of External Components
- Protection and Fault Detection
  - Power-Line FET Control for Inrush Current
  - Extensive Fault Detection Features
  - Fault Output
  - Input Voltage OVP and UVLO
  - Open and Shorted LED Fault Detection
  - Automatic LED Current Reduction With External Temperature Sensor
  - Thermal Shutdown
- HTSSOP-20 Package (PWP)

### Benefits
- Minimum system cost and PCB size with Integrated MOSFET
- Good EMI performance with Spread Spectrum function
- Save MCU resource with
  - Power-Line FET control
  - Automatic LED current reduction with external Temperature Sensor

### Applications
- Backlight for:
  - Automotive Infotainment
  - Automotive Instrument Clusters
  - Smart Mirrors
  - Heads-Up Displays (HUD)
  - Central Information Displays (CID)
  - Audio-Video Navigation (AVN)
LP8867C-Q1 / LP8869C-Q1

Benefits

- Minimum system cost and PCB size with Integrated MOSFET
- Good EMI performance with Spread Spectrum function

Features

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- Protection and Fault Detection
  - Extensive Fault Detection Features
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  - Input Voltage OVP and UVLO
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  - Thermal Shutdown

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Applications

- Backlight for:
  - Automotive Infotainment
  - Automotive Instrument Clusters
  - Smart Mirrors
  - Heads-Up Displays (HUD)
  - Central Information Displays (CID)
  - Audio-Video Navigation (AVN)
LP8863-Q1
Integrated High Efficiency 6-Channel LED Driver for Automotive Lighting

Features

- Six High-Precision Current Sinks
  - Output Current up to 150 mA/Channel
  - Current Matching 1% (typical)
  - Up to 16-bit LED Dimming Resolution
- Individual LED String Brightness Control
  - For Whole Screen or Individual String Dimming Control
  - Dimming Ratio 32,000:1 @ 100Hz PWM
- Simple Configuration
  - Resistor configuration for Boost Frequency, LED PWM Frequency and LED Current
- Automatic String Configuration Detection
  - Tie unused strings to GND
  - Automatically adjusts phase shift for number of LED strings
- I2C, SPI and PWM Brightness Control Modes
- Boost Controller for LED String Power
  - Switching Frequency 300 kHz to 2.2 MHz
  - Boost SYNC input
  - Spread Spectrum for lower EMI
  - Adaptive Voltage Control for Power Optimization
  - Discharge function when boost is disabled
- Input Voltage Operating Range 3 V to 48 V (TBD)
- Extensive Protection Features
  - Open and Shorted LED Fault Detection
  - Boost Output OVP and OCP
  - Boost Input UVLO, OVP and OCP
  - VDD UVLO and Thermal Shutdown

Benefits

- Build-in EMI Reduction
  - Phase shifted LED outputs
  - Boost converter Spread Spectrum
  - Hybrid Dimming (Linear + PWM)
- Boost synchronization input
- Automatic detection of LED string configuration
- Power line FET control (inrush current protection, standby energy saving)
- Safety and Fault tolerance features

HTSSOP-38 AECQ 100

Texas Instruments
Light sensor for cluster
### Comparison Table of OPT300x Family

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<th>OPT3006</th>
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<td>Human Eye</td>
<td>300nm to 1000nm</td>
<td>Human Eye</td>
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<td>1.8uA</td>
<td>1.8uA</td>
<td>1.8uA</td>
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<td>1.6V to 3.6V</td>
<td>1.6V to 3.6V</td>
<td>1.6V to 3.6V</td>
<td>1.6V to 3.6V</td>
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<td>5.5V</td>
<td>5.5V</td>
<td>5.5V</td>
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<tr>
<td><strong>Measurement Level</strong></td>
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<td>0.01 to 83k</td>
<td>0.01 to 83k</td>
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<td>-40 to 85°C (Grade 3)</td>
<td>-40 to 85°C</td>
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<td>-40 to 85°C</td>
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<tr>
<td><strong>Package</strong></td>
<td>USON6(2x2mm)</td>
<td>USON6(2x2mm)</td>
<td>USON6(2x2mm)</td>
<td>USON6(2x2mm)</td>
<td>0.9 x 0.8 x 0.226mm</td>
<td>0.9 x 0.8 x 0.226mm</td>
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<tr>
<td><strong>Notes</strong></td>
<td>Better sensitivity</td>
<td>Automotive Grade</td>
<td>Low Cost ALS</td>
<td>Better angular IR rejection</td>
<td>Thinnest ALS 6 pin operation</td>
<td>Thinnest ALS 4 pin operation</td>
</tr>
</tbody>
</table>
Problem:
Light measurement changes under different light inputs
- User discomfort
- Non-optimum display power

