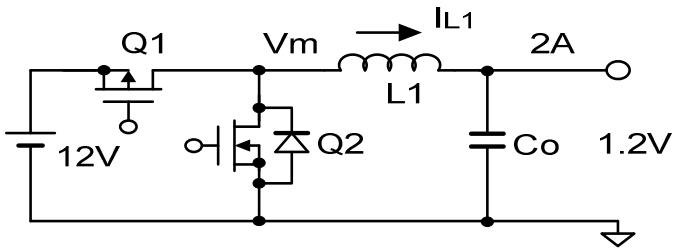
LED Lighting in Automotive Applications

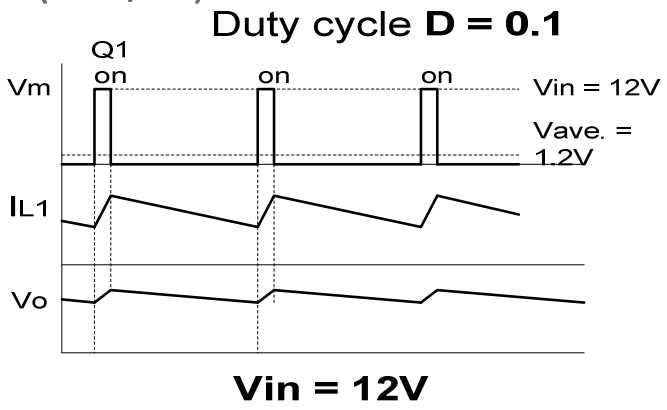
Agenda

1	DC/DC Converter Topologies
2	Power Constraints in Automotive
3	Solutions
4	LED Applications in Automotive

Switching Regulators

- Buck converter (step-down converter).
- Boost converter (step-up converter).
- SEPIC/Buck-boost (Step-up/down converter)
- High efficiency compared to linear, especially if Vin >> Vout.
- Buck converter chops a dc input to a square-wave voltage, and the LC filter averages the square-wave voltage into a DC output.
- Vo = Vin * D where D is the duty cycle (Ton/Ts).





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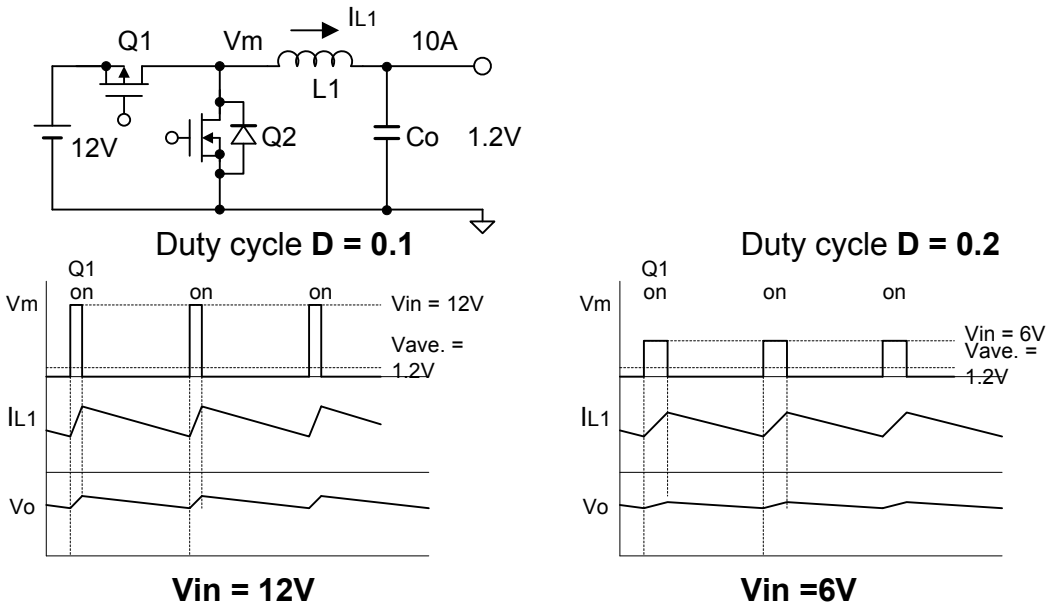
Switching Regulator Operation

- Adjusts the duty cycle to keep Vo constant.
- PWM (Pulse-Width Modulation) normally means constant frequency
- Switching frequency is typical 100kHz to 2200kHz.
- Higher Fsw reduces inductor and capacitor size. But efficiency may decrease.



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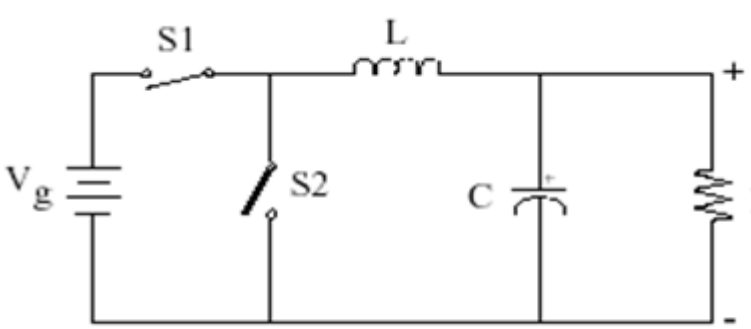
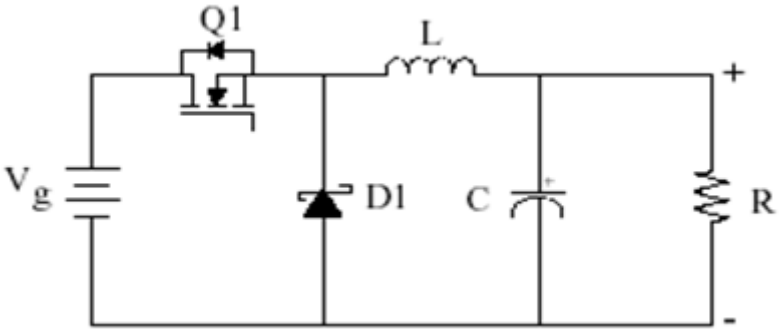
Buck Regulator Overview

- Pulsating input current
  - > Requires large input filter capacitor
- Smooth output current
  - > Small output filter capacitor
- Input current lower than the output current
- Synchronous Rectification vs. Non-Synch Rectification



