



Freescale High-Brightness LED Solutions

The Future of Lighting

Low Power, Lofty Opportunities



Market Overview

The New Light

High-brightness light emitting diodes (LEDs) are taking the lighting industry by storm. Brilliant colors, long life and energy efficiency are just three reasons why high-brightness LEDs are gaining rapid popularity in the automotive, consumer and industrial markets. With improved output intensities, drive circuitry and packaging technologies, high-brightness LED systems offer tremendous opportunities for dazzling new lighting applications.

High-brightness LEDs are used in outdoor signage, innovative building designs, landscaping, traffic signaling, medical diagnostics instruments, aircraft interiors and as alternatives in flashlights, bicycle lights, lanterns and entertainment lighting.

Benefits:

- Energy efficient
- Long operating life (up to 100K hours of operation)
- Fully dimmable saturated colors
- Automatic on
- Environmentally friendly products
- Durability
- Range of true colors
- Compact size
- Programmability
- Design flexibility

High-power LED systems require a constant current to maintain color integrity and provide luminosity. For portable devices the system also needs to be smart enough to alert the user to a low-battery condition and compensate to maintain the constant current through the LED.

Freescale Semiconductor's intelligent high-brightness LED driver solutions can be set to act as a constant current control to configure the LEDs operated in a rated forward current. They also have power saving features to limit the loss on LED driving stages and over temperature/voltage/current fault detection to help protect the system. With Freescale's simple interface, microcontrollers (MCUs) help control the parameters to generate correct colors for a particular application.

In the following pages you will find information about Freescale's controlled solutions for architectural lighting, LCD backlight applications and MR16 LED bulb applications (intelligent flash lights) among other applications that can greatly benefit from LED technology. On our Web site, www.freescale.com/lighting, you'll find the technical documentation you need on Freescale's MCU portfolio and development tools and reference designs to help you get started on your new high brightness LED project development.

Control Interface Application Note

The control of high-brightness LEDs (HBLED) requires a constant current, maintained over temperature and voltage. Care must be taken to design a driver and control system that will optimize reliability and accuracy by delivering constant current. Using a cost effective MCU to power the HBLED increases system flexibility and functionality for the next generation of lighting applications. LED luminosity and reliability depend on the thermal control an MCU can provide. In addition, control protocols such as DALI, DMX512 and the ZigBee™ specification can be implemented at a low cost using MCU-based LED drivers.

Freescale's application note High Power LED Driver Interface (AN3321) introduces the user to MCU-based LED drivers using DC-DC converters with buck, boost or buck/boost topologies. The contents of the application note include:

- Overview of power terminology, LED specifics and MCU interface and control options
- High-brightness and high-current LED control, covering buck, boost and buck/boost topologies
- MCU control of DC-DC converter
- An MCU base driver example with design goals, control loop description and component selection
- Lighting control protocols DALI, DMX512 and the ZigBee specification
- User interfaces, including LCD display, button and slider switch
- Cross references and an appendix with DALI and DMX command stacks

The full application note is available as a PDF download from www.freescale.com/lighting.

Architectural Lighting Application

Innovative new high-brightness LED-based technology can use light to transform spaces, sites and building signs into striking works of art.

HCS08 Microcontroller Family

Required Features

- 16K in-application re-programmable flash memory
- 1K random access memory (RAM)
- 8-channel, 10-bit analog-to-digital converter (ADC)
- SPI, I²C, 2x SCI
- Dual 2-channel, 16-bit timers (IC, OC, PWM)
- Internal clock generator (zero external components)
- Programmable frequency-locked loop (FLL) and post-FLL divider generates from 32 kHz to 20 MHz bus speeds
- Trimmable with temperature and voltage compensation (typically < 2% drift)
- Optional external crystal, resonator or clock
- System protection
- Computer operating properly (COP)
- Low-voltage detect/reset @ nominal 1.8V
- Low-battery warning at nominal 2.4V or 2.1V

Overview

Architectural lighting is an application market where aesthetic design is as important as illumination. It covers outdoor illumination for buildings, towers, bridges, squares, signage and others as well as indoor illumination for rooms, lobbies and halls. Innovative new HBLED-based technology can use light to transform spaces, sites and building brands into striking works of art. It can even be used to replace neon signs and bulb lamps.

