

## Synchronous, Low EMI LED Driver Features Integrated Switches and Internal PWM Dimming

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The breadth of LED applications has grown to encompass everything from general lighting to automotive, industrial and test equipment, sign boards and safety equipment. As a result, the breadth of design requirements for LED drivers has expanded. The latest LED solutions require drivers that are compact, efficient, low noise, and feature high dimming ratios and advanced fault protection. The LT3922 easily meets these demands.

### THE LT3922 WITH INTEGRATED SWITCHES AND INTERNAL PWM DIMMING

The LT3922 36V, synchronous LED driver with integrated 2A switches can be configured as a boost, buck or boost-buck LED driver. Its high efficiency synchronous and integrated power switches fit into a tiny 4mm × 5mm QFN package. This device integrates Linear's most advanced switching technologies, condensing high power capability into tight spaces while controlling the edge rates and mitigating unwanted field emissions. The integrated synchronous switches are run with controlled switching edges that do not ring—offering just the right balance of high efficiency and low noise—and can be run at up to 2.5MHz, resulting in compact solutions.

### CHOICE OF TOPOLOGIES: BOOST, BUCK MODE, BOOST-BUCK

LED strings are driven by a controlled current that does not need to be returned directly to ground. Both LED<sup>+</sup> and LED<sup>-</sup>, or either one, can be attached to non-ground potentials. This opens up the field of options for floating output DC/DC LED driver topologies, including buck mode (step-down) and boost-buck (step-up and step-down). The LT3922's high side PWM TG driver and synchronous switches can be configured as a boost, buck mode or boost-buck LED driver, while retaining use of all of the IC's features—namely, internal PWM dimming, SSFM, low EMI, ISMON output current monitor, and output fault protection carry over from the standard boost topology to the buck mode and boost-buck.

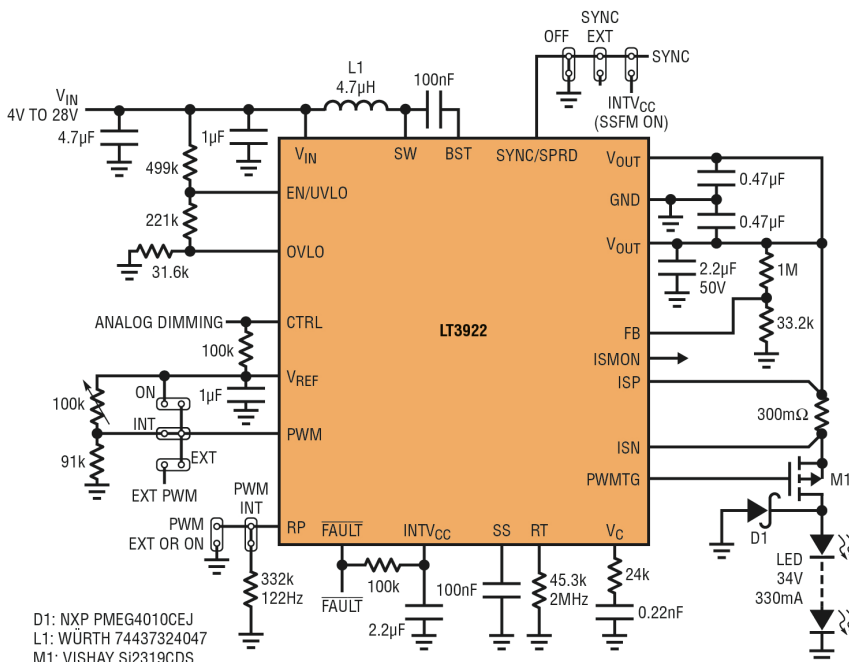


Figure 1. 2MHz regular boost schematic with 2000:1 PWM dimming at 120Hz

### Boost

The LT3922 can power LEDs up to 34V when operated as a boost converter, leaving some headroom, below 40V, for open LED overshoot. The 2MHz, 4V to 28V boost LED driver shown in Figure 1 powers a 330mA string of LEDs at up to 34V. It can be externally PWM dimmed at 120Hz to a 2000:1 ratio or it can be internally dimmed to 128:1 ratio with an analog input voltage on the PWM pin.