Reason:
- Dark Glass transmits IR
- Sources like Incandescent has high IR that reaches sensor due to glass transmissivity
→ Wrong Ambient Light measurement with wideband photodiode
Sensors Hidden Behind Black Glass

**Problem:**
Light measurement changes under different light inputs

- User discomfort
- Non-optimum display power

**Solution:**
- OPT3001 has a very high IR rejection
- Discards most of IR light reaching the actual sensor
- Measures only what is in visible region
  - Correct Ambient Light measurement
Problem:
Not accurate and not linear reading at different light levels (bright daylight vs cloudy or night condition)

→ Display brightness not always adjusted to optimum setting

Solution:
OPT3001 has a auto-gain setting feature, that adjust automatically based on input light level

• No additional adjustment like typically done in discrete solution
• Always in optimal range with good resolution & and tight accuracy between ranges
  ✓ Relative accuracy between gain Range is 0.2%.
→ Optimum display under all light levels
FPD-Link™
TI Ethernet & FPD-Link™ Product Line

Infotainment FPD-Link III SerDes  ADAS FPD-Link III SerDes  Automotive 100M & 1G Ethernet  Automotive PCIe Gen 3

Central ADAS ECU

Body  Chassis  Power train

Switch

Info
tainment  Diagnostic Ports  ADAS

FPD-Link  CAN/LIN/FF

GPU  Head Unit HU  ADAS ECU 1  ADAS ECU 2

Display  PCIe Gen 3
**TI Automotive Connectivity Solutions**

**FPD-Link™**
- **Parallel Data**
- **Clock**
- **Control**

**Embedded Clock and Control**

**High-Speed & High-Resolution Real Time Connections**

**ADAS**
- SVS, CVS, RVC, DMS, FVC
- Raw streaming object data from smart sensors

**Infotainment**
- Cluster, RSE, CID, HUD
- CMS, Rear View Mirrors

**Ethernet AEC-Q100**

**External Gateways**

**Firmware & OBD**
- Diagnostics
- Firmware Upgrades
- Navigation

**100Mbps**

**1000Mbps**

**Auto PHYTER**

**Domain-Domain Connections**

**Backbone**
- Connects between domains

**ADAS**
- Pre-processed object data from smart sensors
- Raw data from low data-rate sensors

**BCM**
- Connects Flexray, CAN, LIN

**1TPCE & RTPGE**
What is FPD-Link™

• What does FPD-Link™ stand for?
  – Short for Flat Panel Display Link

• What does it do?
  – Transports high-speed data such as video over a twisted pair or coax cable
  – Supports a variety of video interfaces (RGB, OpenLDI (LVDS), MIPI CSI-2 & DSI, HDMI)
  – Aggregates video, audio and clock as well as bi-directional data onto one stream

• What are the use-cases?
  – Automotive Infotainment & Cluster: data transfer between ECU and display
  – Automotive ADAS: data transfer between imagers, radar or other sensors to ECU
**FPD-Link™ Legacy**