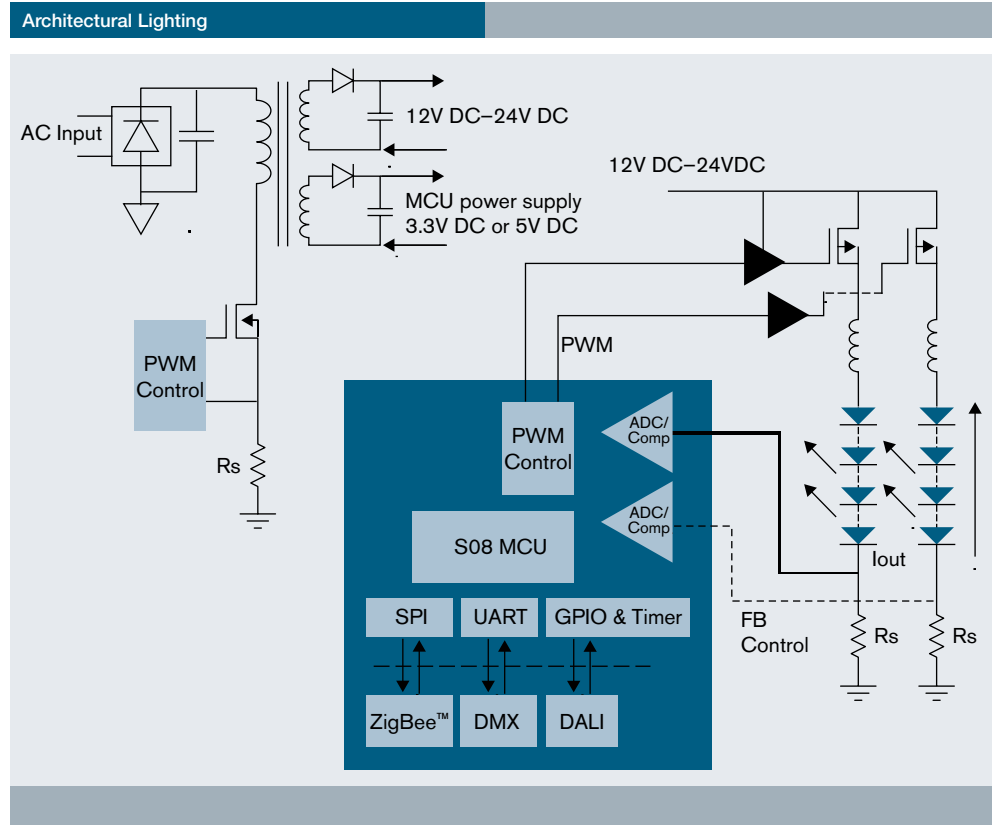
Design Challenge

The MCU-based control solution for HBLED architectural lighting is a lighting playback controller or interpreter, which stores or translates a specific scene or sequence for future playback. It sets the desired dimming level and turns specific light sources on or off to produce the required illumination scene. Furthermore, integrated connectivity enables

the MCU to remotely control additional light sources through such communication protocols as DALI, DMX512, Ethernet, USB, RS232 and the ZigBee specification.

The MCU-based system must be cost effective and flexible enough to support multiple LED-based lighting sources of different types powered by 12V DC–24V DC power supply units. The system also requires enough memory to store different scenes and to support a stand-alone playback mode.

Different techniques are used for dimming control, including pulse-width modulation, frequency modulation and bit-angle modulation. Each technique requires a different level of MCU performance, therefore any MCU-based system should be powerful enough and flexible enough to support any of these dimming techniques.



