TI Innovation Day France 2010

Solutions for Lighting Systems in

Automotive LED Exterior Lighting

Agenda

- Introduction
- Technical overview
- Analog solutions for driving LEDs
  - SMPS controllers
  - Linear regulators
- Digital solutions for driving LEDs
  - C2000 Microcontroller
  - Tools: Software Library, evaluation modules
- LED Headlight Demonstration board
- Summary

Automotive LED lighting

Applications

- Headlamp low-beam
- Headlamp high-beam
- Front turn signal
- Front parking light
- Fog lamps
- Daytime running lights

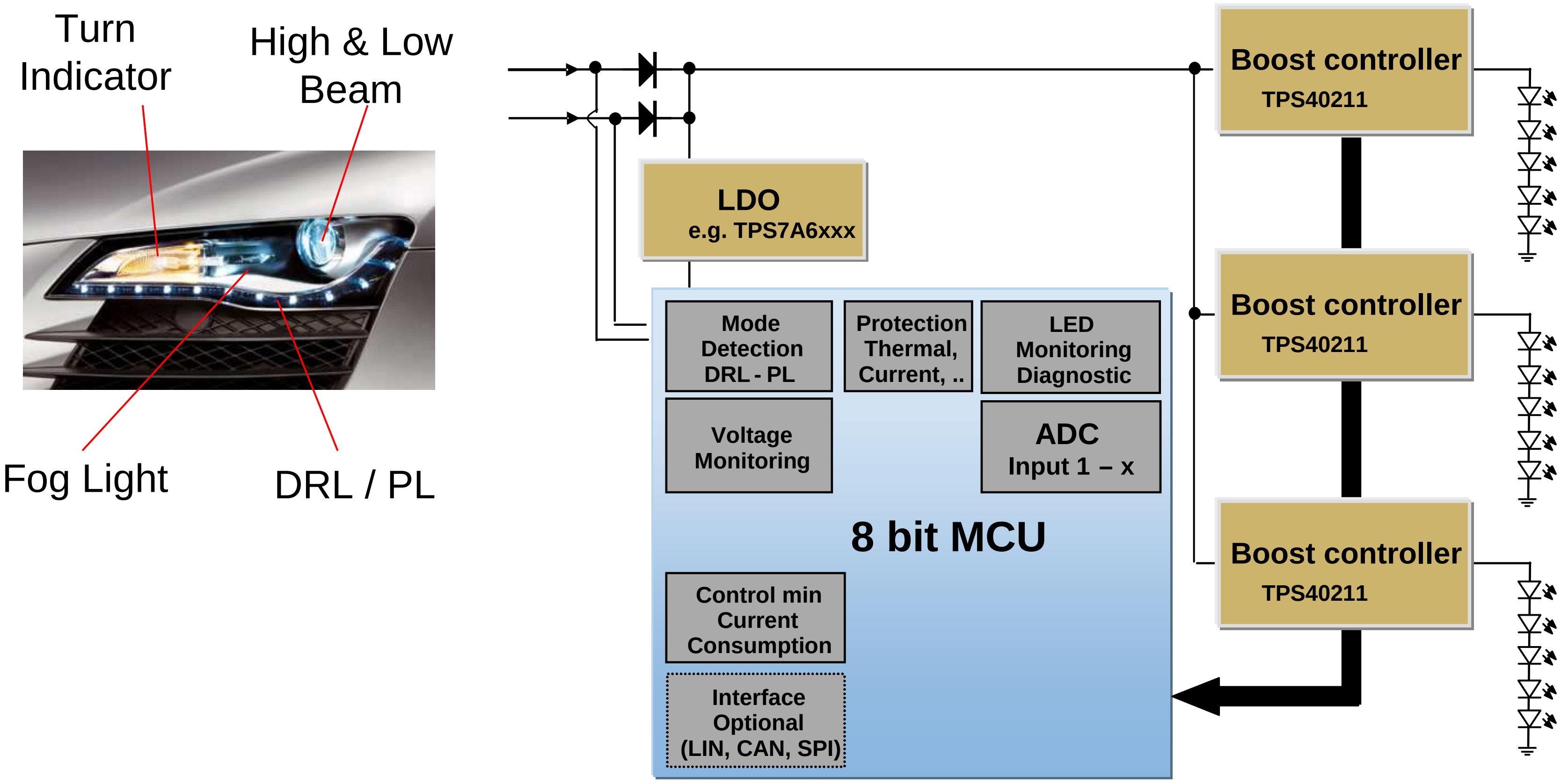
- Dashboard lighting
- Switch illumination
- Entry system
- Reading lamps
- Mood lighting
- Display backlighting

- Rear tail light
- Rear stop light
- Rear turn signal
- CMHSL
- Reverse indicator
- License plate light

