November 2008

Introducing LED Backlight Solutions from Freescale

AC106

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Freescale Display Focus

- The display market is huge
  - Almost 3.7B displays will be manufactured in 2008
- LCD (Liquid Crystal Display) is the dominant technology in the display market
  - Accounts for 3.2B units or 86%
- There are two main types of LCD:
  - Passive matrix LCD
    - Accounts for 1.2B units
    - Primarily gray scale, character/fixed or low resolution displays
    - Serves low end of market
  - Active Matrix TFT-LCD (Thin Film Transistor LCD)
    - Accounts for 1.9B units
    - Primarily full color, pixel based displays
    - Serves high value markets
- Freescale will focus initially on medium/large TFT-LCD displays
  - 506M unit SAM in 2008
  - Requires higher voltage/ higher power electronics
  - SMARTMOS technology provides a differentiator
    - Integration of high voltage, high power, analog and high density logic
- Small TFT-LCD display support
  - Integration in large scale power management ICs

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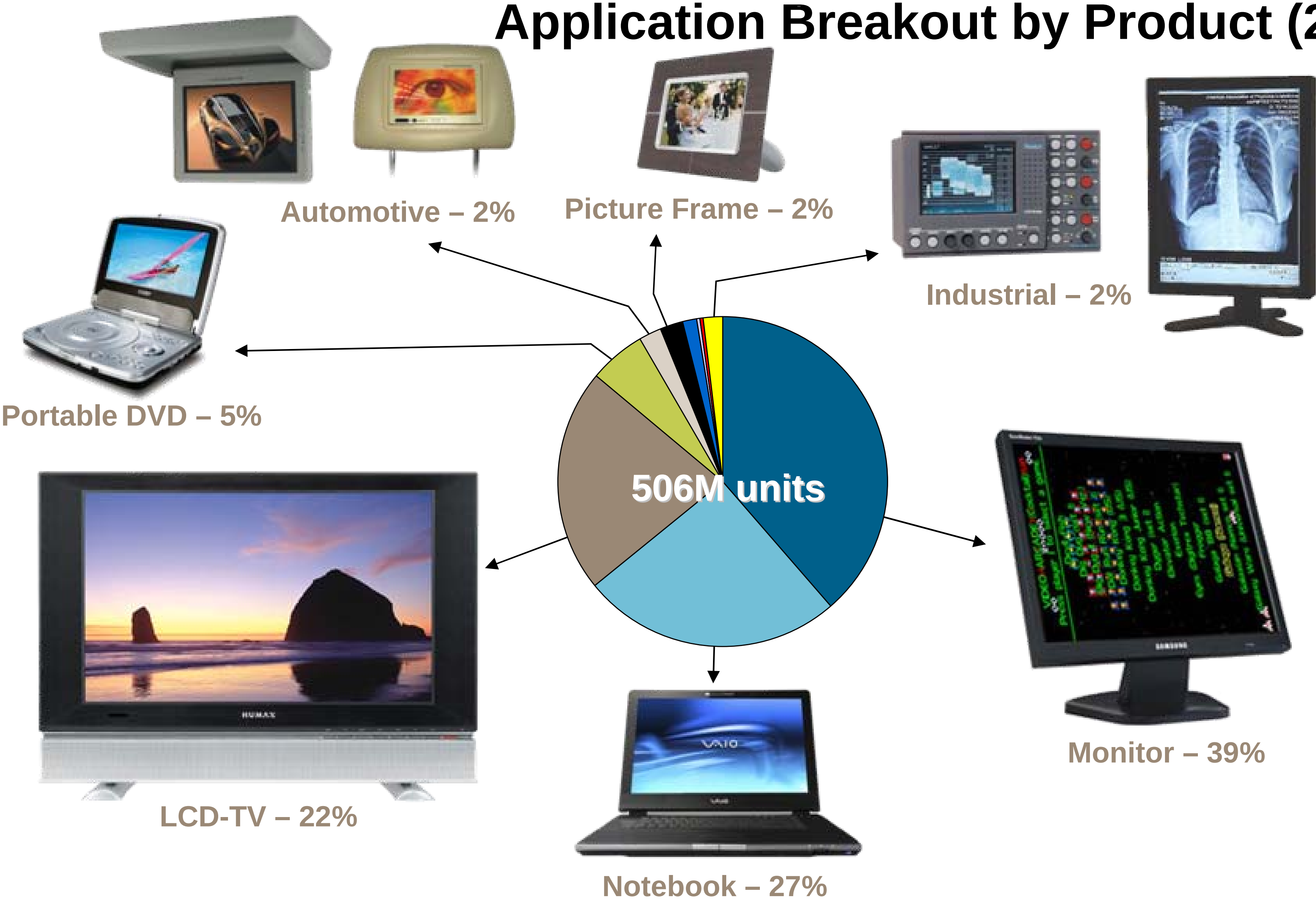
Application Breakout by Product (2008)