DMX512-SMAC Bridge

The 908E625 is a highly integrated single-package 8-bit solution that includes a high-performance HC08 microcontroller with a SMARTMOS™ analog control IC. The HC08 includes flash memory, a timer, enhanced serial communications interface (ESCI), an ADC, serial peripheral interface (SPI) and an internal clock generator module. The analog control die provides fully protected H-Bridge/ high-side outputs, voltage regulator, watchdog and local interconnect network (LIN) physical layer.

The single-package solution, together with LIN, provides optimal application performance adjustments and space-saving PCB design. It is especially suited for automotive mirror, door lock and light-leveling applications control.

MM908E625 Features

- High-performance M68HC08 core
- 1616K on-chip flash memory
- 512 Bytes RAM
- Two 16-bit, 2-channel timers
- 10-bit ADC
- Three 2-terminal hall sensor inputs
- One analog input with switchable current source
- Four low-resistive half-bridge outputs
- One low-resistive high-side output
- 16 microcontroller I/Os

Application Features

An evaluation tool using a Freescale HBLED 908E625 board with a DMX512-SMAC bridge board is a general-purpose platform that allows users to prototype their

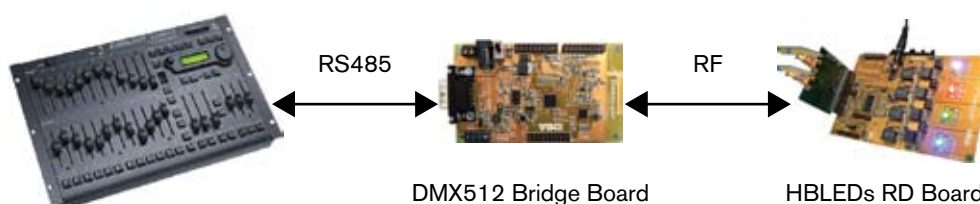
HBLED solutions. It also demonstrates the Freescale-integrated solution using general purpose microcontrollers, analog devices and intelligent distributed control ICs. However, in many applications driving the HBLED is not the only requirement. The DMX512-SMAC bridge board gives users the capability to incorporate wired or wireless connectivity in their HBLED solutions.

HBLED 908E625 Board

- Features the 908E625 MCU
- I/O emulating SPI communication to MC13192 RF transceiver
- SMAC 4.1 to control the MC13192
- Buck regulator implementation to drive HBLEDs
- Capable of driving 4-350 mA HBLEDs
- Internal low-side MOSFETS using current limitation feature
- 100 Hz PWM with 20 steps for LED dimming
- Code Size: 4381 Bytes
- RAM Size: 132 Bytes

DMX512—SMAC Bridge Board

- Features the 9S08GT60 MCU
- Supports DMX 512 serial protocol
- RS485 standard @ 250 Kbps
- Uses SMAC 4.1 to control the MC13192 RF transceiver
- Currently supports four channels
- Code Size: 4018 Bytes
- RAM Size: 1448 Bytes



Freescale High-Brightness LED Solutions

Promotorch

Overview

HBLEDs, offering dramatic improvements in solid-state lighting over traditional LEDs, are rapidly spreading into a number of new applications in automotive, consumer and other important markets. When using this new technology, however, new design challenges need to be addressed. HBLED systems require a high constant-current to deliver superior light output and maintain color integrity. Systems need to be smart enough to know when the source voltage is dropping and to compensate to maintain constant current through the LED.

Freescale's general-purpose 8-bit MCUs are excellent system-level controllers, offering a high level of on-chip integration, including a

10-bit ADC for accurate measurements and an internal band-gap reference to monitor battery voltage for brightness compensation and system battery level.