Synchronous Rectification



Non-Synch Rectification

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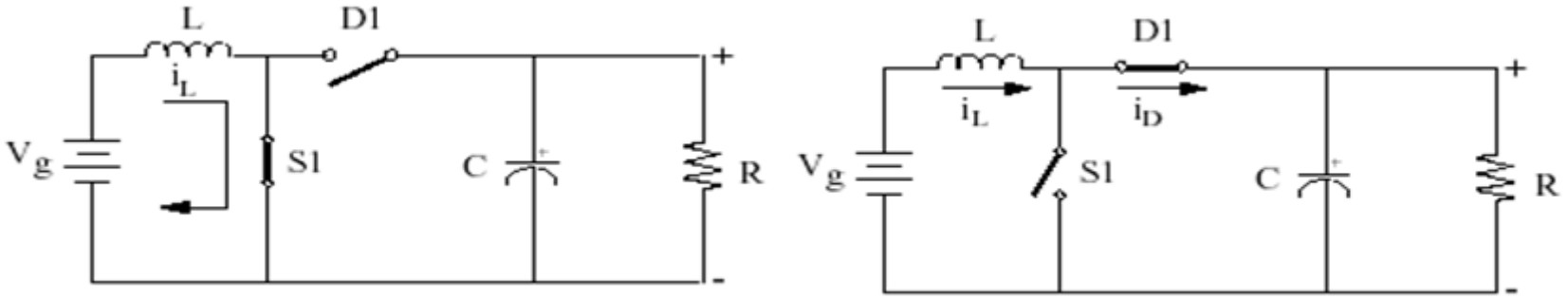
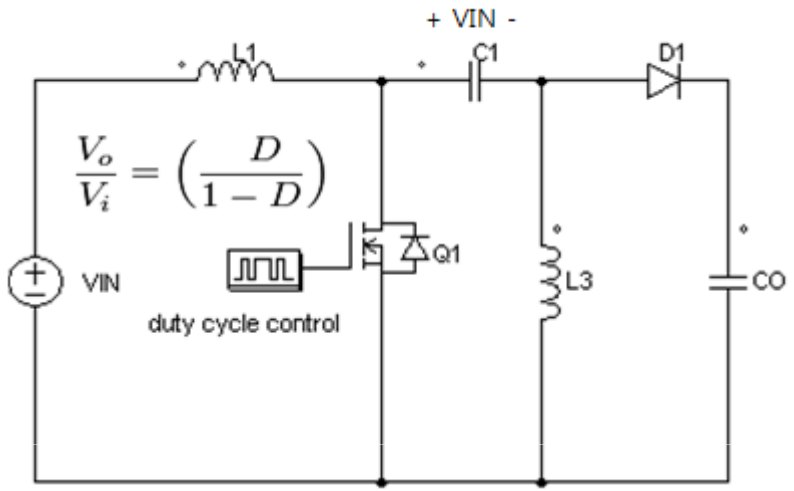
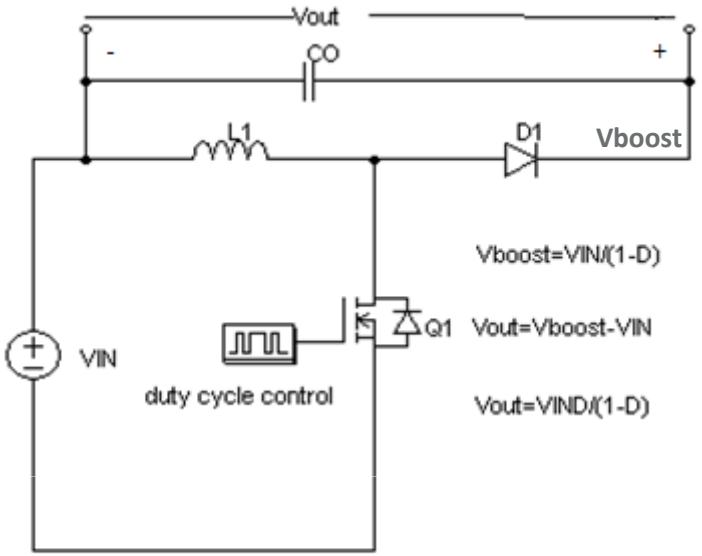
Boost Regulator Overview

- Smooth input current
  - > The inductor filters input current spikes
- Pulsating output current
  - > Bigger output filter capacitor for given ripple requirement
- Input current is greater than the output current
  - > Diode/Inductor/S1 must handle large peak currents



SEPIC & Buck-boost Regulator





- ADVANTAGES of SEPIC
  - > Continuous input current unlike buck-boost
  - > Better EMI
  - > Output is + and is referred to ground
- DISADVANTAGES of SEPIC
  - > More components and so more expensive
  - > Lower efficiency than Buck-Boost

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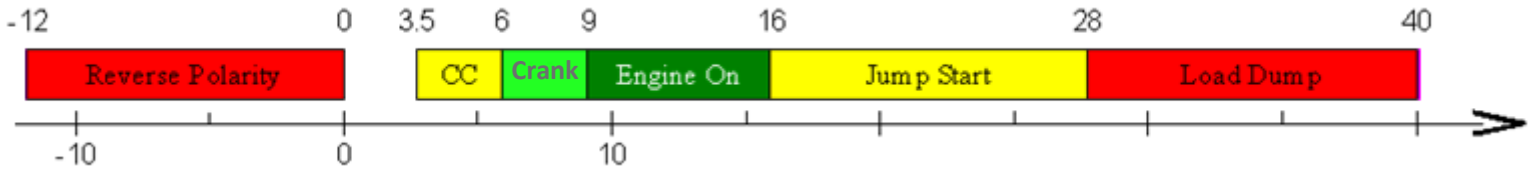
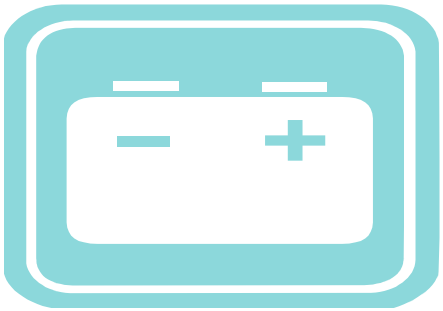
Input Power Quality Overview

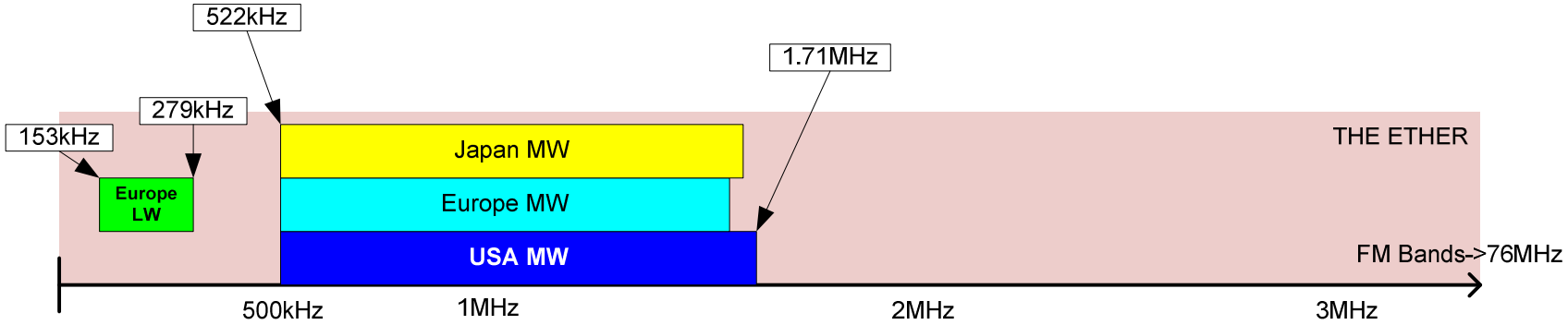


- Operate from 9V to 16V generally (sometimes to as low as 3V)
- Survive reverse battery & Survive 28V battery
- Survive Clamped load dump (42V)