Analog system solution

System with Analog control

Simplified Block Diagram



Multiple independent LED string, analog SMPS or Linear control per string

TPS40210/1-Q1

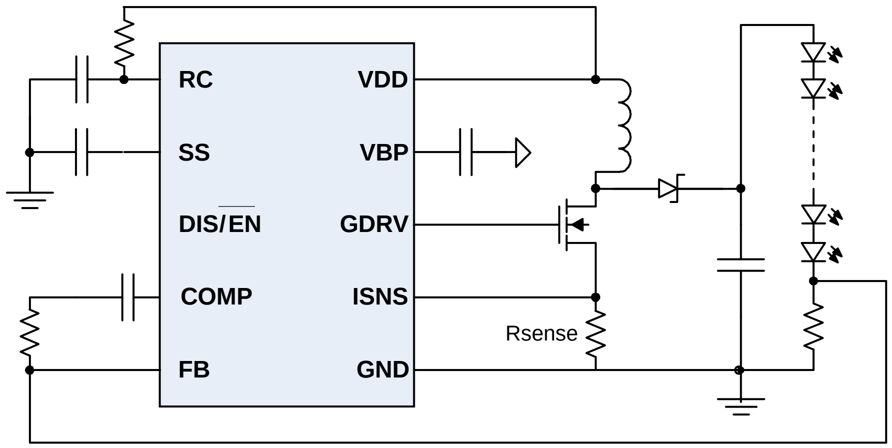
SMPS Boost-Controller

FEATURES

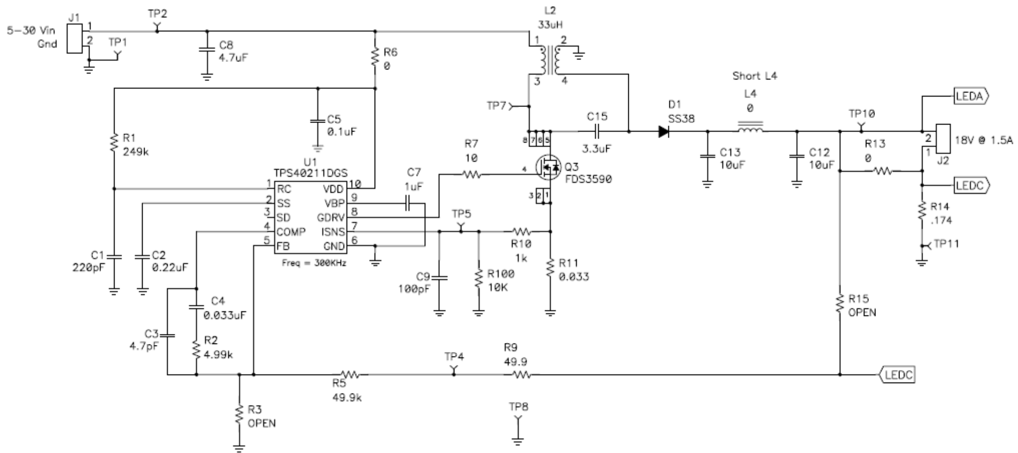
- Wide Input Voltage Range: 4.5V to 52V
- Current Mode Controller
- TPS40210: Internal Ref. Voltage: 700mV
  TPS40211: Internal Ref. Voltage: 260mV
- Internal Under Voltage Lockout
- Programmable Frequency 35kHz to 500kHz
- Frequency Synchronization
- Closed Loop Soft Start
- Over Current Protection
- Integrated NMOS-FET driver
- Small package size - 10 pin MSOP

BENEFITS

- Suitable for LED drive application
- Boost, Flyback and SEPIC topologies possible
- Lower voltage reference option as LED driver reduces power dissipation in shunt



Standard boost topology (Simplified)

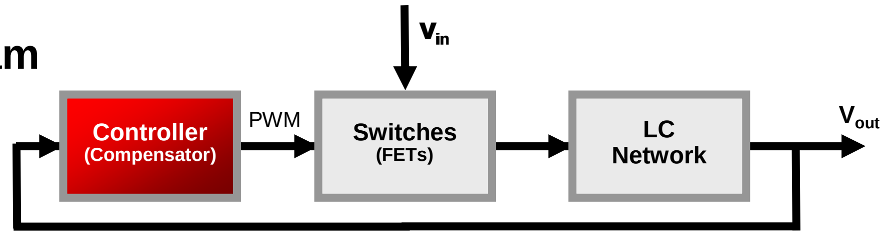


SEPIC topology (TI Reference design)

