Charge Pump Technology in LED Driver Design

Lumissil Microsystems is growing its portfolio of charge pump LED driver offerings for battery operated consumer, medical and IoT markets. These drivers are unique in that they use capacitors for energy storage and transfer, enabling voltage step-up (boost) without the need for costly inductors.

CHARGE PUMP ARCHITECTURE

The fundamental architecture of a charge pump consists of a switched capacitor circuit. It is basically, a voltage doubler, which uses an array of switches to first charge an external capacitor to the input voltage, V_{IN}, then changes switch configuration to add the charged capacitor voltage to V_{IN}, effectively making V_{OUT} double that of V_{IN}.

How Charge Pump Works

The principle of a charge pump uses a controlled switching circuit to alternately charge and discharge capacitor C_{FLY}. Then isolate this charge and add it to V_{IN} during the discharge cycle, see Fig 1.

The capacitive boost operation consists of these two cycles:

- **Charge Cycle:** Two of the four switches (Q2 and Q3) turn on (closed), while the other two switches (Q1 and Q4) turn off (open). This allows capacitor C_{FLY} to charge to V_{IN} voltage.
- **Discharge Cycle:** In this cycle, Q1 and Q4 turn on, while Q2 and Q3 turn off placing C_{FLY} in series with V_{IN} effectively boosting V_{OUT} to 2 x V_{IN}. The output capacitor (C_{OUT}) is now at V_{OUT} ($2xV_{IN}$) and is available to provide current during the charge cycle.

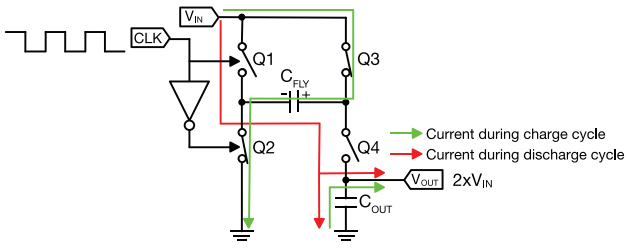

Fig 1: Simplified Charge-pump Block Diagram (Voltage Doubler)

A charge pump circuit leverages the principles of switched capacitors to manipulate voltage levels without the need for inductors, making it a compact and cost-effective boost solution. It operates at high switching frequencies (typically >1MHz) enabling the use of small ceramic or electrolytic capacitors while achieving peak efficiencies of 90-95%. This process allows charge pumps to generate higher voltages from a lower battery supply, which is useful for driving RGB LEDs, since the Green and Blue LEDs require a voltage >3.2V.

OPERATING MODES AND CAPABILITIES

The Lumissil charge pump LED drivers feature multiple operating modes to optimize efficiency across different input voltage ranges. The IS31FL3195 and IS31FL3298 offer 1x and 1.5x modes, while the IS31FL3197 adds a 2x mode, and the IS31FL3198A operates in a fixed 2x mode. This flexibility allows the LED drivers to maintain high efficiency as battery voltage decreases during discharge.

Advanced Features

These devices incorporate various control features such as programmable current levels (256 steps), PWM dimming (up to 4096 levels), and light pattern operation. The IS31FL3195 and IS31FL3197 offer pre-programmed lighting effects for RGBW applications, while the IS31FL3298 extends this to 9 channels with enhanced pattern capabilities. The IS31FL3198A provides specialized high-current capability up to 80mA per channel for high brightness applications.

Power Management

Power efficiency is prioritized through multiple operating modes. Quiescent current ranges from 420µA to 700µA in normal operation, with shutdown currents as low as 0.5µA. Sleep modes and automatic power management features help extend battery life in portable applications.

Integration Benefits

The integration of advanced features like programmable lighting effects, I2C interfaces, and thermal protection allows system designers the flexibility to create lighting effects for battery operated devices. The compact nature of charge pump technology enables highly integrated solutions in small form factors like QFN and WLCSP packages. This integration, combined with minimal external components and programmable features, simplifies LED system design while reducing overall solution size and cost.

APPLICATIONS

Charge-pump LED drivers are widely used due to their suitability for battery-powered applications, offering efficiency, compact size, and operation across diverse battery voltages. They provide programmable current control, PWM dimming, and autonomous operation, enabling various lighting effects and power-saving modes. The IS31BL3228A is appropriate for driving white LEDs in LCD backlights, while the 9-channel IS31FL3298 suits color status indication on portable devices like electronic toothbrushes. For RGB status indicators showing device conditions, the 4-channel IS31FL3195/97 and 3-channel IS31FL3198 are ideal, such as in environmental sensors and electronic price tags. Fig 2 illustrates potential applications in battery-powered devices.

Gaming | Personal Care | Display Backlight | Environmental Sensors | Electronic Price Tag | Wearable Device

Fig 2: Applications in Battery Powered Devices

LUMISSIL CHARGE PUMP FAMILY

Table 1 lists some of the charge pump LED drivers available from Lumissil, and Fig 3 shows the various device schematic. Lumissil continually introduces new products. We encourage you to browse Lumissil's website, www.lumissil.com for the most updated list of charge pump devices.