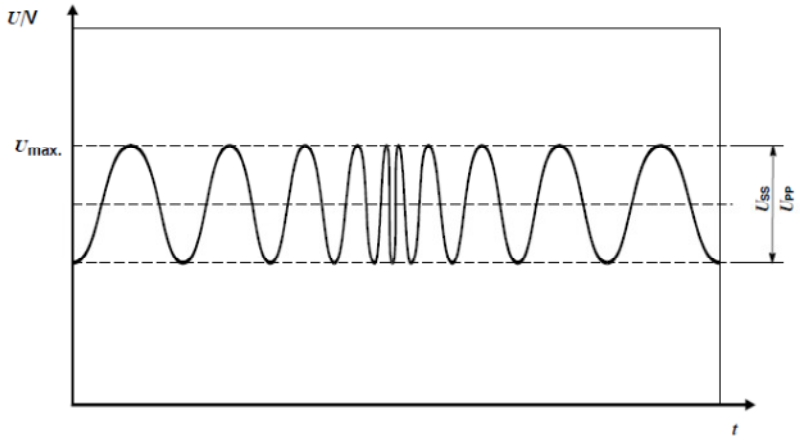
EMC #1: Don’t Disturb

- Avoid certain frequency ranges that might interfere with radio reception



EMC #2: Don’t be disturbed

- Superimposed AC on battery, 1Vpk-pk from 50Hz to 20kHz



- Bulk current injection 50mA/100mA/200mA, 1MHz to 400MHz
- RF Injection, 1MHz to 1000MHz

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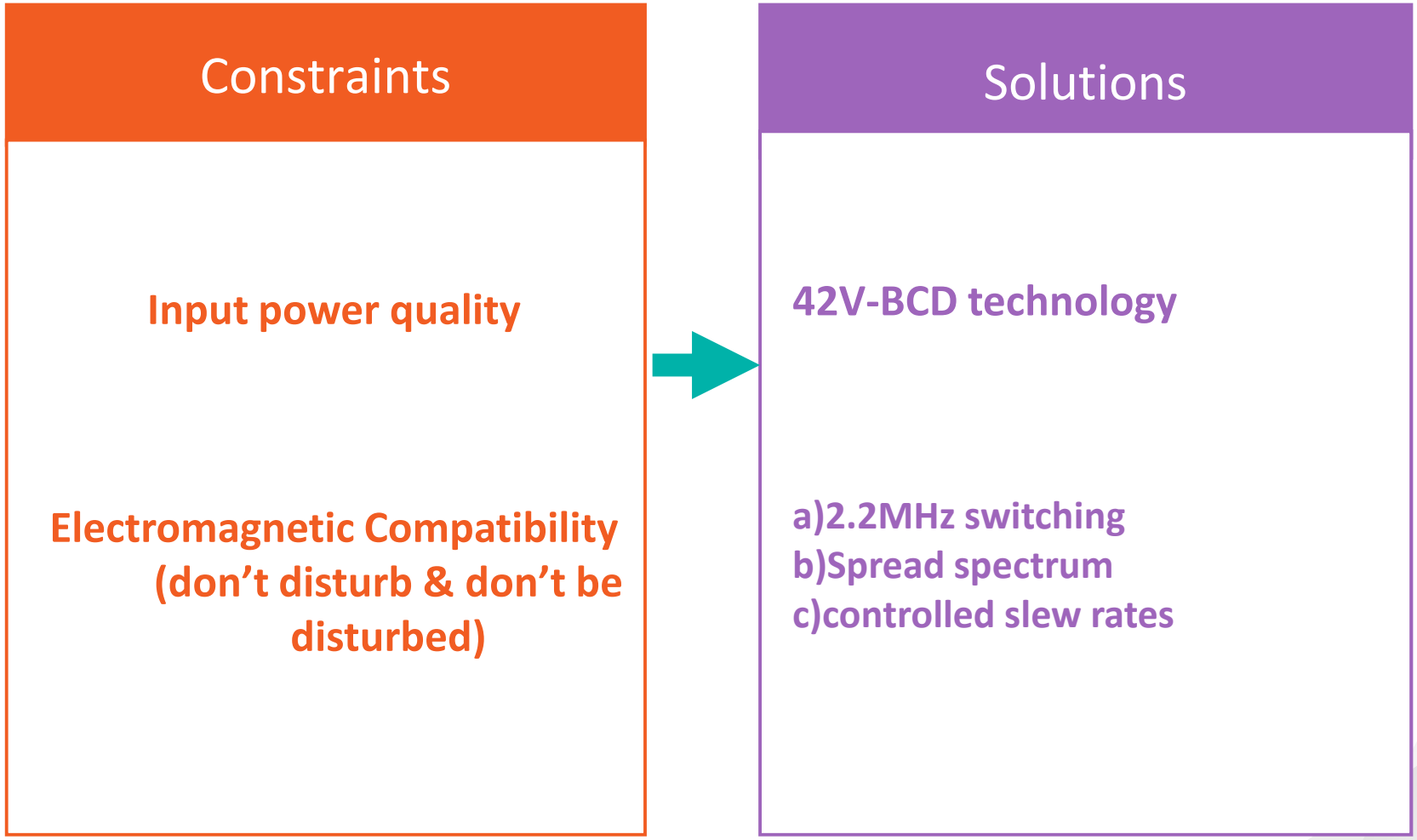
Maxim Technologies to Overcome the Constraints



a. High Frequency Switching

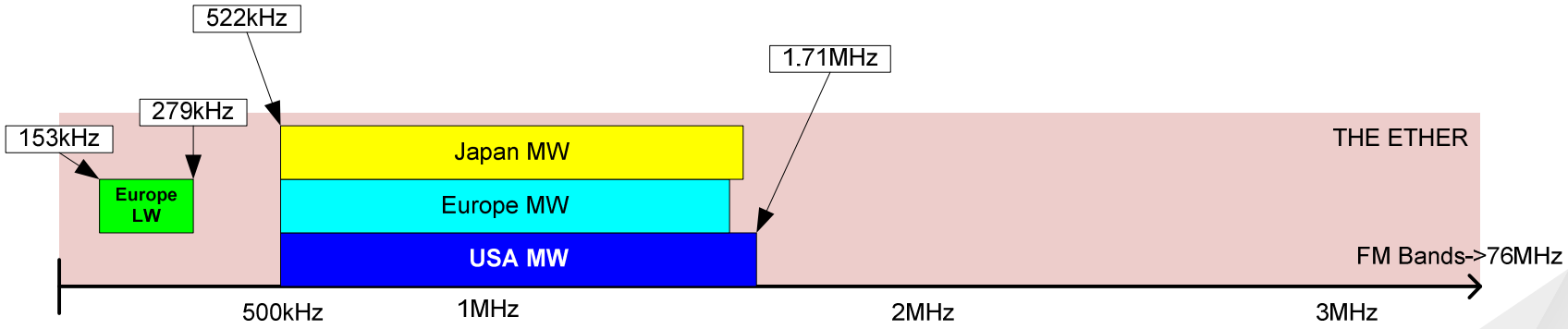
PWM switching frequency above the AM band provides many benefits:

Advantages:

- No AM band EMI Issues
- Much Smaller Passive Components

Disadvantages:

- Potential FM & VHF EMI Issues
- Slightly Lower Efficiency due to Switching Losses



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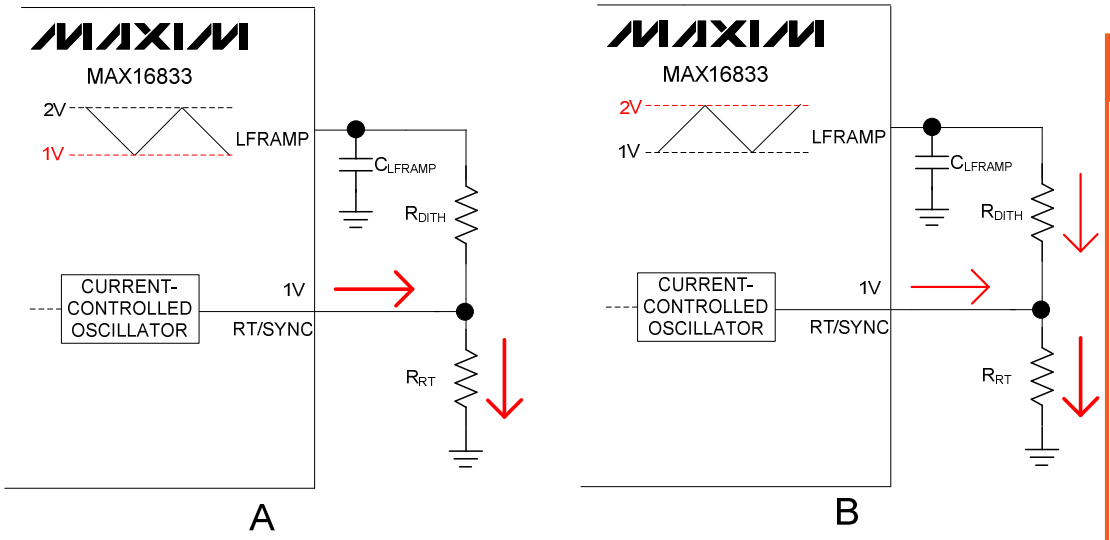
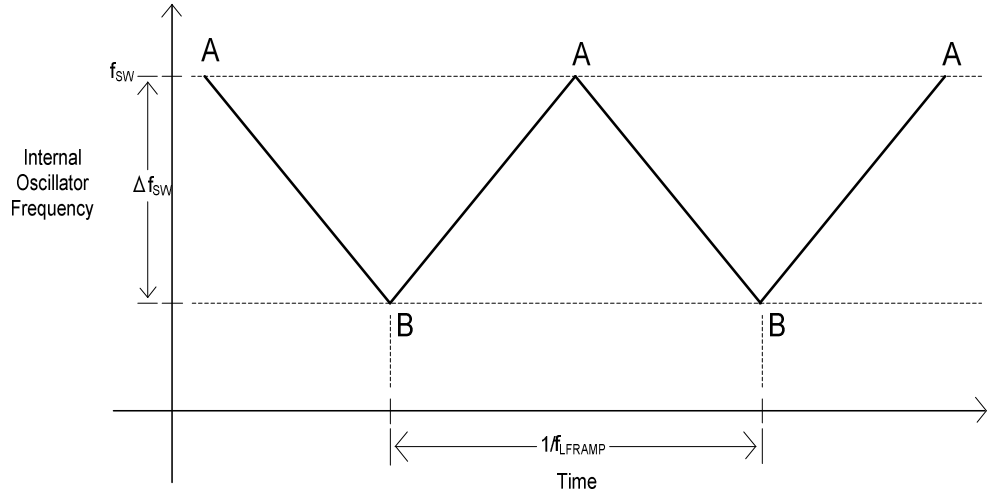
b. EMI Optimization – Flexible Spread Spectrum Implementation