Digital system solution

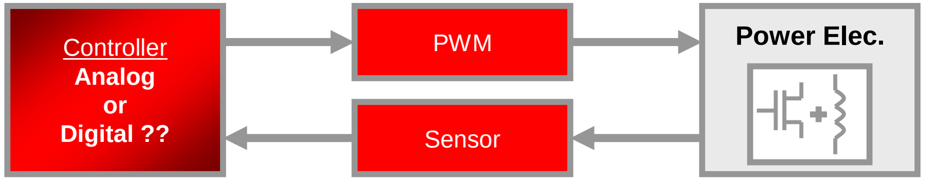
Digital LED control

Generic Power System Block Diagram



The controller block is what differentiates between a digital power system and a conventional analog power system

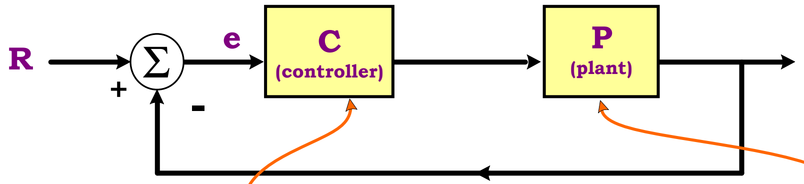
Why Digital Control Techniques?

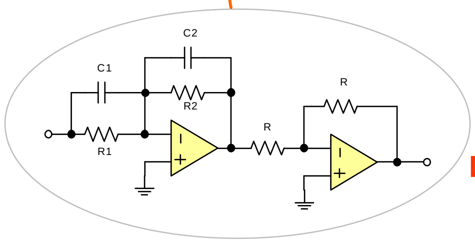


	Analog Controller	Digital Controller
+	• High bandwidth • High resolution • Easy to understand / use • Historically lower cost	• Insensitive to environment (temp, drift,…) • S/w programmable / flexible solution • Precise / predictable behavior • Advanced control possible (non-linear, multi-variable) • Can perform multiple loops and “other” functions
-	• Component drift and aging / unstable • Component tolerances • Hardwired / not flexible • Limited to classical control theory only • Large parts count for complex systems	• Bandwidth limitations (sampling loop) • PWM frequency and resolution limits • Numerical problems (quantization, rounding,…) • AD / DA boundary (resolution, speed, cost) • CPU performance limitations • Bias supplies, interface requirements

Analog vs. Digital

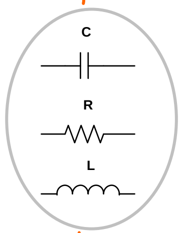
Analog Control System





$$C(s)=\frac{R_2}{R_1}\left(\frac{1+R_1C_1s}{1+R_2C_2s}\right)$$

Need to find: R_1, R_2, C_1, C_2



Energy Storage Elements

$$\frac{d^3y(t)}{dt^3}+k_2\frac{d^2y(t)}{dt^2}+k_1\frac{dy(t)}{dt}+k_0y(t)=f(t)$$

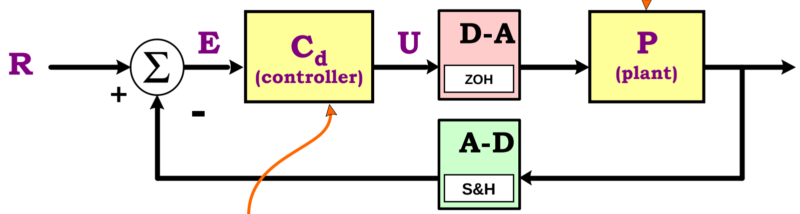
Differential equations
1st, 2nd, 3rd, … order

Laplace Transform

or

Z-Transform

Digital Control System



$$U(n)=a_2\cdot U(n-2)+a_1\cdot U(n-1)+$$
$$b_2\cdot E(n-2)+b_1\cdot E(n-1)+b_0\cdot E(n)$$
$$\textit{where}\ \ldots E(n)=R(n)-Y(n)$$

Need to find: a_1, a_2, b_0, b_1, b_2

Benefits of Digital control for LEDs

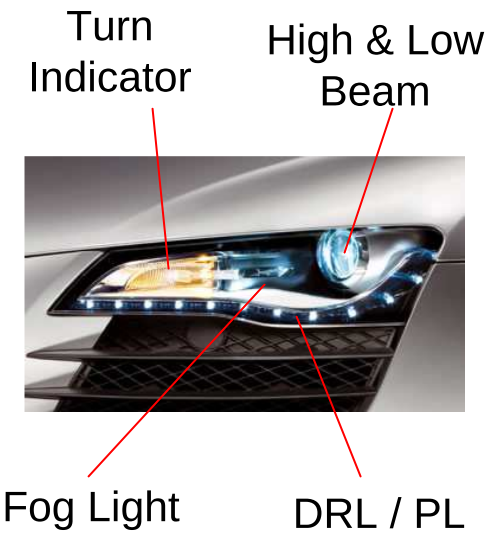
- **Flexibility and Integration**
  - Multiple Outputs/Phases with one controller, simple sequencing
  - Adaptive control with advanced algorithms
  - All parameters quickly and easily adjustable via Software