Driver	# of Channels	V_{IN} Range	Operating modes	Channel Current
IS31FL3195	4	2.7V to 5.5V	1x and 1.5x modes	20mA
IS31FL3197	4	2.0V to 3.7V	1x,1.5x, 2x modes	10mA
IS31FL3198A	3	3.3V	2x mode	80mA
IS31FL3298	9	2.5V to 5.5V	1x and 1.5x modes	20mA
IS31BL3228A/B	4 (A) or 6 (B)	2.8V to 5.5V	1x and 1.5x modes	20mA
IS31BL3232	1	2.7V to 5.5V	-	227mA Torch mode, 1.2A (1s) in Flash Mode

Table 1: Lumissil Charge Pump Products

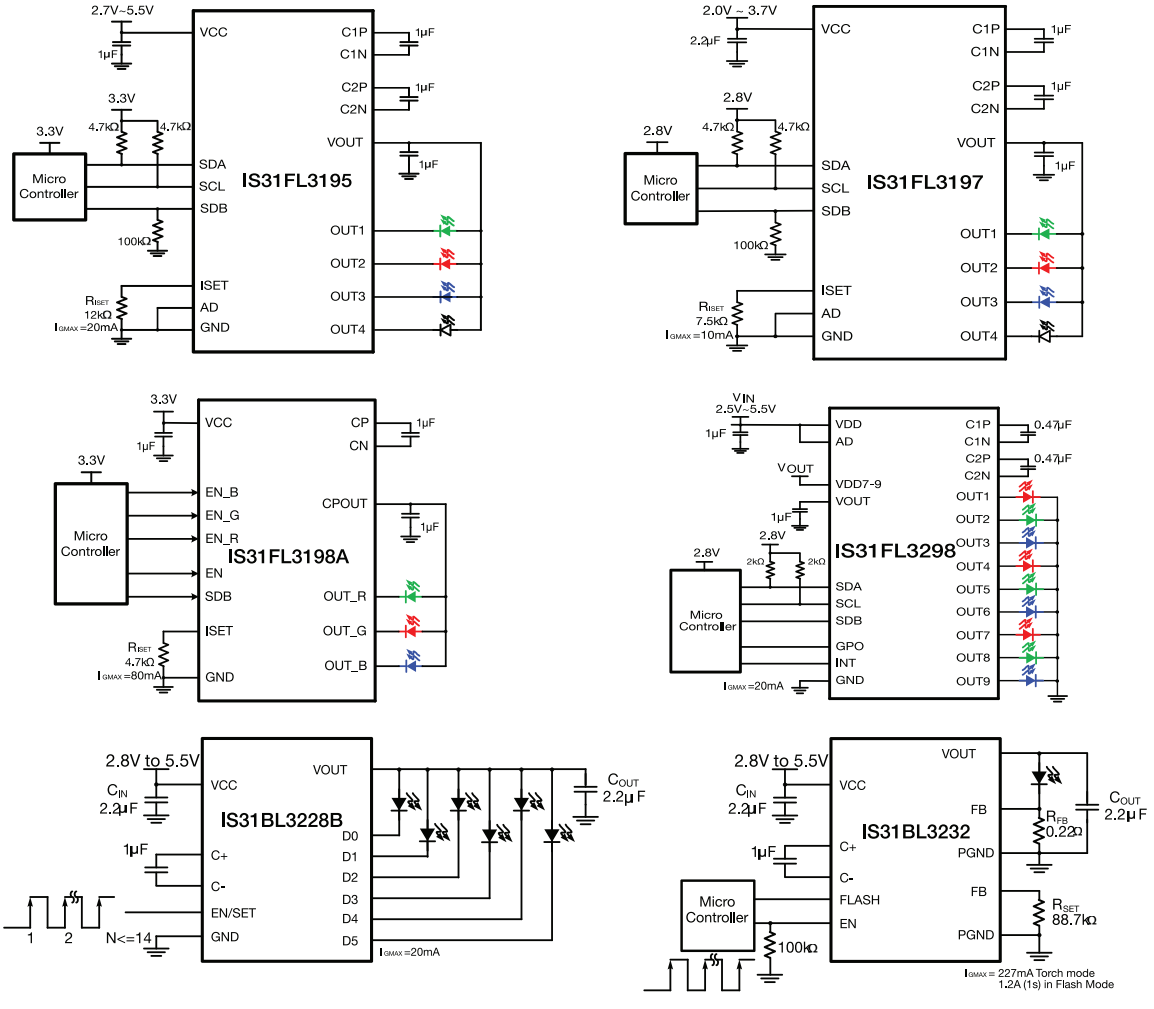

Fig 3: Example Charge Pump Device Schematics