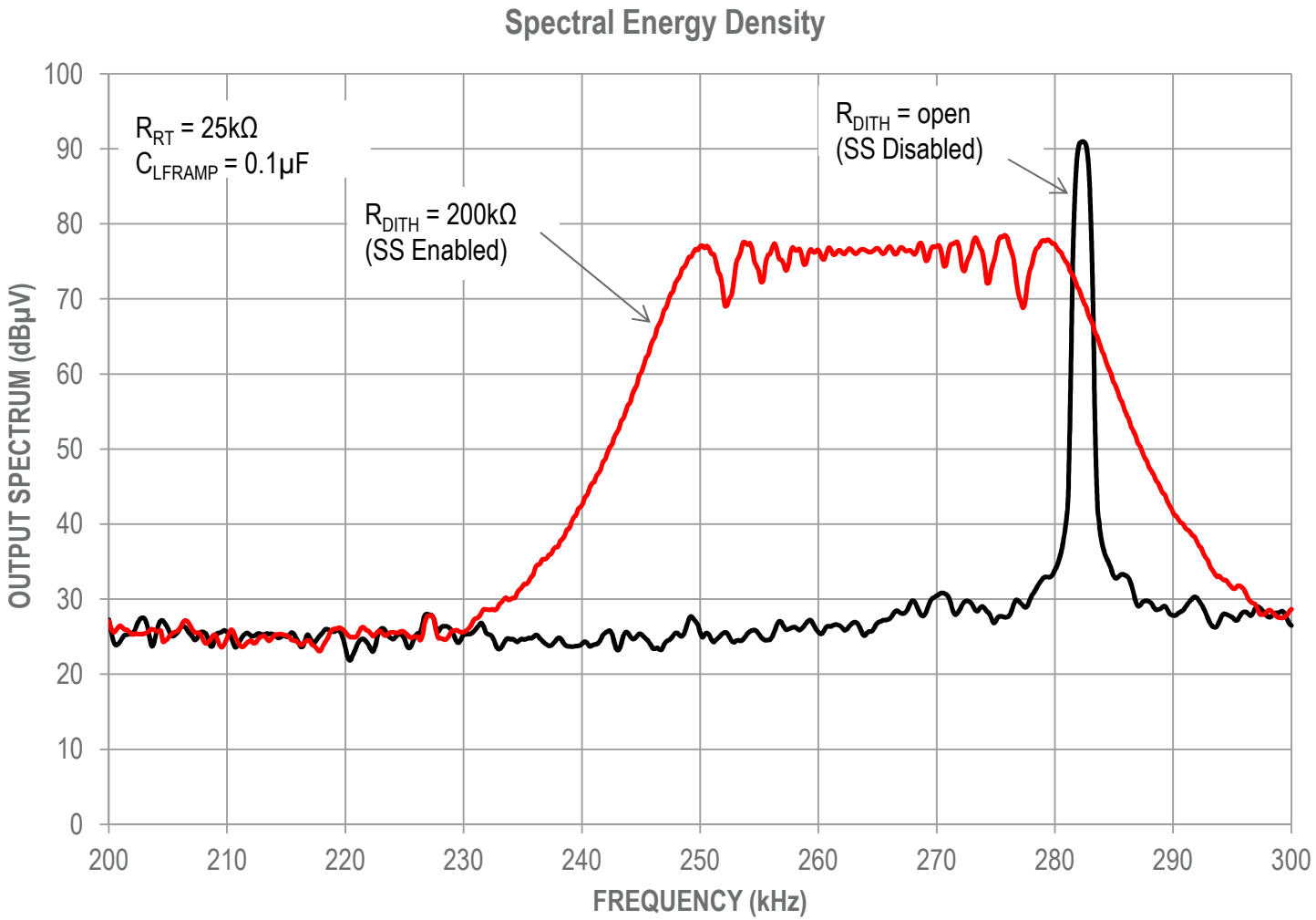


- LFRAMP generates a triangle wave between 1V and 2V.
- The frequency of the triangle wave depends on C_{LFRAMP}.

$$f_{LFRAMP}(Hz) = \frac{50\mu A}{C_{LFRAMP}(F)}$$

- A resistor from RT/SYNC to SGND sets the frequency of the internal oscillator (current-controlled).
- By connecting a resistor between LFRAMP and RT/SYNC, we can change the current being sourced by RT/SYNC and thus the frequency of the internal oscillator.
- **Some devices are available in spread-spectrum and non-spread-spectrum versions**

b. Effect of Spread-Spectrum in Frequency Domain



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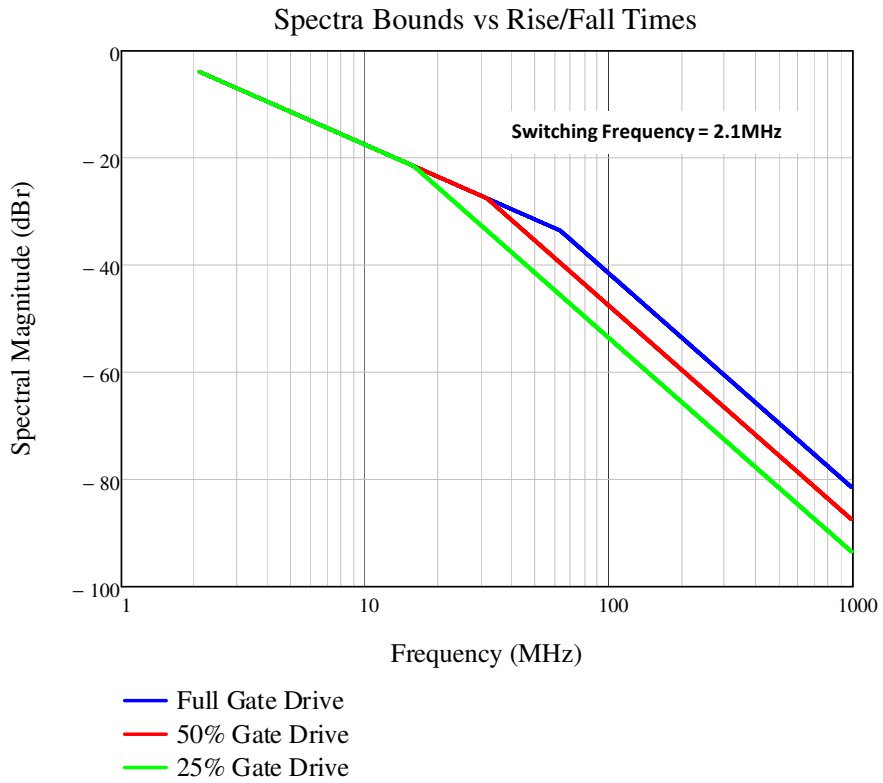
c. EMI Optimization – Gate Drive Strength

- EMI reduction by reducing the rise/fall time of LX is a trade-off between EMI and Efficiency.
- Devices that allow the customer to control the gate drive either by external gate resistors or other method allows the customer to quickly make these trade-offs while running the OEM



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Front lighting

LED configurations and Current Guidelines

- High beam lights 6 to 12 Leds in series with a maximum of 50V. LED currents from 700ma to 1.5A
- Low beam lights 6 to 12 Leds in series with a maximum of 50V. LED currents from 350ma to 1A
- Day time running light 2 to 12LEds in series with a maximum of 50V. LED currents from 350ma to 1A
- Fog light 1 to 6 leds in series.

Topologies (V_{FWD} for white LEDs is $\leq$4V)

- DRLs with <3 LEDs can often use a **buck** converter
- **Boost** is used for output voltages exceeding the load dump voltage (ca. 40V)
- If LED string voltage is less than 40V then most applications use **buck-boost**
- If the number of LEDs in series is greater than 3 and less than 12 then use **buck-boost** or **SEPIC**
- **SEPIC** is used when cathode of LED string must connect to ground.

High-Voltage HB LED Drivers with Integrated High-Side Current Sense: Front Lighting

MAX16833

Benefits

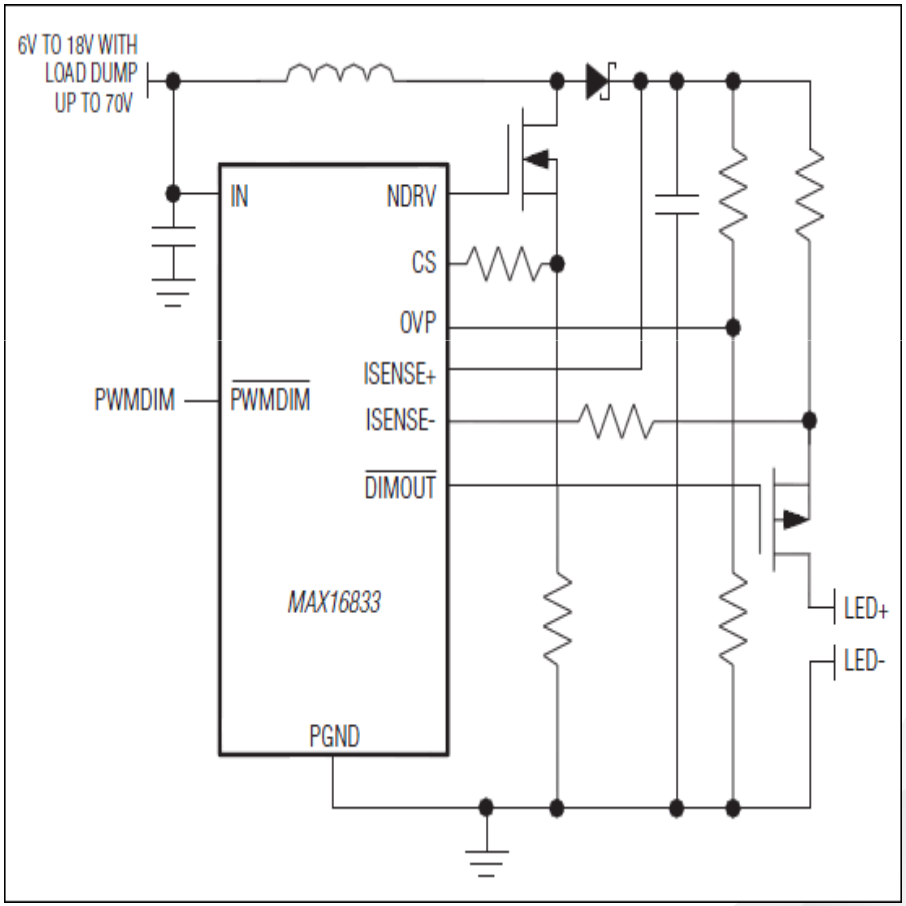
- Reduced Cost Due to Elimination of need for External Protection/Suppression
- Simpler solution Due to Load Dump Handling and Excellent EMI performance