<table>
<thead>
<tr>
<th>FPD-Link I</th>
<th>FPD-Link II</th>
<th>FPD-Link III</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parallel Clock</strong></td>
<td><strong>Embedded Clock</strong></td>
<td><strong>Embedded Clock and Control</strong></td>
</tr>
<tr>
<td>Many to Less</td>
<td>Many to One</td>
<td>Do More (on One)</td>
</tr>
<tr>
<td>• 3/4 Data + 1 Clock = 8 wires</td>
<td>• 2 wires (plus control)</td>
<td>• 2 wires only</td>
</tr>
<tr>
<td>• Cable length ~ 3 meter</td>
<td>• Up to 1.8 Gbps</td>
<td>• Up to 3 Gbps</td>
</tr>
<tr>
<td>• Lower EMI</td>
<td>• Cable length ≥ 10 meter</td>
<td>• HDCP content protection (optional)</td>
</tr>
<tr>
<td></td>
<td>• Reduced weight</td>
<td>• Embedded control channel</td>
</tr>
<tr>
<td></td>
<td>• No ground currents on cable</td>
<td>• Adaptive equalization</td>
</tr>
<tr>
<td></td>
<td>• AEC-Q100, ISO 10605</td>
<td>• Built-in Diagnostics</td>
</tr>
</tbody>
</table>

...plus power transfer (PoC)!

**Texas Instruments**
Continuous, Low-Latency Backchannel

- Ultra-low (<15µs) latency
  - Ideal for remote ISP & camera sync control
- EMI friendly
  - No common mode modulation
  - No pre-emphasis or tuning

- No waiting for video blanking
  - Backchannel sent continuously
- Single pair
  - Works over coax & STP
Common Automotive Video Links with FPD-Link™

*optional for ADAS devices (Power over Coax [PoC])
**: optional on certain IVI devices
***: SER → DES for IVI devices | DES → SER for ADAS devices
FPD-Link™ Applications

Infotainment Displays

ADAS Surround View Cameras & Sensors

Aggregation of video, audio, GPIO, control (I²C, I²S) over one link and backward control.
ADAS and IVI

ADAS
- Camera module
- ISP
- Ser
- Der
- SOC
- Ser

ADAS ECU

IVI
- ISP
- Ser
- Der
- SOC
- Ser
- Der
- SOC
- Ser

Head-unit/Cluster ECU

Display panel

Camera module

ADAS ECU w/ display panel
Advanced Adaptive Equalization

- Automatic algorithm
  - **No adjustment** – compensates for cable type, length, connectors, etc
  - **Adapts during power up**
- **Compensates** for cable ageing effects
- No EMI impact
- Diagnostic function
  - Read out EQ level to monitor cable health
- Supports future data rates over low cost cables
FPD-Link Highlights

General
- Video, Bidirectional Control (I²C, SPI), GPIO and Power
  - Over single twisted pair or coaxial cable assemblies
- Adaptive equalization compensates for cable type, length, age and condition
- Multiple interface options: RGB, YUV, OpenLDI (LVDS), MIPI CSI-2 & DSI, HDMI

Infotainment
- Support for 720p, 1080p & 2K/3K
- Easy-to-use HDCP content protection
- Dithering, White Balance, and Test Patterns
- I²S audio plus I²S clock cleaning

ADAS
- Support for 1 and 2 Megapixel image sensors
- Very low latency
- Synchronized sensors with system clock → no oscillator on sensor side
- Easy frame synchronization using GPIO
- Deserializers with 2:1 input mux
## Link Diagnostics: Layered Protection