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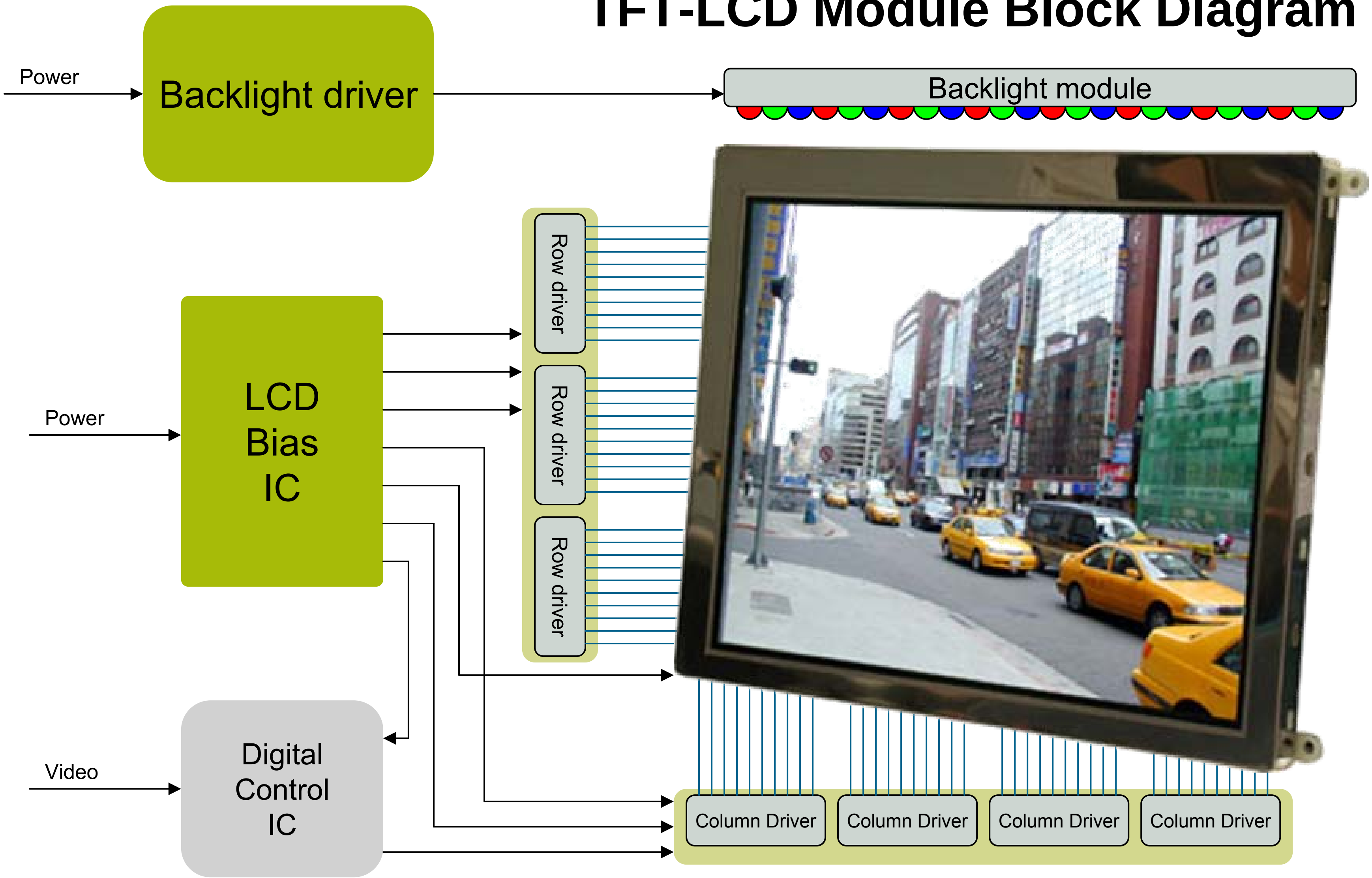
TFT-LCD Module Block Diagram



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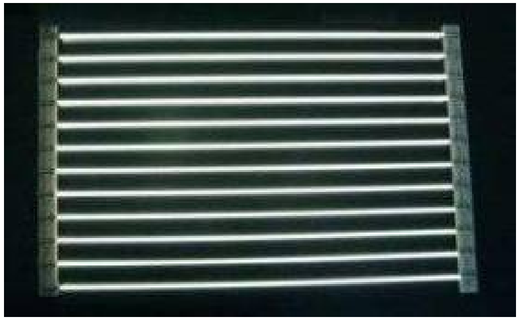
LED Backlighting Introduction

- ▶ LED Backlights dominate the smaller LCD display market
  - Cell phone, GPS, PDA
- ▶ Larger display have traditionally used Cold Cathode Fluorescent Lamps (CCFLs)
- ▶ LEDs now penetrating larger LCD modules
  - Notebooks have largest adoption today – exceed 30% in 2009
  - Monitor and TVs are emerging market



CCFL

LED

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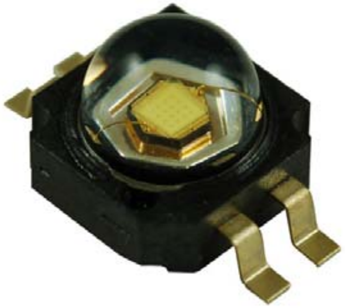
LED Backlight Classification

- The LEDs used in backlighting are characterized in a number of ways

1. Current capability
   - Standard LED – drive current < 50mA
   - High current LED – drive current 50 – 150 mA
   - High power LED – drive current 150 – 1000mA+

Standard LED

2. Color
   - White LEDs
   - Red, Green and Blue LEDs
     - Combined to make white



Philips Luxeon K2
High Power LED

- LED forward voltage depends on color
  - Red ~ 2V, Green ~ 3.5V, Blue/White ~3.5 – 4V

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The LED Advantage

- LEDs have many advantages compared to CCFL
  - Point source characteristics enable more flexible backlight architectures
    - Enables thinner backlight designs
    - Enables advanced backlight architectures
  - Higher efficacy (more light at a give power) – White LEDs only today
  - Longer lifetime (50,000 hrs vs. <10,000 hrs.)
  - Dimmable – accurate with infinite steps
  - Low voltage drivers reduces complexity
  - Environmentally friendly (CCFLs contain mercury)
  - Rugged – CCFLs are glass and can break easily
  - RGB specific advantages
    - Wider color gamut
    - Tunable white point

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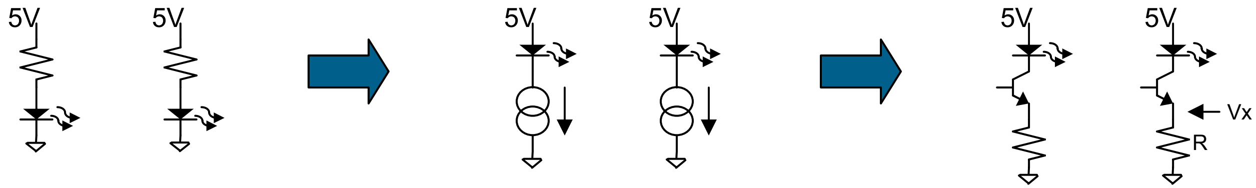
LED Driver Challenges – Current Driver