Promotorch

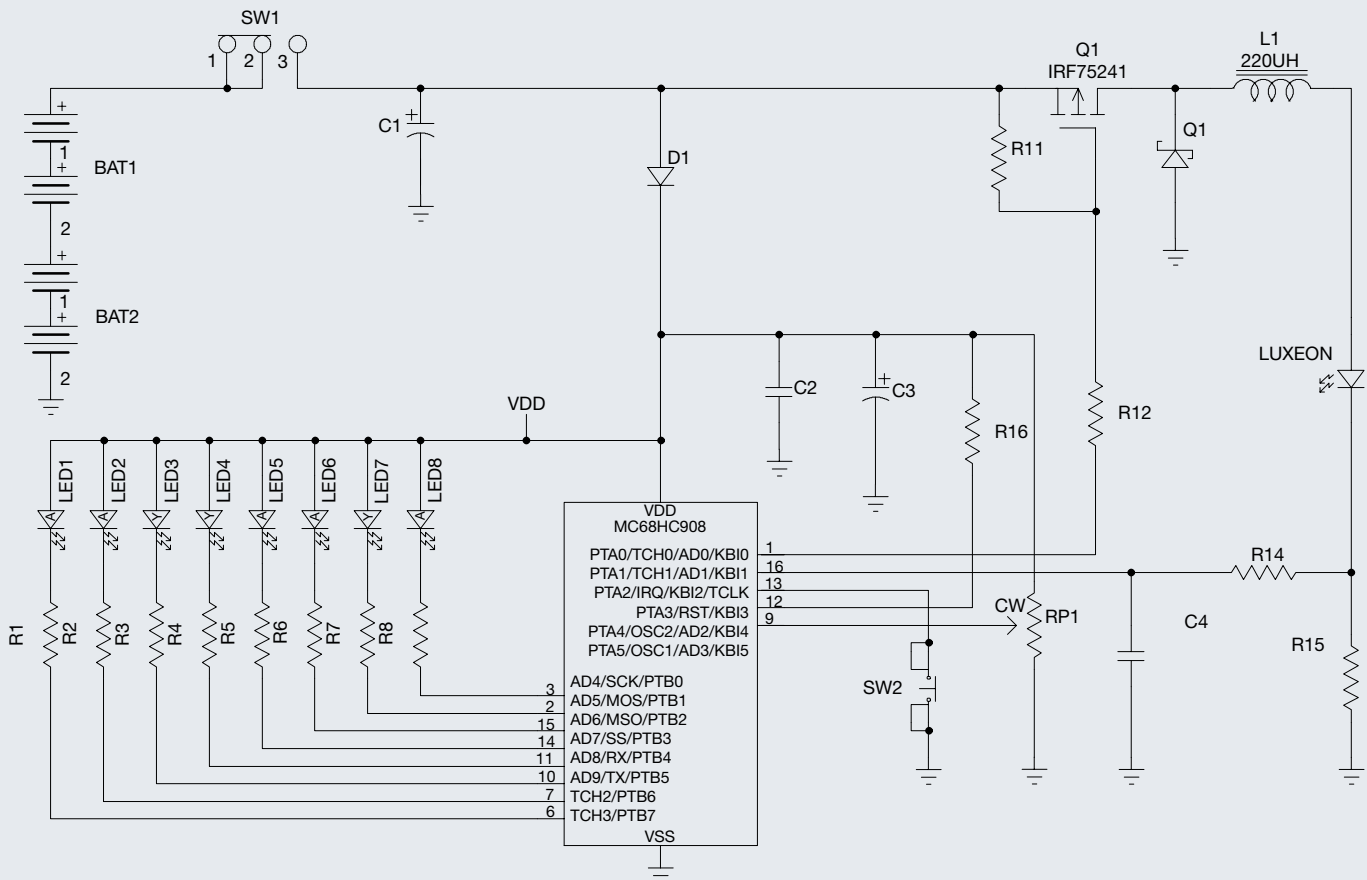
Freescale demonstrates its ability to control HBLEDs with Promotorch, a demo platform based on a buck topology switching power

supply, which maximizes energy transfer between the battery and the HBLED.