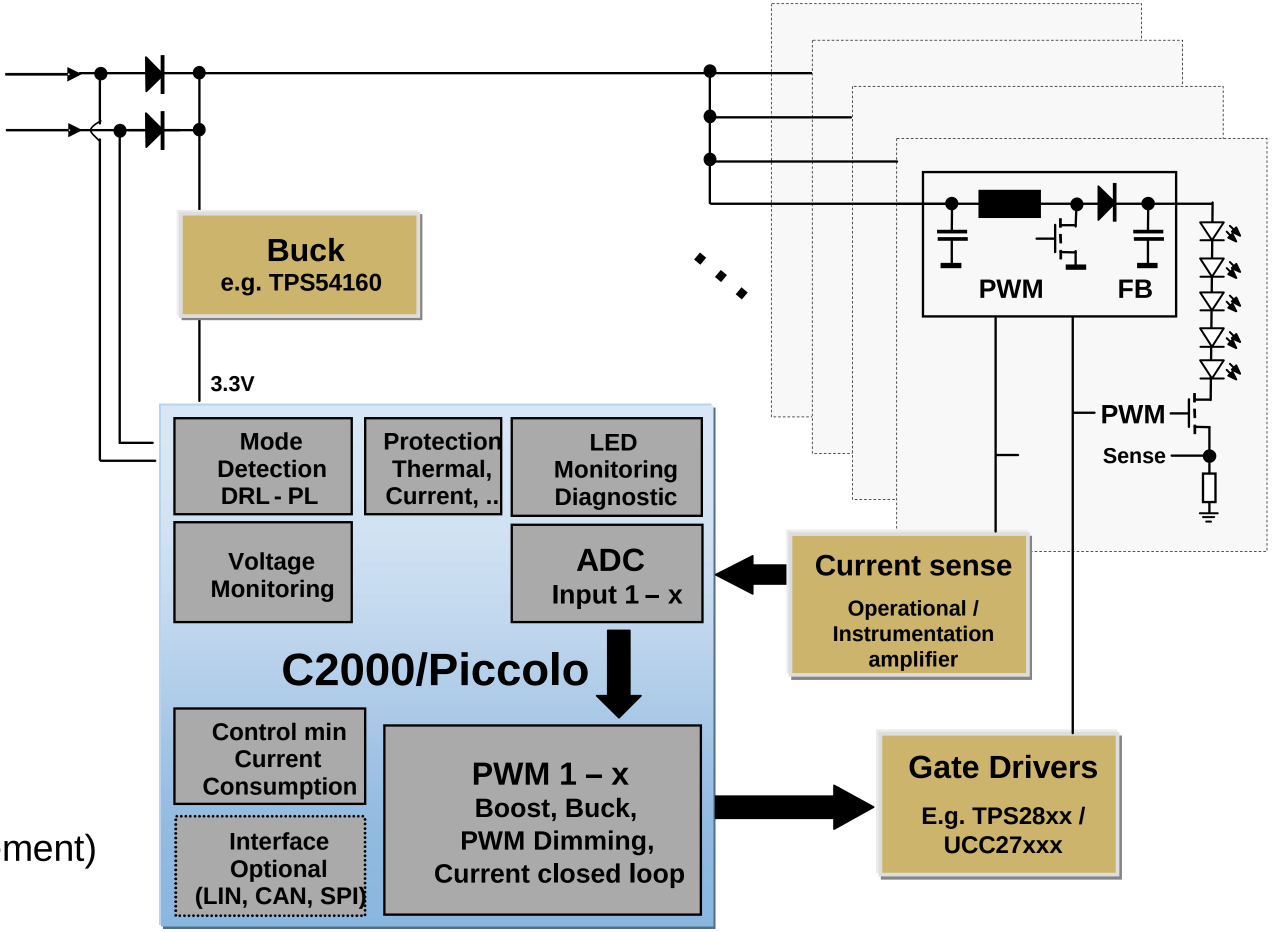
- **Reliability and Efficiency**
  - Intelligent Fault Management
  - Efficiency measurement of the power supply
  - Real-time diagnostic of the power consumption
  - Guaranteed performance over time with adaptive control
  - Failure anticipation

- **System Cost Reduction**
  - Fewer number of components thanks to integration
  - Software can be reused and modified for multiple projects or model variations

System with Digital control

Simplified Block Diagram





Additional functions

- Vertical adj. – range
- Horizontal adj. corner light
- Fan Control (thermal management)
- Networking