- To maintain backlight uniformity, all LEDs must be the same brightness
  - For LED, light output is dependent on current, not voltage
  - Therefore current needs to be matched between LEDs
  - The target of module makers is ±1% matching
  - Complicated by the fact that LED forward voltages (VF) vary by ±10-15%



- Assume the LEDs have a V_F range of 3.0V to 3.6V (Mean = 3.3V) and we want 20mA

R = (5 – 3.3)/20mA = 85Ω
I_{LED1} = (5 – 3.0)/85 = 24mA
I_{LED2} = (5 – 3.6)/85 = 16mA
> Low cost
> Poor matching ±20%
> Not suitable for backlight

Ideal current source
= perfect matching

Real world implementation
Active circuit maintains voltage across current setting transistor - Vx
V_F voltage difference drop across transistor
LED current set by Vx/R
Matching set by Vx accuracy – FSL = ±1% to ±2%
> Best current matching
> Suitable for backlight driver

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LED Driver Challenges – LED Connection

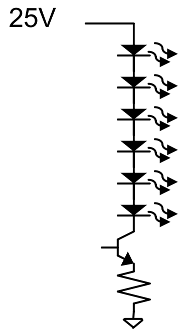
- Each backlight consists of many LEDs - 3 to 1000+ depending on display size
- LEDs can be connected in series or parallel

Series

Perfect current matching

High voltage drivers are more expensive

Inefficient for high step up ratio

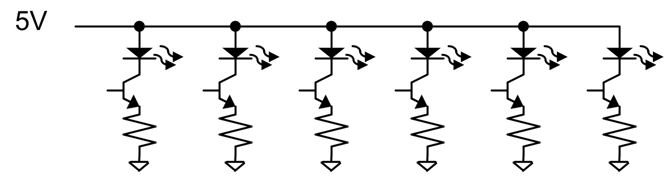


Parallel

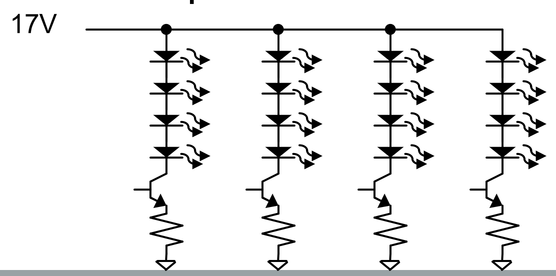
Needs current matching circuits – less accurate

Enables lower voltage drivers

Needs many channels = expensive



- For more than 8 LEDs, a series/ parallel combination is usually used



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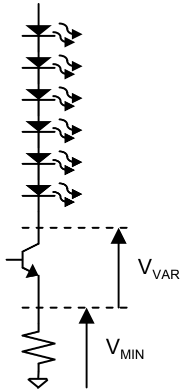
Other LED Driver Concerns

- VF variation between LEDs increases power dissipation/ heating
  - Typical white LED spec'd with V_F = 3.0V min, 3.6V max.
    - Binning can be used to sort LEDs and reduce this variation
  - For a string of 12 LEDs, this means $V_{F(total)}$ = 36V to 43.2V
  - In reality, statistical distribution may give 2V - 3V variation
  - The linear drivers have to absorb this voltage difference (V_{VAR})
  - In addition, there is a minimum voltage in the drivers needed for the current driver (V_{MIN})
    - Reducing this to a minimum, helps keep power dissipation down
    - However there is a trade off with current accuracy
    - Freescale's first products are at 500mV
  - $P_{Diss} = ((n – 1) \times I_{LED} \times (V_{MIN} + V_{VAR})) + ILED \times V_{MIN}$
  - e.g. For 8 channels, driving 50mA LEDs with average variation of 3V
  - $P_{Diss} = ((7 -1) \times 50.10^{-3} \times (0.5 + 3)) + 50.10^{-3} \times 0.5 = 1.08W$



- LED wavelength is dependent on current
  - Therefore PWM dimming is used to change brightness, maintaining a constant current
  - At low brightness's, analog dimming can be used to improve dynamic range (contrast ratio)
    - Eye is less sensitive to color at low intensity
  - For RGB LEDs, wavelength can be tuned with current control

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The Freescale Advantage

- Experience
  - Recruited expert team with many years LED driver experience
  - System group engaged with major LED backlight vendors for complete solution approach
    - Convert LCD panels to LED backlight
    - Understand all aspect of backlight design
    - Deep understanding of LED design challenges

- Technology
  - Freescale SMARTMOS ™ technology
  - Enables integration of high density control logic, with integrated power device and accurate analog control circuits
- Proven capability
  - Our existing custom products are the highest performing LED drivers on the market

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Notebook and Mid-size Display LED Drivers

- Typically use White, Standard LEDs (20 to 50mA)

- The number of standard white LEDs varies depending on the application
  - 10 – 100 LEDs will be used depending on screen size
    - 7” = 10-16 LEDs
    - 12” = ~40 LEDs
    - 14.1” = ~54 LEDs
    - 15.4” = ~60 LEDs
  - Typical applications have a single driver

- Drivers are powered from either
  - Internal 5V or 12V
  - Direct from battery
    - 7 to 20V in Notebooks