The 908QB microcontroller measures the current through its 10-bit ADC then uses that feedback to control light output on the HBLED. A potentiometer controls the brightness. Eight traditional LEDs provide visual feedback on the battery voltage status and the HBLED intensity levels.



Promotorch Demo Board



Overview

Innovative HBLED solutions are rapidly gaining popularity in low-cost applications that require an extremely cost-effective bill-of-materials. However, low-end HBLED applications still require a high level of system control as well as high constant-current to maintain color integrity and high light output. Freescale's general-purpose ultra-low-end

Recommended Device

Key Features

8-bitMC9S08AW60

PWM, 10-bit ADC, SCI,
SPI, I²C, Flash, ICS

16-bitMC9S12GC26

PWM, 10-bit ADC, SCI,
SPI, Flash, Low-Pin
Count

DSC56F801

PWM, 10-bit ADC, SCI,
SPI, Flash, Low-Pin
Count

KA2 8-bit MCU offers an economical solution for this application. The on-chip analog comparator is designed to provide an accurate current measurement, which allows feedback control to maintain a constant level in the LED forward current.

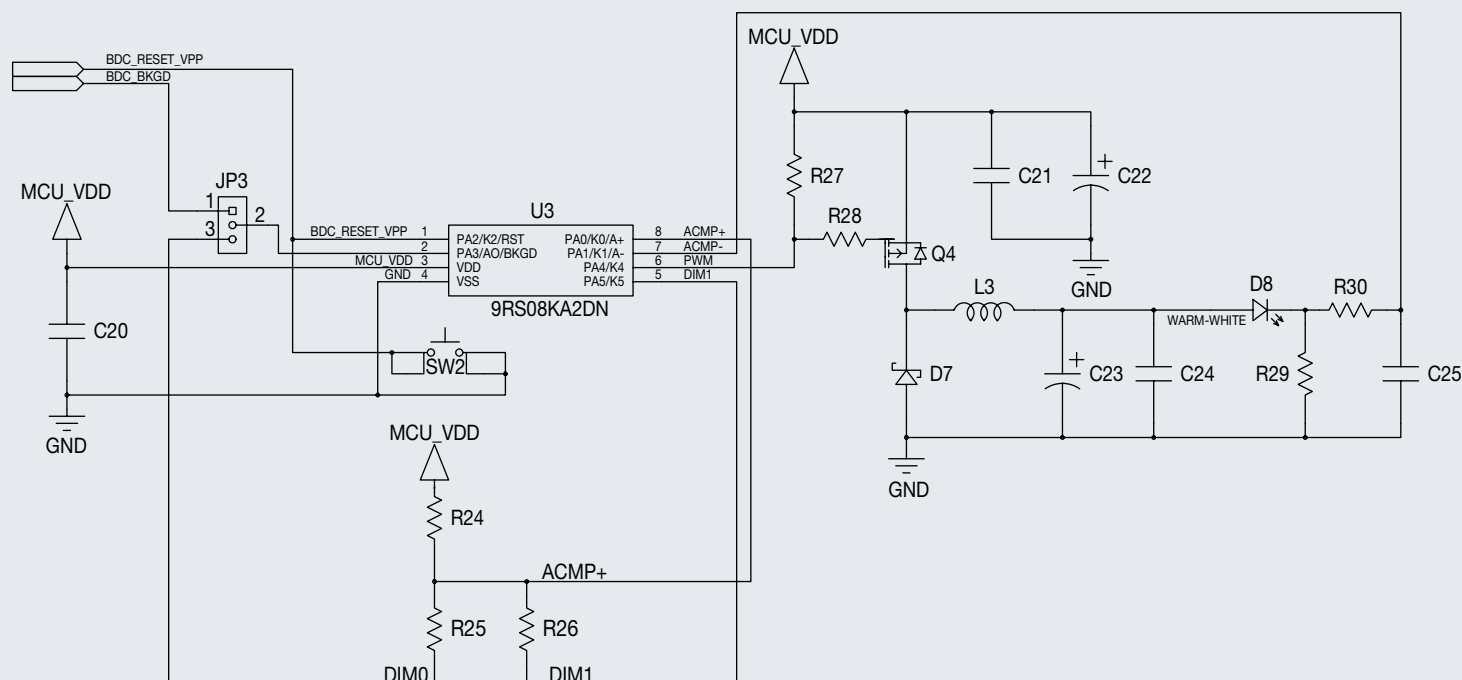
KA2 HBLED Demo

Freescale demonstrates its ability to control the HBLEd with a KA2 demo unit based on a buck topology switching power supply.

This maximizes energy transfer between the battery and the HBLED. The KA2 microcontroller is used to measure the current through its on-chip analog comparator, then uses that feedback to control luminosity intensity on the LED. The user can toggle between two MCU-controlled potential divider settings to vary the LED brightness levels. The demo unit also includes an open-source BDM interface for easy firmware evaluation.



MC9RS08KA2 EVB+HBLED Demo

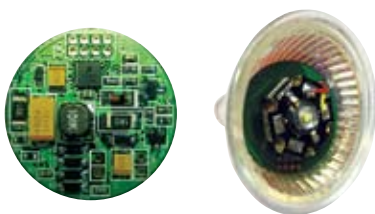


MR16 LED Bulb Application

Overview