It survives open LED and LED<sup>+</sup>-to-ground short-circuits and reports these faults by asserting its FAULT pin. The output current can be monitored via the ISMON pin, even during PWM dimming. At 2MHz switching frequency, its fundamental EMI harmonic resides above the AM band, but its EMI is still low. Spread spectrum frequency modulation (SSFM) can be added to spread the switching frequency between 2MHz to 2.5MHz and reduce the EMI at the fundamental and its many harmonics. The efficiency of the 2MHz boost converter remains as high as 91% at 12V<sub>IN</sub> due to the integrated synchronous switches. At lower V<sub>IN</sub>, when the peak inductor current hits its limit, the output current is gracefully reduced without flicker while the LEDs remain on.

### Buck

The input voltage can be as high as 36V and a string of LEDs can be driven at up to 1.5A when the LT3922 is used in a buck mode topology, as shown in Figure 2. The high side ISP and ISN current sense input and PWMTG PMOS driver are easily moved to the high side of the LEDs, which is connected to the input in buck mode. LED<sup>-</sup> is connected directly to the inductor and not to ground. When driving two, 1A LEDs at 6.5V, the synchronous buck mode efficiency is as high as 94% at 12V V<sub>IN</sub> and remains as high as 89% at 36V V<sub>IN</sub>. The high bandwidth of the buck mode converter allows it to work with a 1000:1 PWM dimming ratio at 100Hz.

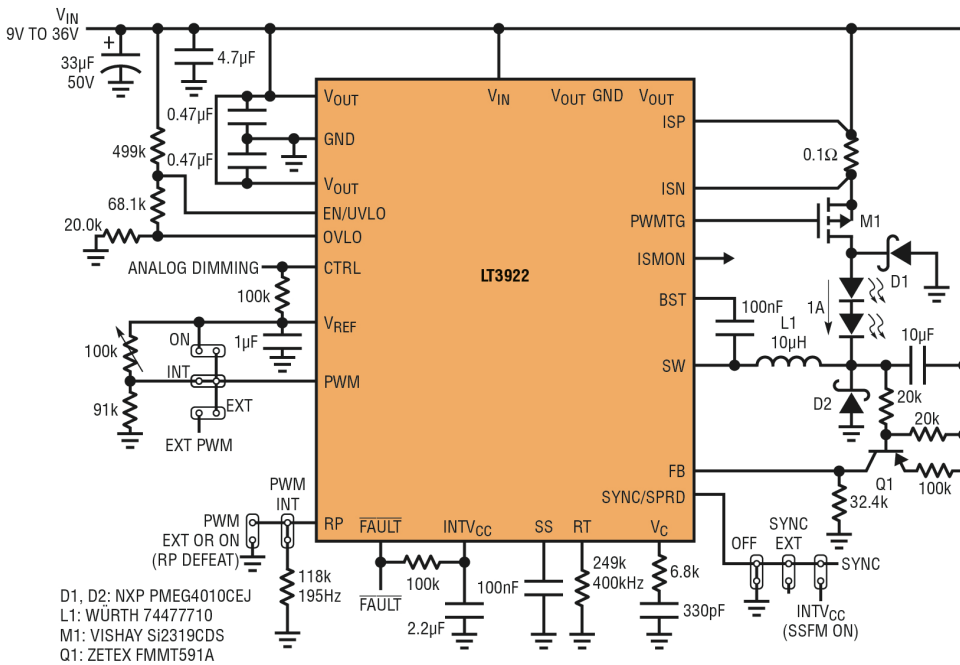


Figure 2. 400kHz buck mode LED driver with 1000:1 100Hz PWM dimming brightness control