<table>
<thead>
<tr>
<th></th>
<th>Feature</th>
<th>Description</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Pattern Generation</td>
<td>Generates video patterns for test</td>
<td>test mode</td>
</tr>
<tr>
<td>11</td>
<td>BIST</td>
<td>Bit error rate test</td>
<td>test mode</td>
</tr>
<tr>
<td>10</td>
<td>Prog. Interrupt</td>
<td>Programmable open drain interrupt pin flags errors to processor</td>
<td>always active</td>
</tr>
<tr>
<td>9</td>
<td>Prog. Alarm Bit *</td>
<td>Programmable alarm signal provides module health monitoring</td>
<td>always active</td>
</tr>
<tr>
<td>8</td>
<td>Voltage/Temp Meas *</td>
<td>Monitors up to 2 voltages as well as internal temperature</td>
<td>always active</td>
</tr>
<tr>
<td>7</td>
<td>Frame Count</td>
<td>Verifies no frozen frames (note: frame count is sent by imager)</td>
<td>always active</td>
</tr>
<tr>
<td>6</td>
<td>I2C Write Protect *</td>
<td>Protects sensor module misconfiguration if I2C has bit errors</td>
<td>always active</td>
</tr>
<tr>
<td>6</td>
<td>CSI-2 CRC *</td>
<td>Verifies end-to-end link integrity and bit error rate</td>
<td>always active</td>
</tr>
<tr>
<td>5</td>
<td>SerDes CRC</td>
<td>Verifies SerDes link integrity and bit error rate</td>
<td>always active</td>
</tr>
<tr>
<td>4</td>
<td>CSI-2 Input Check *</td>
<td>Checks for data integrity from sensor data at input to 953</td>
<td>always active</td>
</tr>
<tr>
<td>3</td>
<td>Lock Detect</td>
<td>Verifies link established</td>
<td>always active</td>
</tr>
<tr>
<td>4</td>
<td>Internal Oscillator</td>
<td>Internal serializer oscillator establishes link even without clock</td>
<td>always active</td>
</tr>
<tr>
<td>2</td>
<td>Adaptive EQ Level</td>
<td>Read relative cable quality via I2C (7 levels)</td>
<td>set at power up</td>
</tr>
<tr>
<td>1</td>
<td>Link Fault Detect</td>
<td>Cable open, + to - short, short to ground, short to battery, incorrect link</td>
<td>always active</td>
</tr>
</tbody>
</table>

*: 953/954 for ADAS only

- **test mode**
- **normal operation**
Display & Camera Resolutions – today

FPD-Link III

- 800 x 480: WVGA
- 1280 x 720: 720p HD
- 1280 x 960
- 1920 x 1080 | 2048 x 1080
- 1920 x 1200

1.0 1.2 1.3 2.0 2.3 Megapixels
**DS90UX94xA**

for 2K/3K Applications

- Supports Pixel Clock up to **210MHz** for 2K resolution
- **2880 x 1080 @60fps**
- Dual lane FPD-Link III
- **Backward compatible** to 720p generation (DS90UX92x)

- **High Speed Bidirectional GPIOs** up to 2.5MHz in the back channel, OR
- SPI control interface up to 3.3Mbps via the backchannel
- **I²C Control Interface** up to 1MHz
FPD-Link Value Proposition

- Most comprehensive Infotainment SerDes product portfolio in the industry
  - RGB, OpenLDI, CSI-2 MIPI, HDMI, DSI interfaces, …and adding more
  - QVGA, WVGA, 720p, 1080p and 2K/3K display support, …and beyond
- Benefits from forward and backward compatibility between existing 92x & 94x product families – it applies to future families as well
- Migration path to 1080p and 2K/3K displays
  - 1st in the Industry
- Adaptive cable equalization
  - 1st in the industry
- On-chip HDCP memory
  - 1st in the industry
FPD-Link™ Learning Center Videos Online

Visit the FPD-Link™ Learning Center!!

Training Subjects:
1. Introduction to FPD-Link SerDes
2. Diagnostic & Data Protection
3. FPD-Link Parameters & Transmission Channel
4. Power over Coax (PoC)
5. Interfaces
6. Tools

Starting an FPD-Link™ design today?
Texas Instruments FPD-Link™ Learning Center can help light the way.
○ Learn more

1. Introduction to FPD-Link SerDes
   1.1 ADAS product portfolio overview

2. Diagnostic & Data Protection
   2.1 Diagnostics status monitoring, data protection & built-in self-test (BIST)

3. FPD-Link Parameters & Transmission Channel
   3.1 High-speed serial link basics
   3.2 Basic transmission parameters
   3.3 Common connectors & cables for automotive applications
   3.4 What you need to know about the transmission channel
   3.5 Inline & common mode chokes - use & effect on the transmission channel

4. Power over Coax (PoC)
   4.1 Power over Coax (PoC) basics
   4.2 Power over Coax (PoC) design
   4.3 Power over Coax (PoC) evaluation