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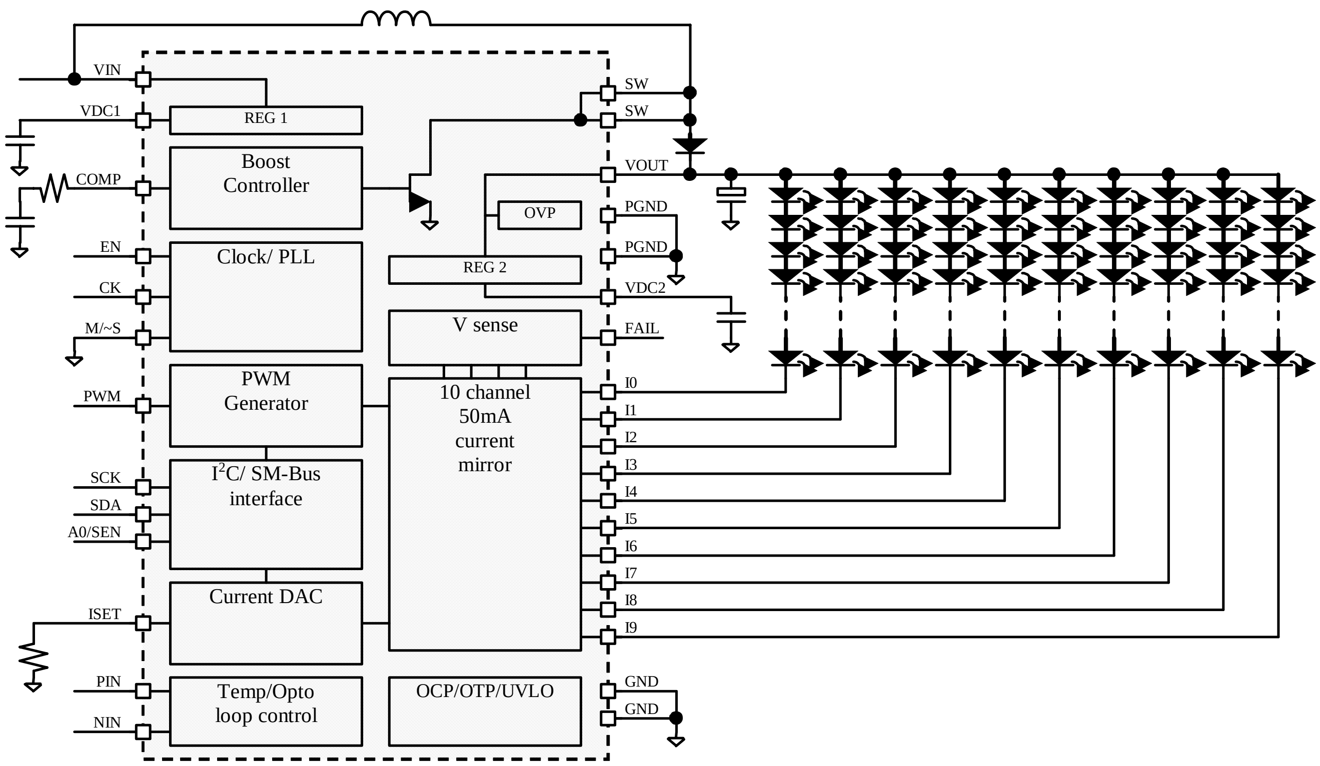
MC34844 LED Driver

- **Applications**
- Notebook
- Industrial/medical/instrumentation
- Portable DVD
- Automotive
- Picture frame

- **Features**
- Input voltage 7V to 30V
- 3.5A integrated boost
- Output voltage up to 60V
- 10-channel current driver
  - ±2% current matching
- Programmable LED current
  - Up to 55mA per channel
- Dynamic Headroom Control
  - Improves device efficiency
- Multiple control options
  - I^2C/ SM-Bus interface
  - PWM input
  - Analog control
- Programmable PWM generator
  - 100Hz to 20kHz frequency
  - 255 step PWM duty cycle
- PWM synchronizing capability
  - Improved matching between devices
  - Remove Waterfall issues
- User programmable OVP
- LED failure detection
- OTP/OCP/UVLO lockout
- 32-Ld 5x5x0.8mm TQFN package

- **Samples:** June 2008



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MC34844 Advantages

- Accurate, programmable current drivers
  - Mirrors match to < ±2%
  - At low PWM ratios, current control offers further dimming range
- PWM synchronize circuit
  - Matches PWM clocks in each device for matched PWM outputs
  - Frequency and duty ratios are then both matched
  - Improves brightness matching between devices
- 100Hz to 25kHz dimming range
  - Can be locked to multiple of frame frequency for improved brightness matching
  - Can be programmed above audio frequency for reduced noise in some systems
- 7V to 30V input range ideal for notebook applications
- Dynamic headroom control improves system efficiency/ reduces dissipation in driver
  - Measures voltage across all LED strings
  - Sets boost voltage to minimum capable of driving all channels, reducing voltage across drivers

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Monitor and TV LED Drivers

- For monitors and TVs both white and RGB LEDs are used
- Can use all types of LED from Standard to High Power (50mA to 350mA)
- The number of LEDs depends on the size of panel, and the type of LED
  - Can use 2000 – 4000 standard LEDs
  - For high power LEDs, a few hundred units are used
  - Requires multiple drivers per system
- Power typically comes from a 24V supply

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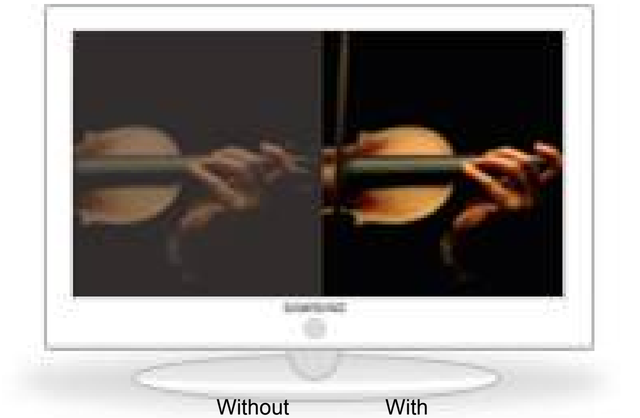
Monitor and TV LED Backlight Architectures

- ► Innovative LED backlight architectures are being used to overcome drawbacks of the LCD technology
- ► One such drawback is contrast ratio
- ► A second is power consumption
- ► Local dimming improves both
  - Backlight is divided in to a number of zones
  - The backlight is then adjusted depending on the picture content
    - Contrast ratio improvements up to 500,000:1 possible
      - Standard LCD ~ 5000:1
    - Reduces power dissipation up to 60%
      - The backlight consumes 30%+ of power in LCD-TVs