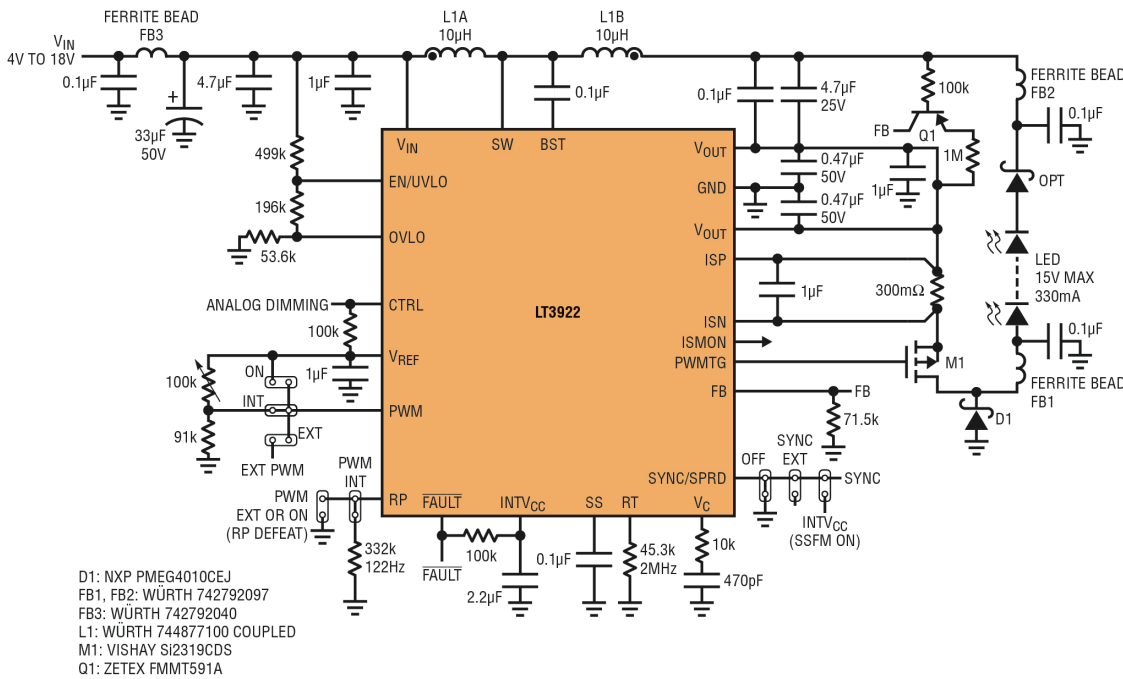


Figure 3. 2MHz boost-buck LED driver with low input and output ripple. This solution passes CISPR 25 Class 5.

### Boost-Buck

The LT3922 boost-buck topology in Figure 3 supports an input voltage range extending above and below the LED string voltage. The sum of the LED string voltage and the input voltage must remain below 35V to keep the ISP and ISN voltage below the 40V absolute maximum.

This patented low EMI topology features a boost-type low ripple input inductor and a buck mode-type low ripple output-facing inductor. A 4V–18V automotive input or multiple battery chemistry input (5V, 12V and 19V) boost-buck converter can drive an LED string voltage anywhere between 3V and 16V.

As in the other topologies, the PWMTG driver simplifies PWM dimming MOSFET connection. Open- and short-circuit protection are not compromised in the floating LED topologies. An optional diode on LED<sup>-</sup> protects against LED<sup>-</sup>to-GND short-circuits.

The 2MHz converter in Figure 3 features 85% efficiency (87% without EMI filters) at 12V  $V_{IN}$ , 15V  $V_{LED}$ , 330mA  $I_{LED}$  and up to 2000:1 PWM dimming ratio at 120Hz. This solution fits the requirements of an automotive daytime running light, signal light, or tail light LED driver, due to its size, versatility and low EMI.

### AUTOMOTIVE LIGHTING

So much about LEDs make them ideal for use in automotive lighting. There is a visual appeal of LED tail and daytime running lights. Efficient LED headlights are robust, with lifetimes orders of magnitude longer than their relatively burn-out-prone filament-based predecessors. Drivers are small and efficient with wide input and output voltage ranges, and should feature low EMI.