5. Interfaces
   5.1 Infotainment (IVI) back channel basics
   5.2 FPD-Link IO interfaces: RGB, OLDI, HDMI, D-PHY/CSI, D-PHY/DSI
   5.3 Bidirectional communication channel in FPD-Link ADAS products
   5.4 ADAS serializer clocking modes
   5.5 Advanced ADAS serializer clocking mode

6. Tools
   6.1 Use of Analog Launch Pad (ALP) GUI to configure the FPD-Link EVMs
CAN/LIN Transceivers
TCAN104x-Q1 Family
CAN FD / CAN transceivers with Standby mode

Common Features
- CAN / CAN FD compatible with data rates up to 5Mbps
- Standby mode with bus wakeup
- DC Bus-Fault Protection: ±42V to ±58V
- Common mode range: ±12V to ±30V
- Fast Loop Times: <200ns
- Interfaces with 5V or 3.3V MCU I/O (“V” version)
- ±16kV HBM ESD and ±15kV IEC for bus pins
- Ideal Passive – High impedance I/Os when unpowered
- TXD dominant state time out

<table>
<thead>
<tr>
<th>Feature</th>
<th>TCAN1042</th>
<th>TCAN1043</th>
<th>TCAN1044</th>
<th>TCAN1046</th>
<th>TCAN1048</th>
</tr>
</thead>
<tbody>
<tr>
<td>±70V Bus-Fault protection</td>
<td>✓ (H)</td>
<td>✓ (H)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus-Fault protection</td>
<td>±58V</td>
<td>±58V</td>
<td>±42V</td>
<td>±42V</td>
<td></td>
</tr>
<tr>
<td>Maximum data rate</td>
<td>5 Mbps (G)</td>
<td>5 Mbps (G)</td>
<td>5 Mbps</td>
<td>5 Mbps</td>
<td></td>
</tr>
<tr>
<td>Wake / Inhibit</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.8V V_{IO} support</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dual CAN support</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Grade 0 option</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

TCAN105x devices supports Sleep mode only

- TCAN1042: 8-pin SOIC, 3.0mm x 3.0mm Wettable flanks
- TCAN1043: 8-pin VSON, 3.0mm x 3.0mm Wettable flanks
- TCAN1044: 14-pin SOIC, 8.65mm x 6.0mm
- TCAN1046: 14-pin SOIC, 4.5mm x 3.0mm Wettable flanks
- TCAN1048: 14-pin SOIC, 4.5mm x 3.0mm Wettable flanks

- TCAN1042: 5.0mm x 4.0mm
- TCAN1043: 8.65mm x 6.0mm
- TCAN1046: 8.65mm x 6.0mm
- TCAN1048: 8.65mm x 6.0mm
TLIN102x-Q1 Family
Local Interconnect Network (LIN) Transceiver

Common Features

- LIN Physical Layer Supports Specification Rev 2.2a and SAEJ2602
- Extended Supply Voltage Operation 4 V – 36 V
- Sleep Mode with wake-up from LIN bus or host
- Bus Fault Tolerant up to ±45 V
- ±8 kV IEC 61000-4-2 Contact Discharge, HBM, LIN pin
- TXD Dominant State Time-out Protection
- Under Voltage Protection on Vsup
- Thermal Shutdown Protection
- Unpowered Node or Ground Disconnection Failsafe at System Level

Differentiated Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>TLIN1029-Q1</th>
<th>TLIN1022-Q1</th>
<th>TLIN1024-Q1</th>
<th>TLIN1021-Q1</th>
<th>TLIN1027-Q1</th>
<th>HVDA100-Q1</th>
<th>HVDA195-Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of LIN transceivers</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dominant State Timeout</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Wake Pin</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Inhibit Pin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pins per package</td>
<td>8</td>
<td>14</td>
<td>24</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

TLIN202x devices support up to ±58V bus fault protection and $V_{SUP}$ max of 48V