F2803x MCU Series
Piccolo B microcontroller

PERFORMANCE

- 60 MHz C28x 32-bit CPU
- Control Law Hardware Accelerator
- Full software compatibility with previous generations

FEATURES

Core
- C28x 32-bit CPU (single cycle 32-bit MAC)
- Control Law Accelerator

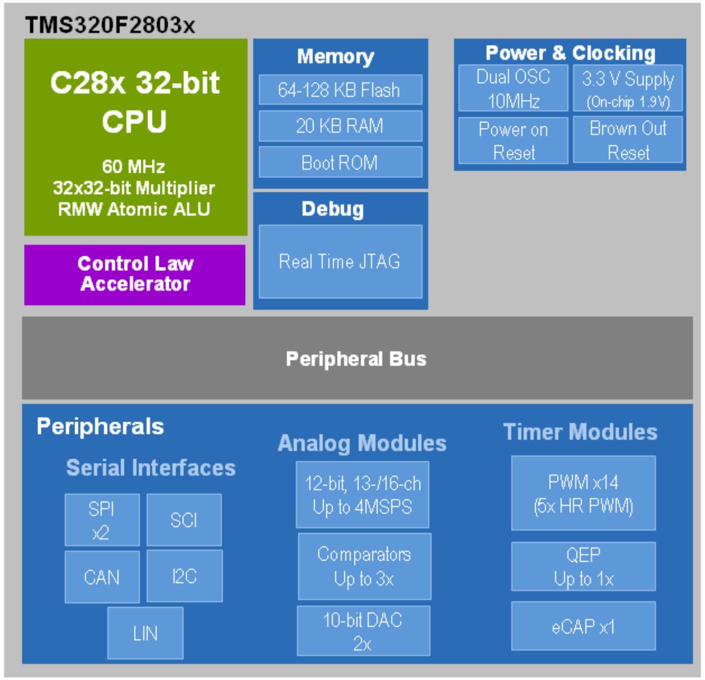
Memory
- Flash: 64-128 KB
- RAM: 20 KB

Peripherals
- Single 3.3V supply
- 2 High accuracy on-chip oscillators (10MHz)
- Best in class PWM and event capture capability
- 150ps resolution on PWM duty & frequency
- 12-bit ratio-metric ADC with individual channel triggers
- Three analog comparators with 10-bit reference
- CAN 2.0B up to 16 mailboxes
- Up to 44 General Purpose I/Os