The tiny LT3922 LED driver features low EMI, high efficiency and fault protection required in automotive environments. It can be powered from the automotive 9V–16V input range and operates to 36V in the face of transients and down to 3V (cold-crank conditions). Its low EMI Silent Switcher® architecture, SSFM, and controlled switching edges make it ideal for powering LEDs with low EMI. Its versatility makes it useful in boost, buck and boost-buck applications for exterior daytime running lights, signal lights, tail lights, and headlight segments as well as interior dashboard and heads-up displays with high dimming ratio. Built-in flexibility and fault protection reduce the number of required components to protect against short and open LED strings.

The 400kHz automotive boost LED driver in Figure 4 passes CISPR 25 Class 5 EMI tests, as shown in Figure 5, which shows conducted and radiated EMI test results of the LT3922 along with class 5 EMI limits. This is a result of a combination of LT3922 low EMI features, including, but not limited to, controlled switching edges and spread spectrum frequency modulation (SSFM). Of course, proper layout and a small amount of ferrite bead filtering (FB1 and FB2) should be used for best EMI results.

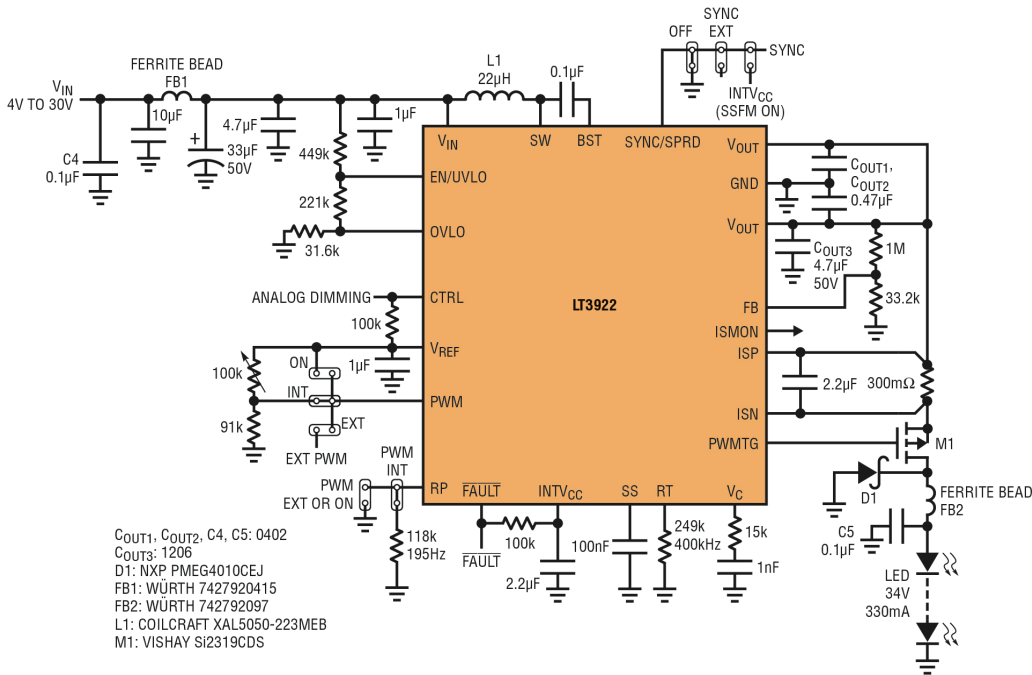


Figure 4. 400kHz automotive boost LED driver with filters for low EMI and option for 100%, 10% or 1% internally generated PWM dimming. EMI tests (Figure 5) show that this solution passes CISPR 25 Class 5.

### BUILT-IN FEATURES FOR LOW EMI

The LT3922 includes a number of features that enable designers to easily achieve low EMI solutions. First of all, LT3922 incorporates Linear’s patented Silent Switcher architecture, where internal synchronous switches minimize hot-switching-loop size and controlled switching edges do not ring.