Local Dimming



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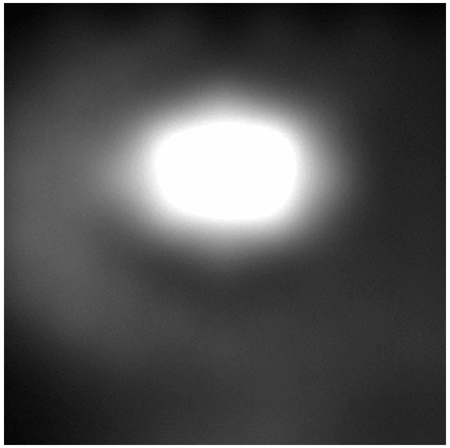
Local Dimming Backlight Example

Input Image



LED array

LCD with correction

Output image

Source : Brightside/ Dolby

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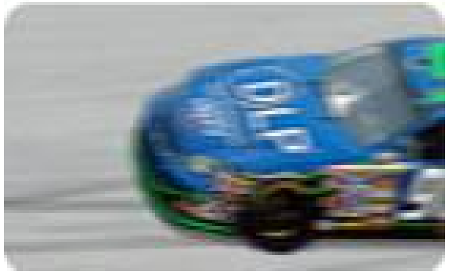
Monitor and TV LED Backlight Architectures

- Another problem with LCD is motion blur
- This can be improved using scanned backlights
  - Backlight is divided in to rows
  - Light is scanned down the display at frame rate
  - One or more rows can be illuminated at a time
  - Eye tricked in to seeing faster refresh
  - This removes the blur effect
- Can be combined with local dimming

With Scan



Without Scan

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TV/Monitor LED Driver Chipset

- Design to meet requirements of different backlight configurations
- Separate DC:DC and driver sections enable flexible design
  - # of Drivers depends on number of channels to be driven
  - Support for single DC:DC for whole panel, or local zone/multi-zone DC:DC
- Supports RGB or White LED backlighting
- Support various LED currents
  - 16-channel, 60mA device is first product
  - Future support up to 240mA LEDs
- Support for local dimming panels
- Support for scanning
- **Target Sample Date:** September 2008

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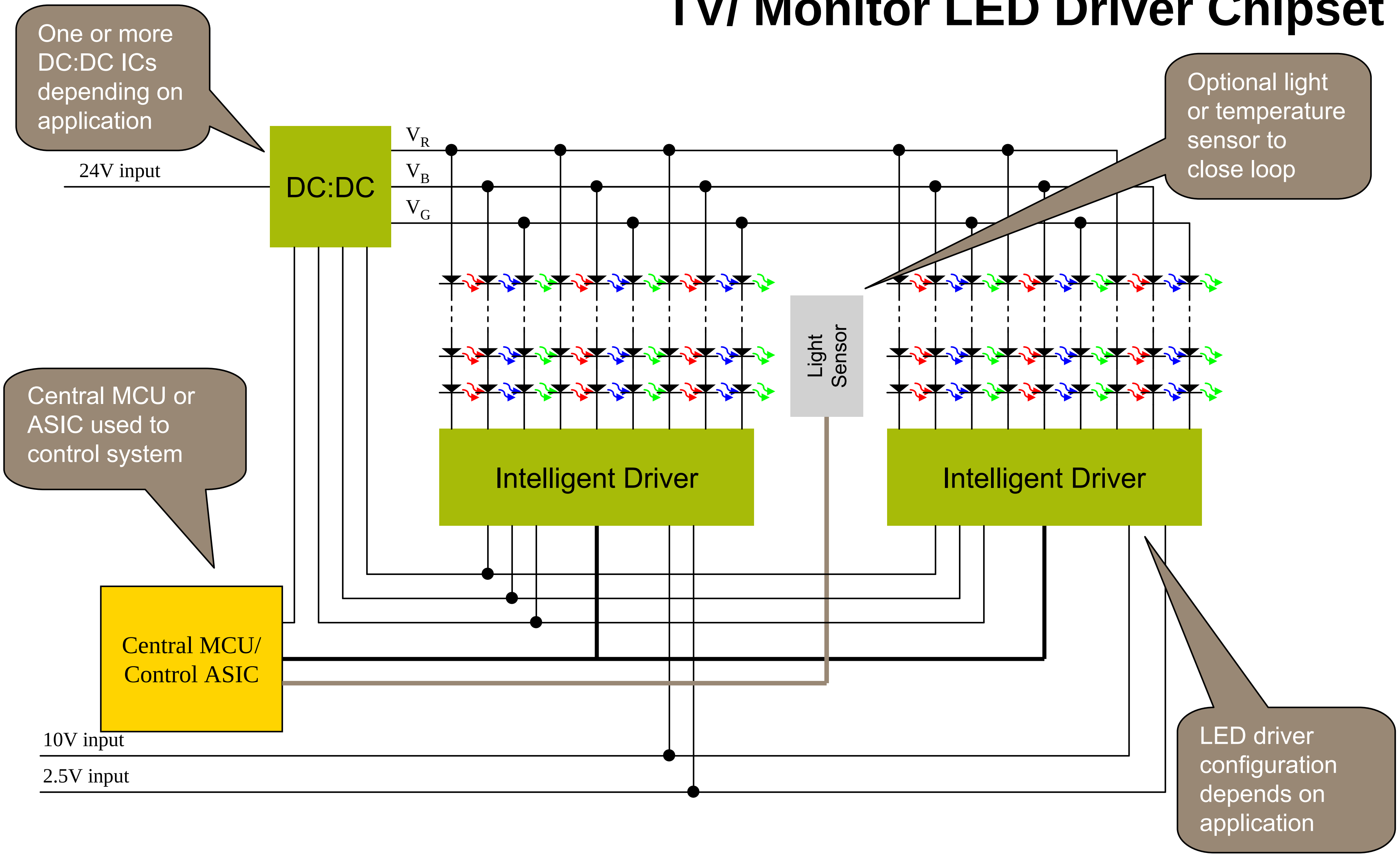
TV/ Monitor LED Driver Chipset