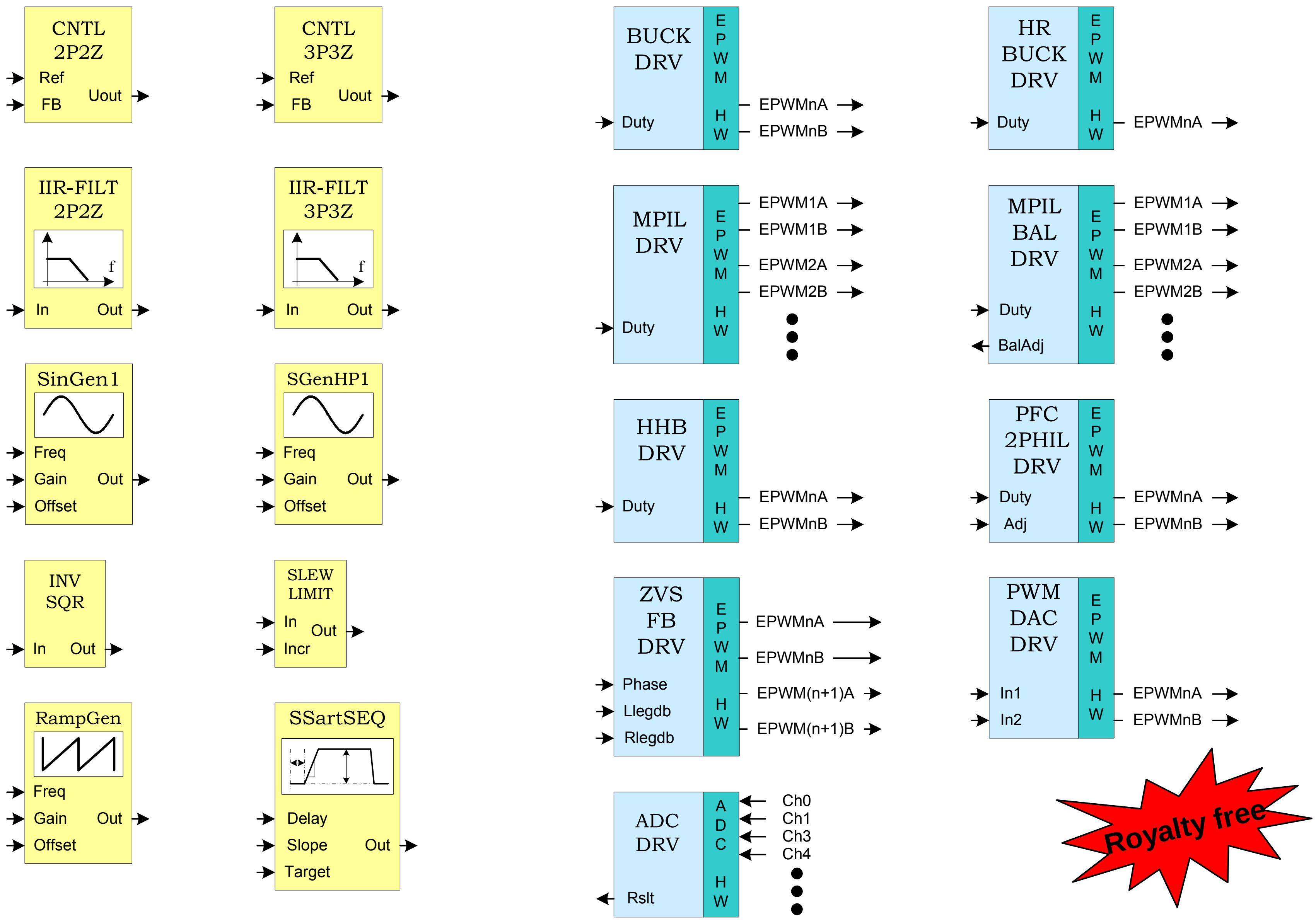
Packages: 64-pin TQFP, 80-pin LQFP

BENEFITS

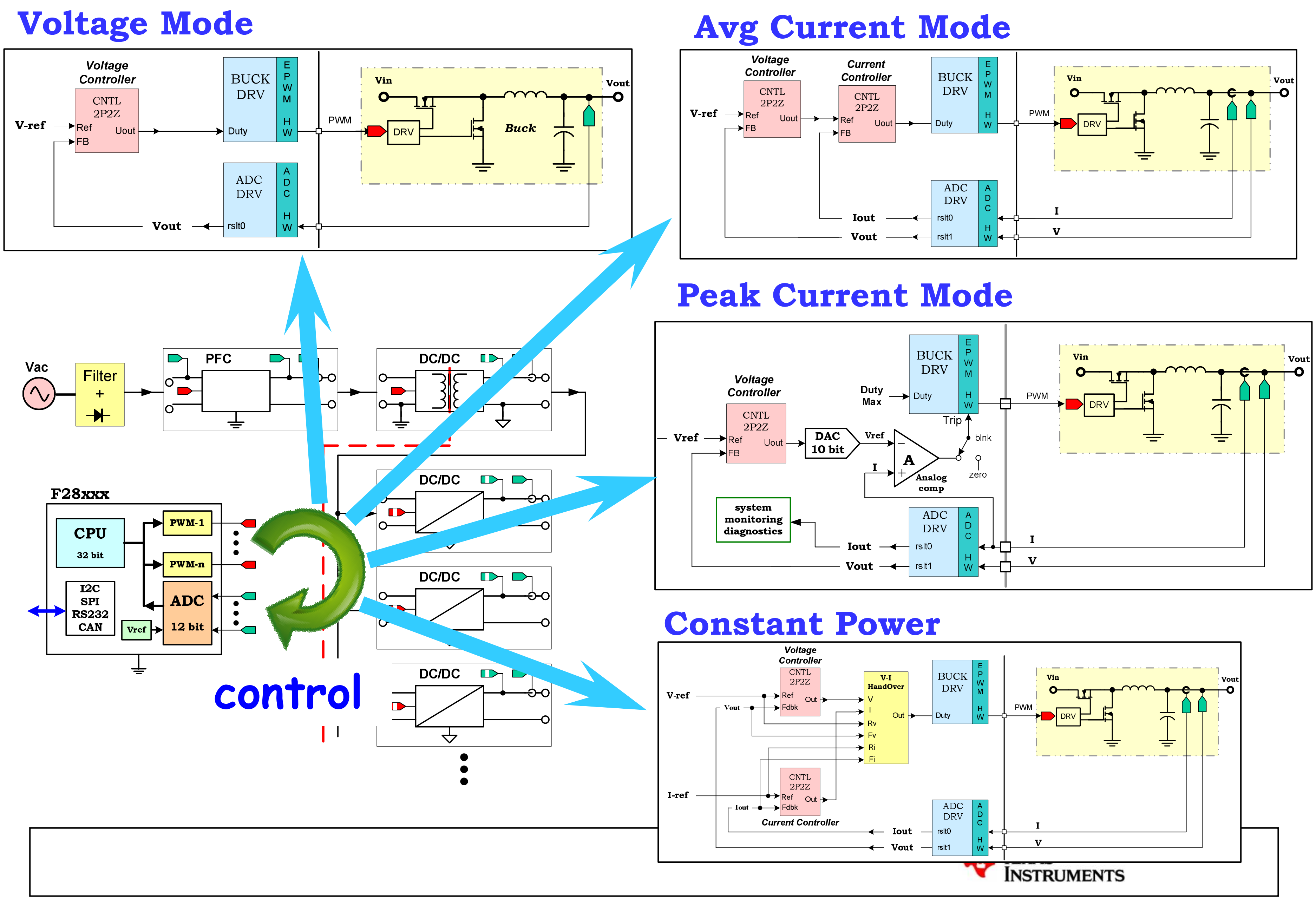
- Supports multiple independently controlled LED strings
- Monitoring and diagnostics through software
- Communication over in-vehicle CAN and/or LIN network
- Supports addition ECU functionality like motor drive for fans, cornering lights, etc.
- LED temperature monitoring and compensation