Features

- Optional LFRAMP Output Reduces EMI
- Dimming with P-channel MOSFET driver
- 65V Input and Output Capability
- Output Short, Output OVP, Open and Shorted LED, Over Temperature Protections
- Fault Indicator Output
- Same board can be used for boost and buck-boost
- SEPIC, Boost, Buck-boost, High Side Buck

Applications

- Automotive Exterior Lighting
- DRL/Fog Lamps/Turn Indicators/RCL



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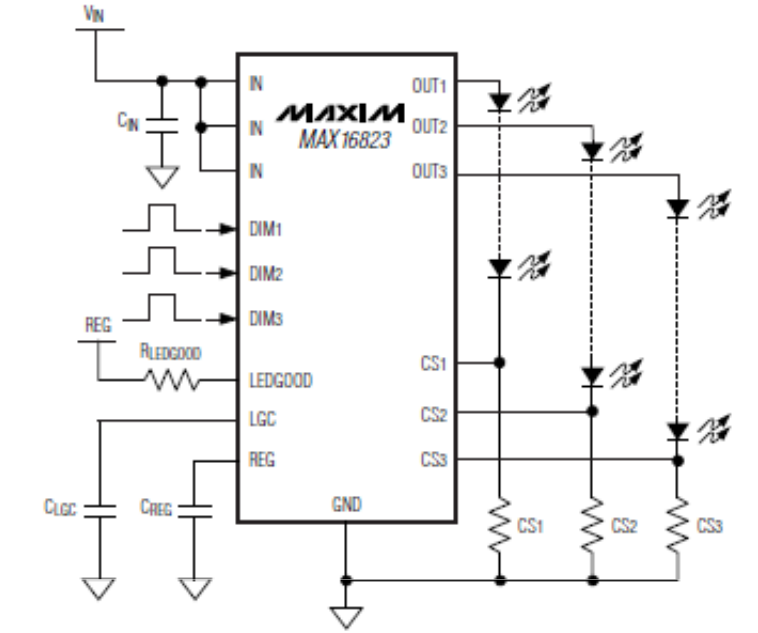
Tail lights

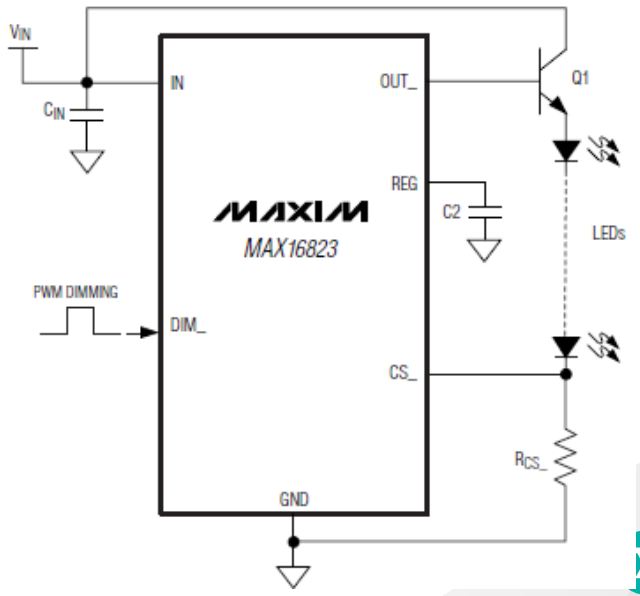
Requirements

- Multiple Linear LED drivers are required for all the lights in the rear
- Separate dimming input per channel
- Brake light and tail light use the same leds with different dimming intensities. Brake lights use 100% dimming and tail lights use 10% dimming at 100/200Hz
- When LED currents exceed 100ma then external bi-polar is used to handle power dissipation
- Turn light uses 1hz dimming at 50% duty cycle
- Thermal shutdown is required
- Switchers are used for currents exceeding 350ma

Parts for tail lights

- MAX16839, MAX16823, MAX16836 and other linears
- MAX16833, MAX16832 and MAX16834 for switchers





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Center Stack Displays

Topologies

- Most small size displays use 1 to 2 strings. Number of Leds per string varies from 5-10 leds
- Larger size displays use 3 to 4 strings. LEDs per string from 7 to 12
- Use boost for number of Leds per string higher than 7
- Use SEPIC for Leds less than 7

Features needed for displays

- Dimming ratio greater than 1000:1
- LED currents vary from 40ma to 150ma per string
- Dimming frequencies from 200 to 500Hz
- Most applications have same LED current in all channels
- Open LED and multiple LED short detection, protection and fault flag
- Typical load dump is 28V. No fault flag during load dump
- No flicker during cold crank allowed
- No flicker at start up allowed
- Sustain 24V input for one minute

Heads Up Displays

Topologies

- Most small size displays use 1 to 2 strings. Number of Leds per string varies from 5-10 leds
- Larger size displays use 3 to 4 strings. LEDs per string from 7 to 12
- Use boost for number of Leds per string higher than 7
- Use SEPIC for Leds less than 7