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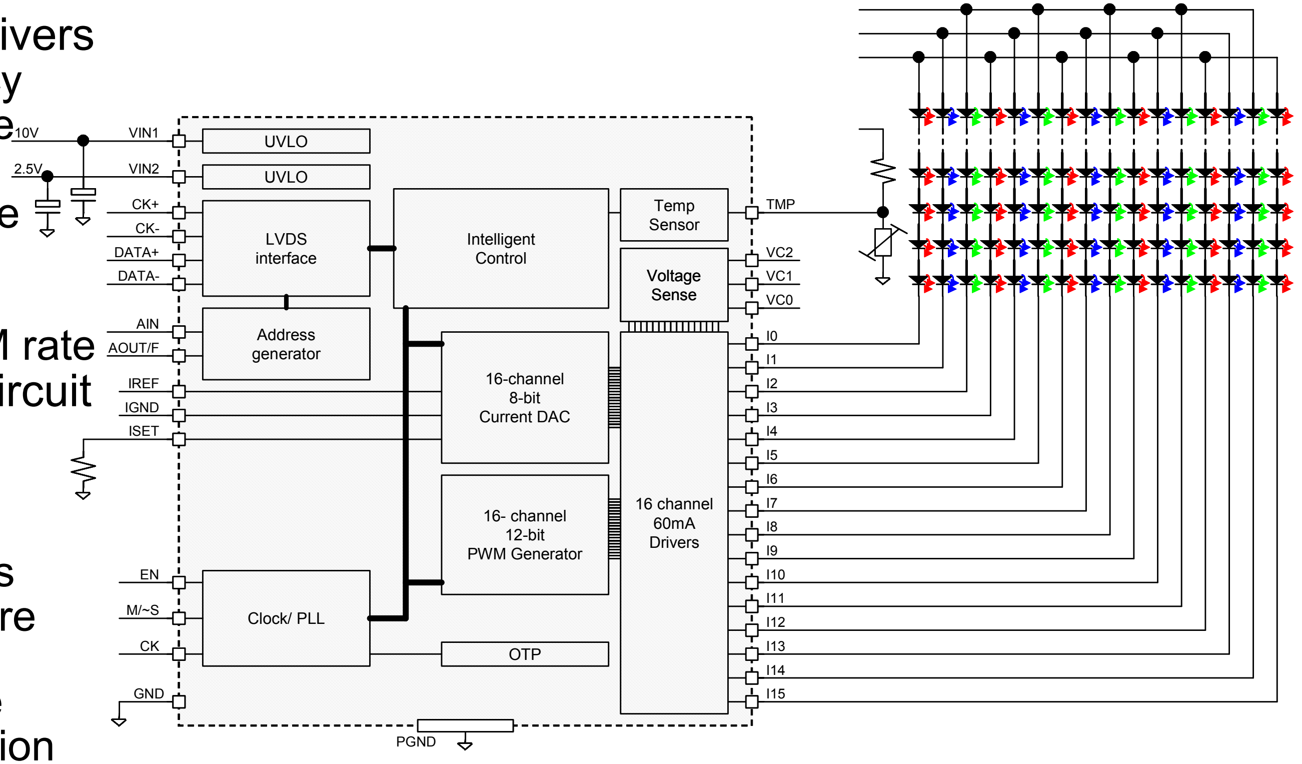
Intelligent Driver IC

- **Features**
- 12V and 2.5V IC inputs
- 16 channel intelligent drivers
  - ±1% current accuracy
  - 60V max. LED voltage
  - 60mA max IF current
  - Current programmable to 8 bits
- 12-bit SMART PWM
  - 100Hz to 25kHz PWM rate
- Clock synchronization circuit
- RSDS interface
  - Program offset ratios
  - Program brightness
  - Program LED currents
  - Read back temperature and status
  - Global program mode
  - Auto address generation
  - 60MHz interface
- 40-Ld 6x6 QFN package
- -40° C to +85° C operation



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Advantages

- 12-bit, 100Hz to 25kHz PWM with synchronizing function
  - Provides larger dimming ratio – improving contrast ratio
  - Frequency can be sync'd to 120Hz frame rate, or superset of frame frequency to remove waterfall
- 8-bit programmable current per channel
  - Improves dimming range for higher contrast ratio
  - Provides for RGB LED wavelength tuning
  - ±1% current matching at full scale
- Chip-to-Chip PWM sync function
  - 100% matching of frequency and duty cycle between devices
  - Provides better brightness matching between devices
  - Removes visual artifacts
- High speed control interface
  - Provides fast updates for local dimming mode
  - Special command sets for row scanning function and global setup
- Auto-address generator
  - Start-up routine automatically sets device address
  - Removes need for dedicated pins to set device address
    - A single board design can be used across the backplane
    - No operator interaction to set device addresses