Software Library approach



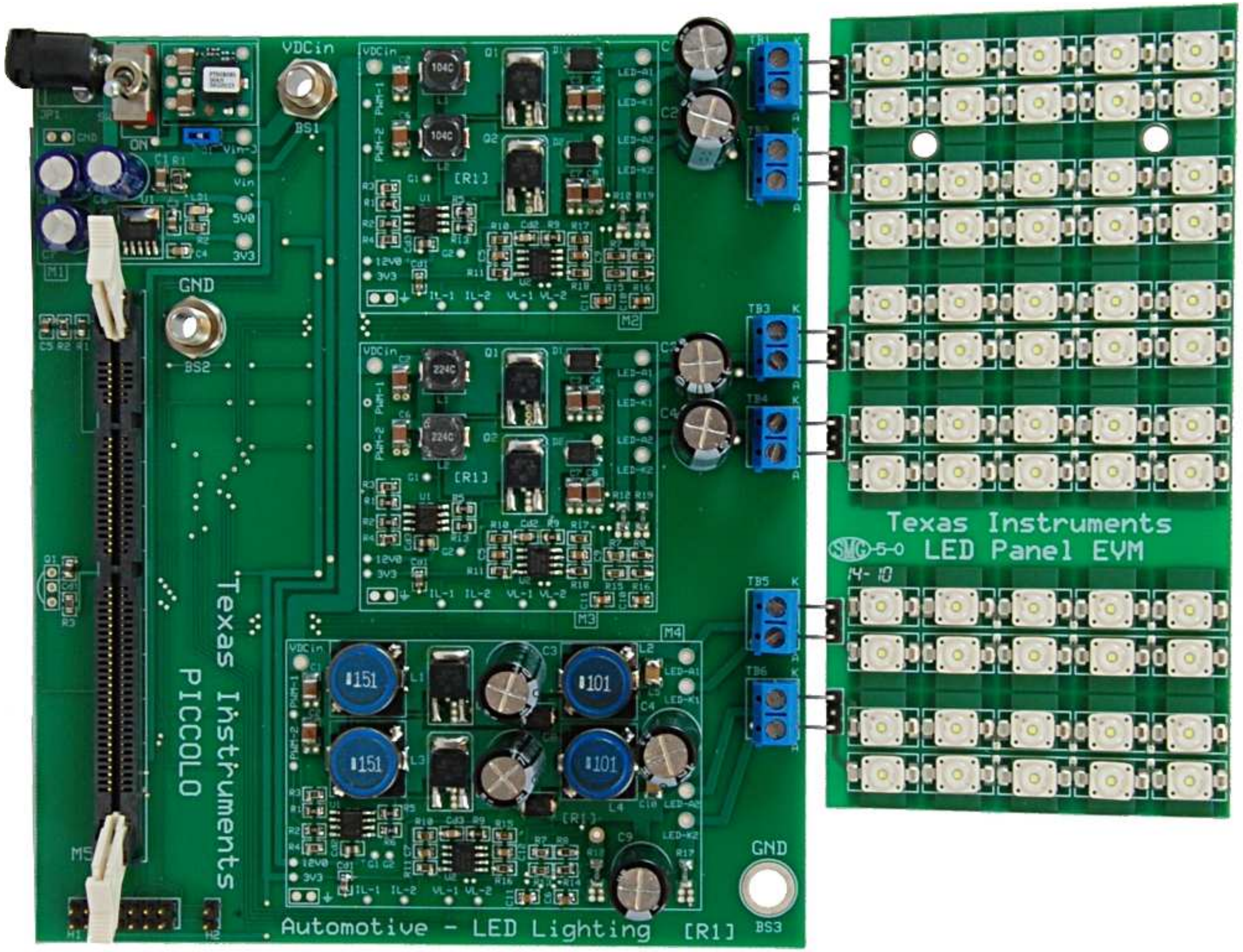
Power Stage – Loop Control with TI SW library