TLIN1029-Q1
8-pin SOIC
6.0mm x 4.9mm
Wettable flanks

TLIN1022-Q1
8-pin VSON
3.0mm x 3.0mm
Wettable flanks

TLIN1024-Q1
14-pin SOIC
6.0mm x 8.65mm
Wettable flanks

TLIN1024-Q1
14-pin VSON
3.0mm x 4.5mm
Wettable flanks

TLIN1024-Q1
24-pin QFN
5.5mm x 3.5mm
Wettable flanks
CAN SBCs
TCAN45xx-Q1 Family
Single 5 Mbps CAN FD to SPI System Basis Chip (SBC)

Common Features

- Fully integrated, standalone CAN FD to SPI SBC
- ISO 11898-1, ISO 11898-2:2016, Bosch M-CAN v 3.2.1.1 Compliant
- Includes: SPI slave controller, CAN FD controller, Single CAN FD Transceiver, VREG, watchdog and more
- 5 Mbps CAN FD Signaling Rate with full support for classic CAN
- ±42V DC Bus-Fault Protection
- ±12V Common mode range
- ±8kV HBM ESD and ±8kV IEC 61000-4-2 (Contact) 
- Integrated 5V VREG providing up to 70 mA from 12 V Vbat
- Low power Sleep and Standby modes w/ multiple wake methods
- INH and WAKE for System VREG and wake control

Differentiated Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>TCAN4551</th>
<th>TCAN4561</th>
<th>TCAN4550</th>
<th>TCAN4560</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO1 / GPO2</td>
<td>GPO</td>
<td>GPO</td>
<td>GPIO and GPO</td>
<td>GPIO and GPO</td>
</tr>
<tr>
<td>Selective Wake (PN)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Watchdog</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>5V VREG Output</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Pin to Pin / Layout / Software Compatible

Smaller than 8-pin SOIC
SPI & CAN FD controller, transceiver, watchdog and more in less space than standard 8-pin CAN transceiver SOIC

4.5mm x 3.5mm 20-pin QFN Wettable flanks

Excellent toe fillet improves AOI

Samples : Now
RTM : 1Q19
TCAN45xx-Q1 Block Diagram
Automotive Ethernet
**DP83TC811-Q1** | Automotive Grade 100BASE-T1 Ethernet PHY

**Unshielded Single Twisted Pair Ethernet PHY**

### Features

- 100Mbps over 60m USTP – **IEEE802.3bw**
  - Interoperable with other 100BASE-T1 PHYs
- Multiple MAC interfaces: **SGMII** / **RGMII** / **RMII** / **MII**
- **Low latency** 2x less than competition (<150ns)
- **Low active power** Up to 2x lower than competition (300mW)
- IEC 61000-4-2, +/-8kV Contact Discharge
- Integrated components to **save on BOM** cost
- Diagnostic tool kit – SQI, TDR, ESD monitor, temp & voltage sensors
- Optimized for EMI and EMC performance
- **Pin to Pin compatible with future 1000BASE-T1**

### Benefits

- Easy to interface with systems using other vendor PHYs.
- Provides design flexibility via multiple MAC interface support
- Low latency allows for faster response in time sensitive applications
- Ideal for battery powered applications. Low heat dissipation.
- Reliable performance in high ESD environments.
- Reduces over all system size, complexity, and cost
- Advanced feature set allows monitoring overall system status.
- Meets strict automotive EMI/EMC standards.

### Applications

- Backbone/Gateway – Connects all domains
- ADAS – Pre-processed object data from smart sensors
- Telematics Control Unit (TCU)
- Automotive External Amplifier
- Automotive Head Unit

![6x6 mm wettable flank](image)
DP83TC811 Available EVM Boards

**DP83TC811EVM**
- Features back-to-back interface for 100BASE-TX
- Onboard controller that uses USB to MDIO GUI

**New!**

**DP83TC811SEVM**
- Features SMA connectors
- MAC interface connection
DP83TC811 Diagnostic Tool Kit

- Electrostatic Discharge Sensor (Patent Approved)
- Signal Quality Indication (SQI)
- Time Domain Reflectometry (TDR)
- Temperature Sensor
- Voltage Sensor
- PRBS and Loopbacks
Tell-Table LED driver
## Multi-channel Automotive LED Indicator Family