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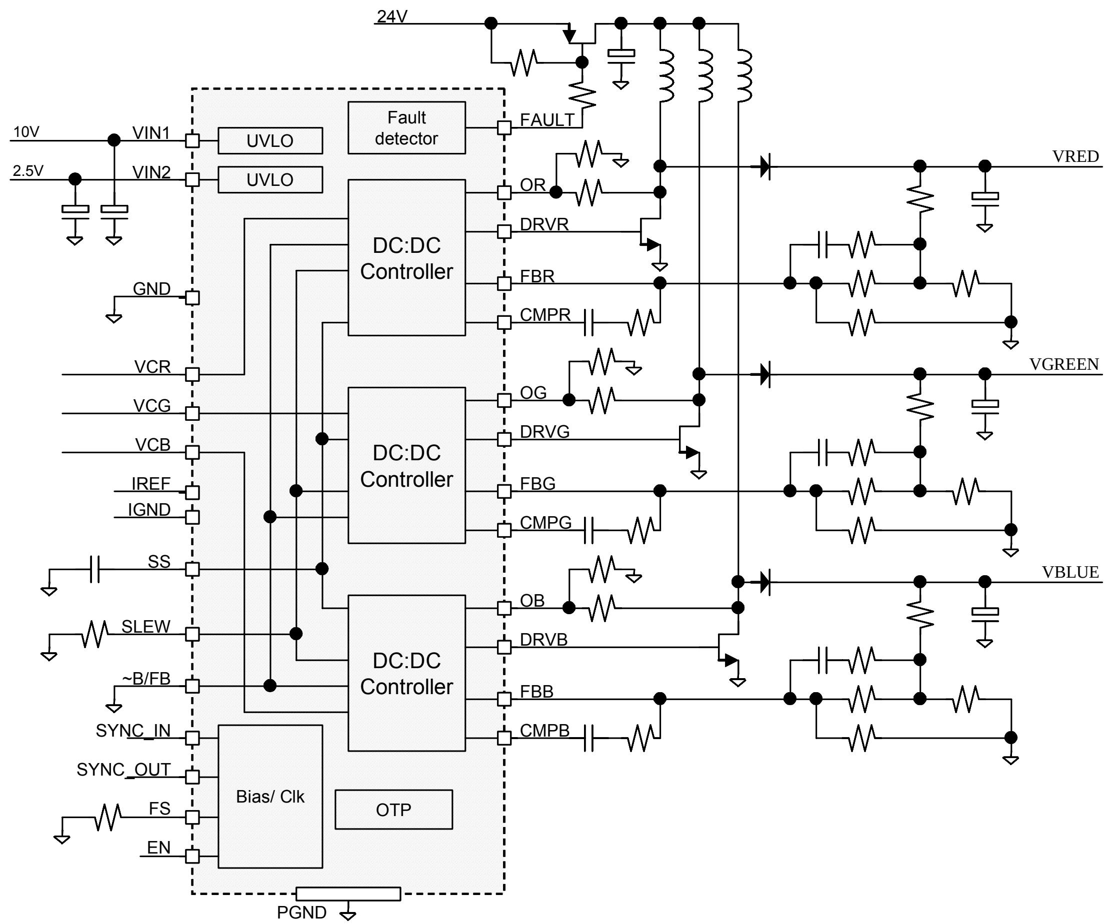
Power IC

- **Features**
- 12V and 2.5V chip supplies
- Boost or Buck configurations
- 3 x DC:DC controllers
  - Supports any FET
  - 750mA gate drive
  - Soft start
  - Over voltage protection
- Programmable frequency
  - 200kHz to 1.2MHz
- Frequency synchronization mode
- Programmable slew rate
- Programmable soft start
- Input side safety switch
- OTP/OVP/OCP/UVLO lockout
- 28-Ld 5x5 QFN package



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Advantages

- Each channel can be configured for boost or buck mode
  - Depending on input voltage and # of LEDs, output can be lower or higher than input
    - e.g 8 RGB LEDs on 24V input, R = 16V out, GB = 28V out
- DHC (Dynamic Headroom Control) function especially designed to work with Serpent II IC
  - Proprietary digital interface between Anaconda II and Serpent II
  - Provides noise immunity and high speed DHC update
- External FET architecture enable current to be scaled to requirement
- Programmable switching frequency enables efficiency to be optimized depending on application
- Switching frequency sync function reduces cross talk and noise

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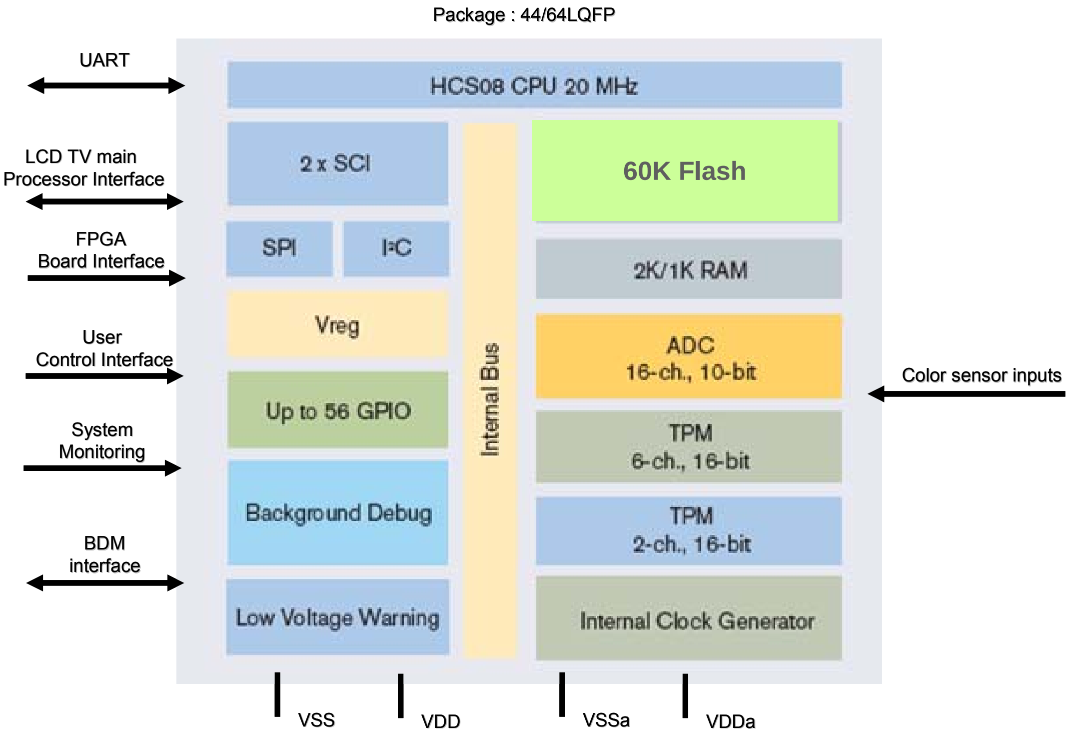
LED Backlight Controllers