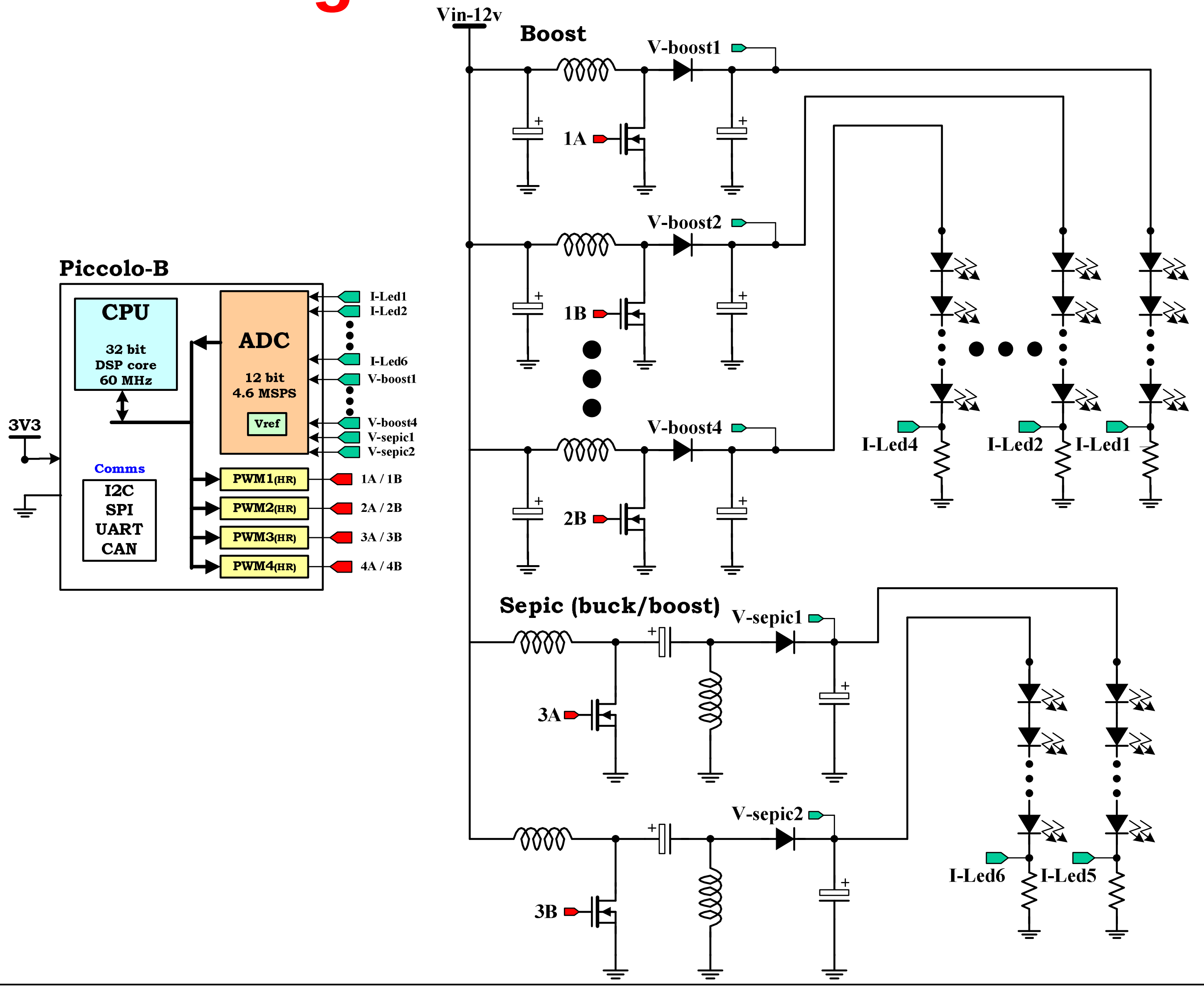
Automotive LED Lighting Demo

Specifications

- Input: 8-24 Vdc
- Output: 25-50 Vdc,
  0-1 A/string
- 4x Boost stages
  2x Sepic stages
- Current-mode control
  (average)
- Control Loop:
  100 kHz, 2P2Z / PID
  6x independent strings
- Switching Freq: 300 kHz



Circuit Diagram



Demo / Test GUI