HBLEDs offer several advantages over halogen bulbs for high-power lighting solutions. These include longer operating life, low-volt operation and no mercury or fragile glass. The major design challenges when replacing halogen bulbs with HBLEDs include: how to implement a drop-in replacement for a compact-sized halogen bulb in a standard MR16 form factor; how to convert a 12V supply to drive the LED with constant current and how to control dimming settings without additional wiring.

Freescale's general-purpose 8-bit MC68HC908QT2 MCU offers a high level of on-chip integration for this application, including an 8-bit ADC designed to provide accurate measurements on LED forward current, a 16-bit timer module to generate a PWM control signal for DC-DC conversion and on-chip flash memory for storing the dimming settings.



LED Bulb Demo

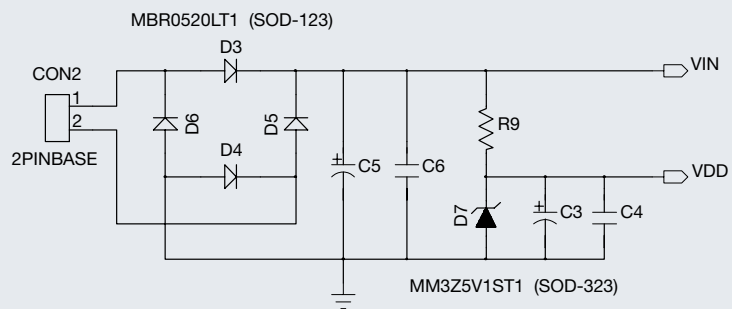
The QT2 is used as an intelligent driver to control the LED brightness level. A buck topology switching converter is implemented to convert a 12V input supply to a current regulated output for LED driving. Power metal-oxide semiconductor field-effect transistor (MOSFET) switching is controlled by the MCU's PWM output, and the LED current is monitored by an ADC module through a current sensing circuit. Based on the feedback voltage from the ADC, the MCU is designed to adjust the PWM duty cycle in close-loop control to keep a constant LED driving current. The dimming level can be adjusted by directly changing the regulated LED current, which is proportional to the target value used in the ADC comparison loop. The pre-set dimming levels (target values) are stored in MCU flash memory. When the system is powered on, the brightness setting is established when the previous dimming level is restored from memory. The current dimming level is designed to be saved in memory again if the system is operated for more than 12 seconds, otherwise the next step dimming level will be recognized as the configuration for the next power-on-brightness setting. There is no additional control signal for dimming setting, only the power-on-time is used.