### New Generation

<table>
<thead>
<tr>
<th>Model</th>
<th>Features</th>
</tr>
</thead>
</table>
| TLC6C598/12-Q1 | - Shift Register Power Logic  
- 40V Breakdown Voltage  
- Vcc = 3 ~ 5.5V  
- Const. <50mA per channel (8/12 ch)  
- Thermal Shutdown Protection |
| TLC6C5816-Q1 | - Shift Register Power Logic  
- 40V Breakdown Voltage  
- Vcc = 3 ~ 5.5V  
- Led Open & Short Diagnostic |
| TLC6C5712-Q1 | - Const. Current Sink  
- 3V Breakdown Voltage  
- Vcc = 3 ~ 5.5V, SPI  
- Cont. <75mA/ch (12 ch)  
- 2 PWM Input  
- 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

<table>
<thead>
<tr>
<th>Model</th>
<th>Features</th>
</tr>
</thead>
</table>
| TPIC6C596 | - Shift Register Power Logic  
- 33V Breakdown Voltage  
- Vcc = 4.5 ~ 5.5V  
- Cont. <100mA per channel (8 ch) |
| TPIC2810 | - 12C Power Logic  
- 40V Breakdown Voltage  
- Vcc = 3 ~ 5.5V  
- Cont. <100mA per channel (8 ch) |

### Topology

- **V_{BAT}: 9-18V**

  - No Diagnostic  
  - Simple ON/OFF  
  - Requires Parallel wires from MCU

- **V_{BAT}: 9-18V**

  - No Diagnostic or Simple Diagnostic  
  - Simple ON/OFF  
  - MCU Serial I/F & Daisy Chain Option

- **V_{CC}**

  - 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
  - Rds(on) 6.2 Ohm (25°C Junction, typ)
  - Rds(on) 13.5 Ohm (150°C 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vcc operating voltage</td>
<td>3 ~ 5.5 V</td>
</tr>
<tr>
<td>Output voltage maximum rating</td>
<td>40 V</td>
</tr>
<tr>
<td>Channel output maximum current</td>
<td>50 mA</td>
</tr>
<tr>
<td>Rds(on) typical</td>
<td>6.2 Ω</td>
</tr>
</tbody>
</table>

Battery 5 V - 40 V

3 V – 5.5 V
TLC6C5x-Q1 Setting Analog Constant Current Output to 20mA

- To set 30mA full range current, 20.5kΩ reference resistor can be used. Thus the reference current is 60µA generated by 1.229V reference voltage. ($K=500$)

$$I_{REF} = \frac{V_{REF}}{R_{REF}} = 60\mu A$$

$$I_{OUT,MAX} = I_{REF} \cdot K = 30mA$$

- By setting 8bit current DAC to 0xAA (170 in Dec), LED current is at 20.04mA during ON state.

$$I_{OUT} = I_{OUT,MAX} \cdot \frac{DC+1}{256} = 20.04mA$$

- PWM could be applied at the same time for group dimming and resolution extension.
TLC6C5xxx-Q1 Advanced Full Diagnostics

TLC6C5x supports full diagnostics features for LED, including:

– Thermal Pre-warning
– Over Temperature Warning & Protection,
– LED Short Detection,
– LED Short to GND Detection,
– LED Open Detection,
– LED Weak Supply Detection,
– Off-state LED Open/Short Detection,
– Adjacent Pin Short Detection,
– Reference Resistor Open/Short Detection & Protection,
– Input PWM Timeout Monitor
– ERR pin programmable to map reported faults
– SPI register lock feature for content protection
TLC6C5xxx-Q1 Reference Diagnostics & Protection

Once reference open/short fault is detected on reference resistor, maximum output current will be switched to default value. The \text{ERR} pin will be pulled low with Ref\_Fault\_Flag register set.
TLC6C5xxx-Q1 LED Failure modes detection & distinction

- Common LED faults includes LED Open, LED Short to GND, LED Short to Supply and Weak LED Supply, as depicted above.
- All the faults can be detected and distinguished by TLC6C5712 in both ON and OFF state with advanced diagnostics.
Thanks
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