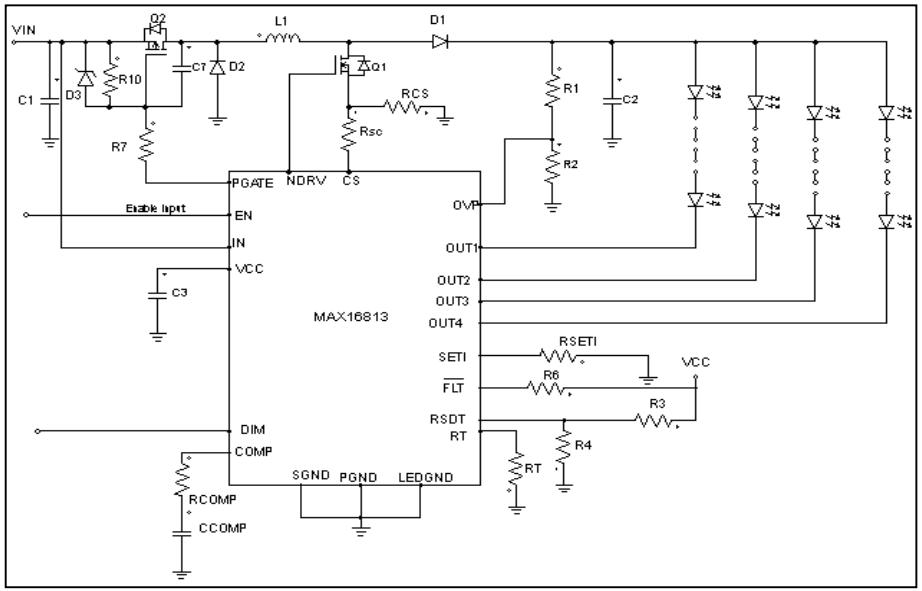
Features needed for HUDs

- Dimming ratio greater than **5000:1**
- LED currents vary from 40ma to 150ma per string
- Dimming frequencies from 200 to 500Hz
- Most applications have same LED current in all channels
- **Some applications required separate analog dimming for better contrast ratios**
- Open LED and multiple LED short detection, protection and fault flag
- Typical load dump is 28V. No fault flag during load dump
- No flicker during cold crank allowed
- No flicker at start up allowed
- Sustain 24V input for one minute

Displays

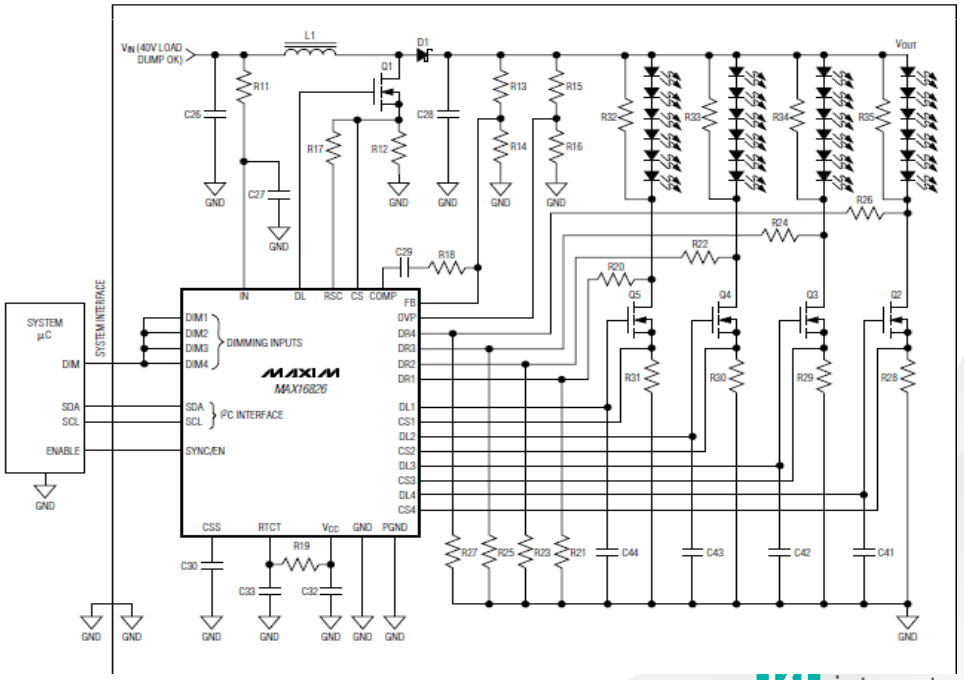
IC's for displays

- MAX16814, MAX16813 both for quad channels
- MAX16838 for dual channels
- MAX16834 for single channel
- MAX16826 for quad channels with I2C control



Features of different ICs

- MAX16814 for 2 to 4 channels with external switching mosfet but integrated current sinks
- MAX16813 for 2 to 4 channels with added output capacitor short protection and internal spread spectrum
- MAX16838 has 2 channels and integrated mosfets
- MAX16834 for single channel with external mosfets
- MAX16826 has 4 separate individual current sinks that can be separately controlled by I2C. Best performance IC for HUD's and other high performance displays



High Efficiency 4-Channel LED Driver with High Voltage DC-DC Controller

MAX16814

Benefits

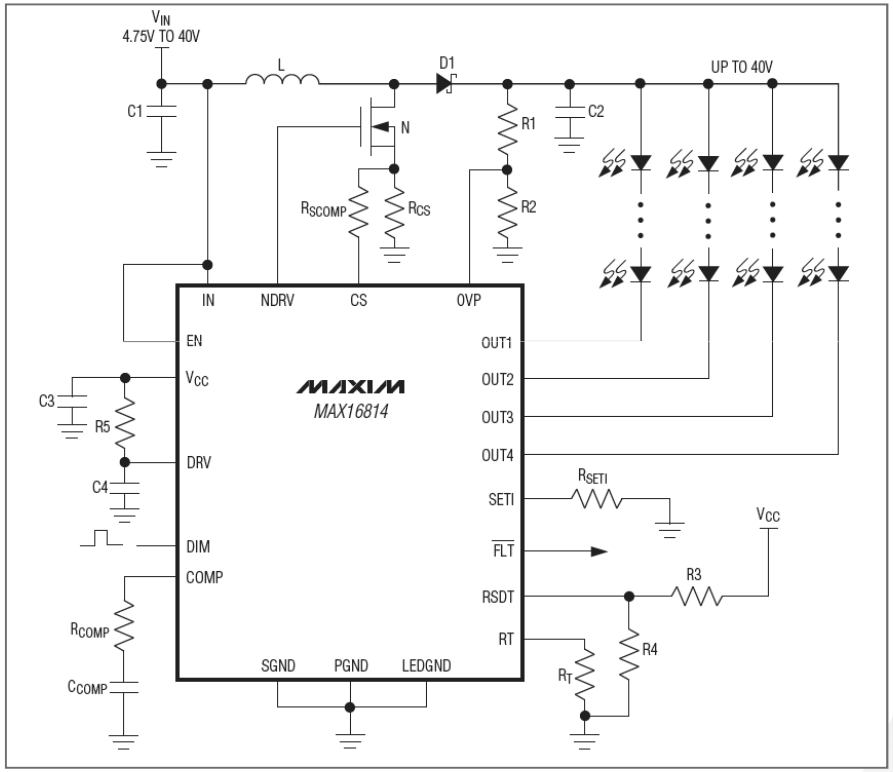
- Adaptive Output Voltage Control Optimizes System Efficiency
- 5000:1 PWM Dimming with Support for 1uS Pulse Widths Provides Wide Dynamic Range