Options for Advanced Functionality

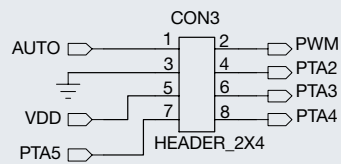
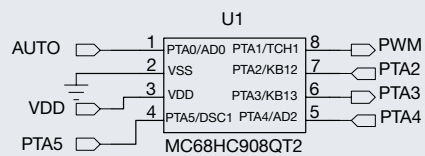
Recommended Device	Key Features
8-bit	
MC9S08QG4	PWM, 10-bit ADC, SCI, SPI, I ² C, Flash, ICS, ACMP
16-bit	
MC9S12GC26	PWM, 10-bit ADC, SCI, SPI, Flash, Low Pin Count
DSC	
56F801	PWM, 10-bit ADC, SCI, SPI, Flash, Low Pin Count

QT2 LED Demo Board

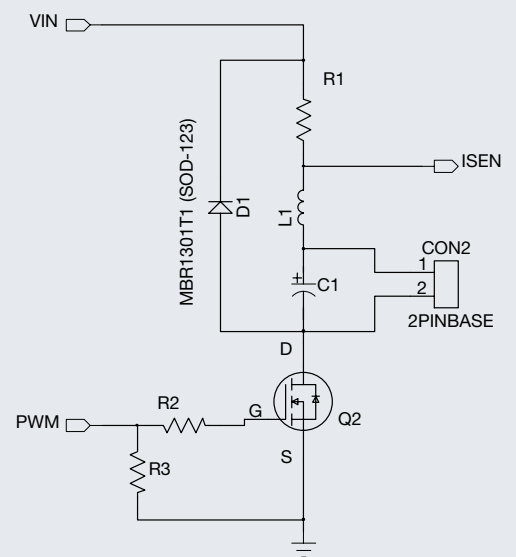
Supply



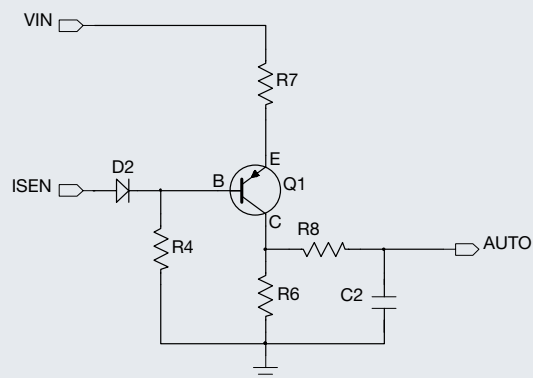
MCU



DC-DC Converter



Current Sensing



Freescale High-Brightness LED Solutions

Backlight Solution

Freescale offers exceptional support, helping customers to design smarter products and get them to market faster.

Overview

Using an HBLE LED backlight system in an LCD monitor or TV offers dramatic advantages over conventional cold cathode fluorescent lamp (CCFL) backlighting, delivering more brilliant colors and brighter pictures in a more environmentally friendly solution, since this is a totally lead-free and mercury-free solution. HBLE LED backlight system design requires a smart and adaptive control methodology to ensure optimized color space for different display contents, excellent color contrast for desktop publishing and a consistent color setting in manufacturing.

Freescale provides a comprehensive range of solutions with value extending far beyond a basic controller or analog control circuit.