- For RGB color control, simple 8-bit MCU is sufficient
  - Freescale solution based on 68HC9S08AW60
  - Patented color control system architecture
  - Demo available in exhibit hall and at Meet the Expert sessions



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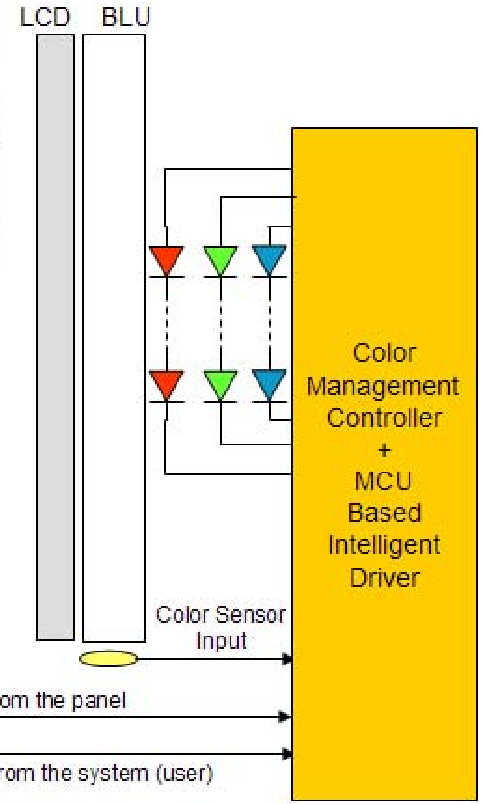
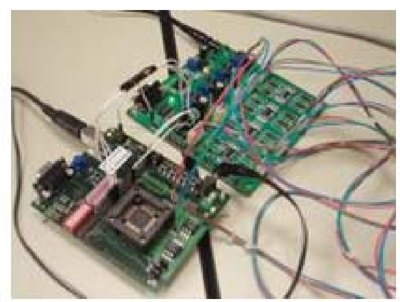
Freescale Color Management Control System



Features :

- **FSL 8bit MCU** is used as the color management controller
- >100% NTSC color gamut
- System input or user defined color space coordinate as the reference
- Close loop with color analyzer for BLU color temperature alignment
- Color sensor close loop to maintain the desired color temperature with error less than 0.005 count of CIE standard
- LED and analog driver characteristic profiles are considered



$$(f_{R/G/B}) = F(X_{R/G/B}, Y_{R/G/B}) \bullet F(X_W, Y_W)$$

$(f_{R/G/B})$ is the fraction of R, G, B for color mixing

$(X_{R/G/B}, Y_{R/G/B})$ are the R/G/B LED color space as selected from particular LED binning

(X_w, Y_w) is the desired white point color space

Auto calibration is possible in the manufacturing stage !

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Future LED Driver Products

Triple DC:DC
Buck, boost or buck-boost configurations
Targets monitor/ TV applications

16-Channel LED Driver
White or RGB LED
Targets monitor/ TV applicators

Next generation products target emerging backlight architectures with higher resolution local dimming, higher power LEDs and different control schemes

MC34844 - 100-LED BL Driver
10-channel with integrated FET
Targets medium/ notebook applications

More application specific standard products targeting specific applications.
Support for different number of channels and current level

Panel Size ->

2008 2009 2010

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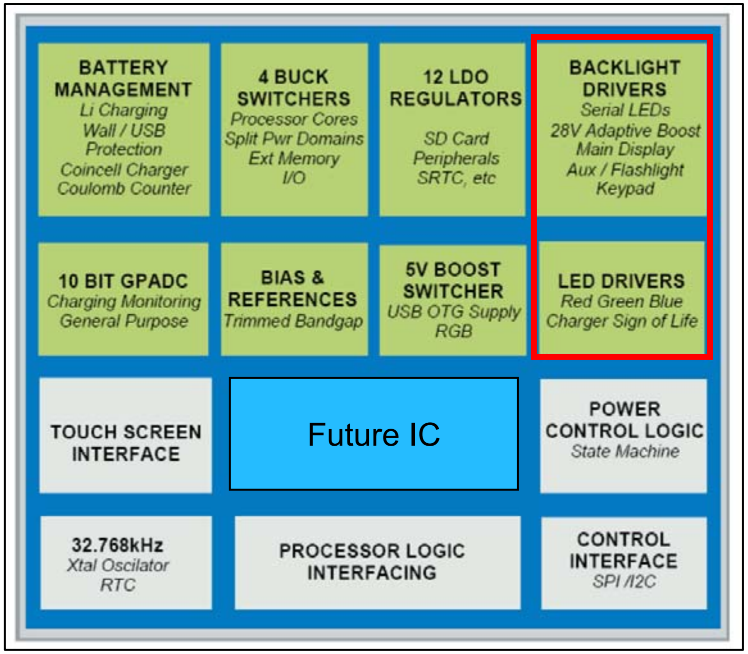
Small Panel Solutions

- White LEDs dominate small panel backlighting
  - Cell phones, DSC, smart phone, PDA, MID, GPS…
- Historically have used separate LED driver
- Majority applications now moving to integrated solutions
- Freescale supports this market through integrated solutions only



PMIC for portable products

Integrates LED driver

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Product Demonstration

- Exhibit Hall:
  - LCD monitor with RGB LED backlight using Freescale control MCU and LED driver chipset

- Meet the expert session:
  (Tuesday 2PM and Wednesday 1:45PM)
  - Local Dimming backlight using Freescale LED driver chipset and FPGA controller
  - Monitor backlight using Freescale white LED backlight driver

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Summary

- Freescale highly focused on LED backlight market
- Leverage system expertise and Freescale advanced technology to provide differentiated, enabling products
- Custom products moving in to production today
- First standard products now sampling
- Advanced LCD-TV system will sample in Q4'08
- Future road map to cover all types of LED backlight requirements

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Questions?

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Related Session Resources

Session Location – Online Literature Library

http://www.freescale.com/webapp/sps/site/homepage.jsp?nodeId=052577903644CB

Sessions

Session ID	*Title*

Demos

Pedestal ID	*Demo Title*

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