Features

- V_{IN} = 4.75V to 40V(abs max= 45V)
- Programmable Switching Frequency (200kHz to 2Mhz), programmable or externally synchronized.
- Output OVP, Open and Shorted LED, Over Temp Protection with Fault Indicator Output
- Flexible Application: Boost, SEPIC, Boost-Buck

Applications

- Automotive Displays, LED Backlights
- DRL/Fog Lamps/Turn Indicators/RCL



Status: Production

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Integrated, 2-Channel, High-Brightness LED Driver with High-Voltage Boost and SEPIC Controller

MAX16838

Benefits

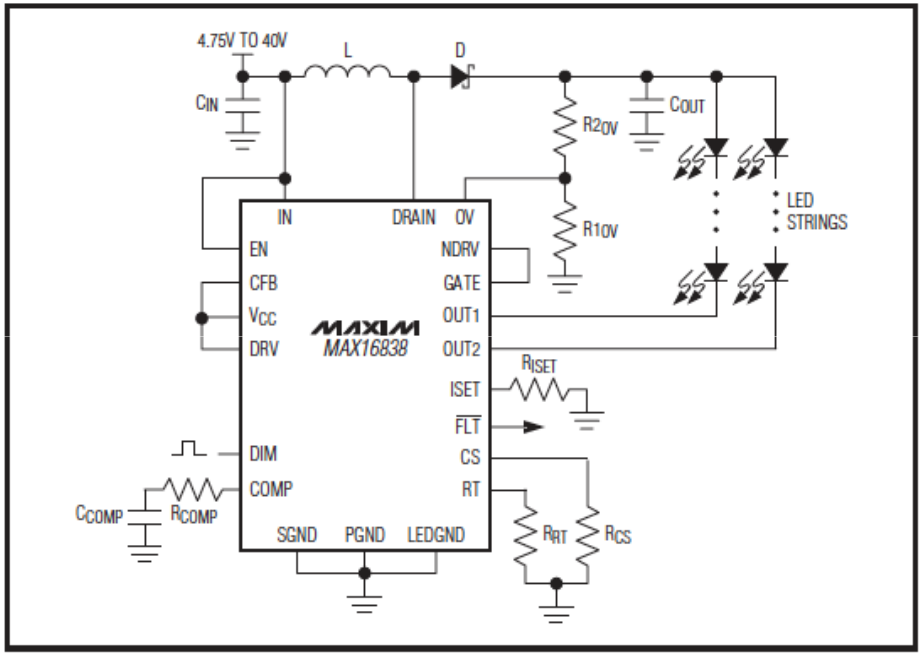
- Integrated switch FET reduces solution size and cost
- Support for two strings (up to 150mA ea.) well suited for small-to-medium LCD displays

Features

- V_{IN} = 4.75V to 40V(abs max= 45V)
- Programmable Switching Frequency (200kHz to 2Mhz), programmable or externally synchronized.
- Output OVP, Open and Shorted LED, Over Temp Protection with Fault Indicator Output
- Flexible Application: Boost, SEPIC, Boost-Buck

Applications

- Automotive Displays, LED Backlights



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Programmable, 4-Channel LED Driver with output voltage optimization and fault detection

MAX16826

Benefits

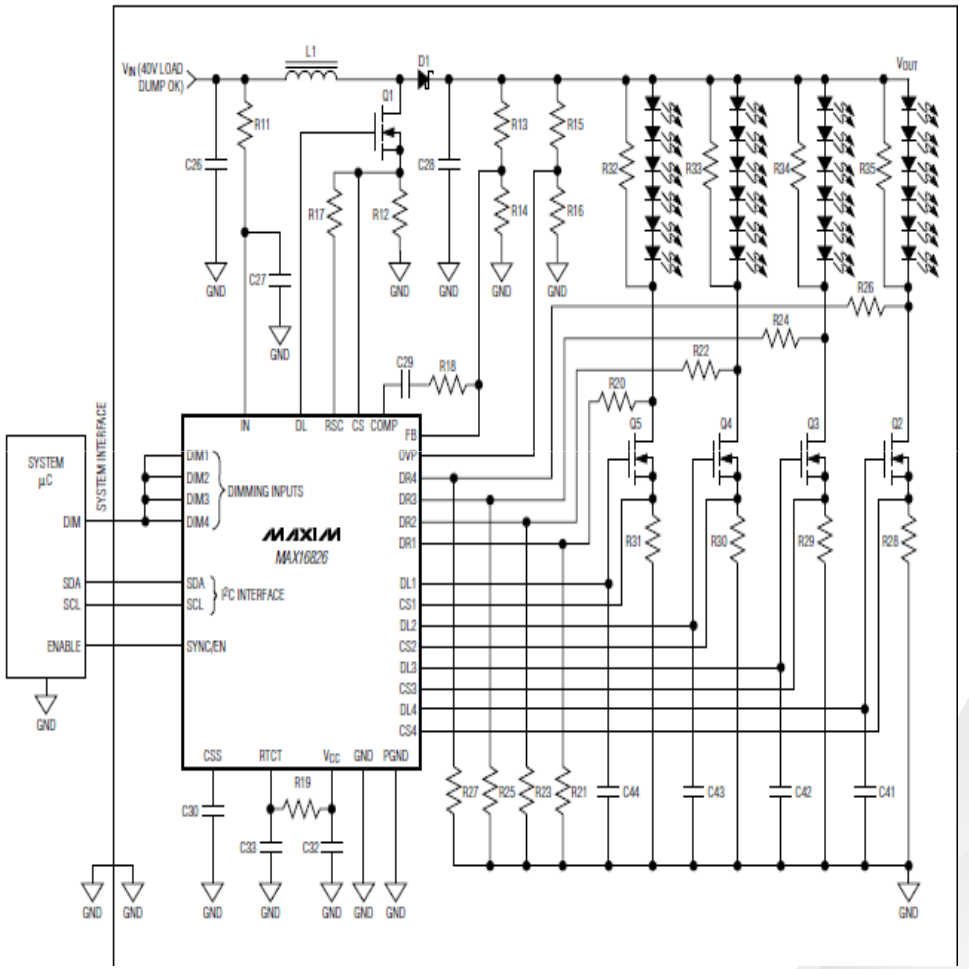
- Separate individual LED current by I2C
- Separate dimming control with dedicated control pins

Features

- V_{IN} = 4.75V to 24V(abs max = 30V)
- Programmable Switching Frequency (100kHz to 1Mhz)
- Output OVP, Open and Shorted LED, Over Temp Protection with Fault Indicator Output
- Flexible Application: Boost, SEPIC

Applications

- Automotive Displays, LCD TV LED Backlights
- DRL/Fog Lamps/Turn Indicators/RCL



Status: Production

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Other Material

- MAXIM Automotive Product

  http://www.maximintegrated.com/products/automotive/

- MAXIM Automotive HB LED Driver

  http://www.maximintegrated.com/products/display/led/automotive-lighting.cfm

- Website Resource
  - > Part selection parameter tables
  - > Datasheets
  - > Evkit datasheets
  - > Application notes