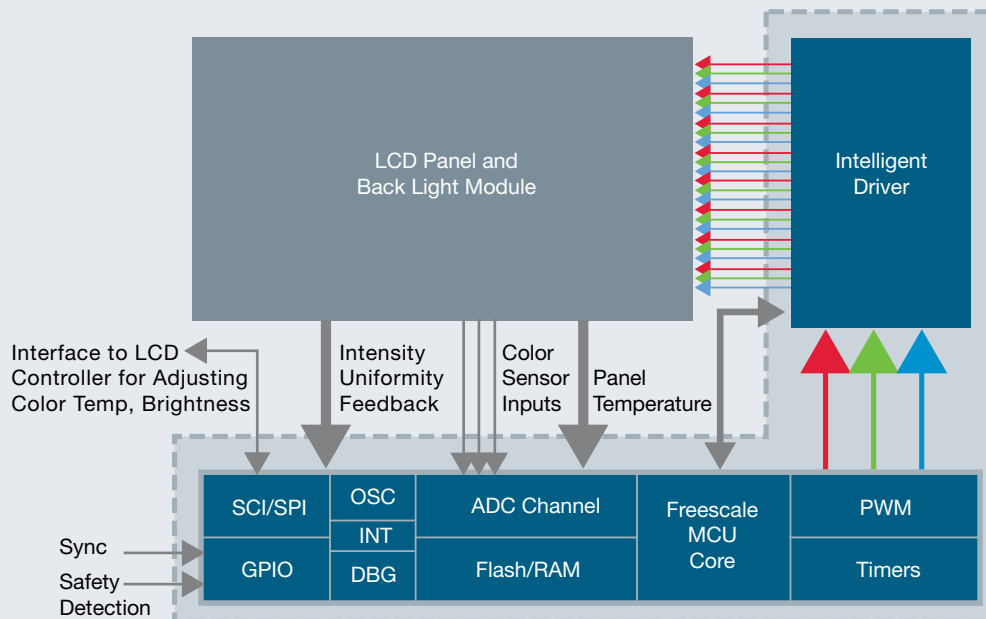
Intelligent Driver

The intelligent driver solution creates new opportunities for cost-effective HBLE LED backlight designs. It includes constant-current control to configure the LEDs operated in rated forward current, a power saving feature to limit the loss on LED driving stages and over-temperature/voltage/current fault detection to help protect the system. A simple interface can easily set up the desired color space, and the MCU can control all parameters to generate the correct colors for a particular application. The control algorithm maintains accurate color tracking over the temperature range and is able to compensate for characteristics drift on analog devices.

Options for Advanced Functionality

Recommended Device	Key Features
8-bit	
MC9S08QG4	PWM, 10 bits ADC, SCI, SPI, I ² C, Flash, ICS, ACMP
16-bit	
MC9S12GC26	PWM, 10 bits ADC, SCI, SPI, Flash, Low Pin Count
DSC	
56F801	PWM, 10 bits ADC, SCI, SPI, Flash, Low Pin Count

Backlight LCD Display



Implementing DMX512 Protocol

Entertainment lighting markets have adopted the DMX512 protocol because it's simple and has the necessary characteristics for a single, unified-illumination standard.

The HBLED market is attracting new players as low-end MCUs enable new applications. These newly enabled applications include automotive signage, mobile appliances and a wide variety of general illumination systems. Some novel uses for HBLEDs range from water purification modules to automated systems for cultivating vegetables through the combined use of RGB LEDs.

In many cases, these new applications will be controlled by a central control unit that requires a connectivity interface. In the lighting market today this connectivity is dominated by two protocols: DMX512 and DALI. Freescale's Application Note DMX512 Protocol Implementation Using MC9S08GT60 8-bit MCU (AN3315) details how the DMX512 protocol can be deployed using a popular Freescale 8-bit microcontroller. The contents of the application note include:

- Overview
- DMX512 protocol overview, including physical layer and data protocol
- Software implementation with software flowchart, code description advantages and disadvantages of using interrupt or non-interrupt methods, interrupt- and non-interrupt-based code and DMX512 frame-detection code
- DMX512 implementation constraints
- DMX512 hardware implementation
- Test considerations and conclusions

The full application note, DMX512 Protocol Implementation Using MC9S08GT60 8-bit MCU, is available as a PDF download from www.freescale.com/lighting.



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