Figure 6 shows how the LT3922’s pinout enables placement of small, high frequency capacitors near the two  $V_{OUT}$  pins to minimize hot-loop size and EMI.

The switching edge rate is controlled by the LT3922, eliminating high frequency ringing that is common in switching converters without this feature. The LT3922’s controlled switching edges reduce power switch high frequency EMI without degrading efficiency and power capability.

SSFM in the LT3922 spreads the resistor-set switching frequency up and down from 100% to 125% of its value at a rate of 1.6kHz for the 400kHz converter. This decreases both the peak and average EMI in the converter at low and high frequencies. The feature is easy to turn on and off by connecting the SYNC/SPRD pin to  $INTV_{CC}$  or GND, respectively.

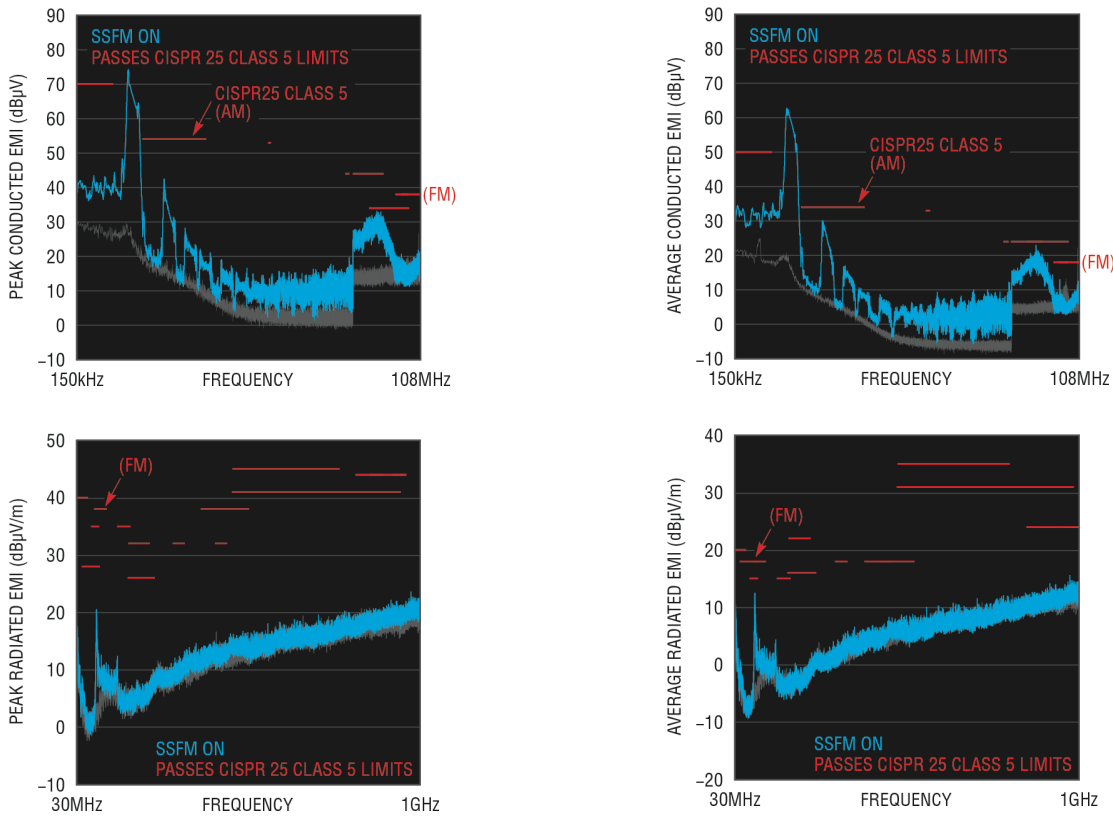


Figure 5. EMI profile of the 400kHz LED driver shown in Figure 4, which passes CISPR 25 Class 5 with minimal EMI filters. A larger LC filter can be added to the input if further EMI reduction is needed for specific manufacturer EMI requirements.

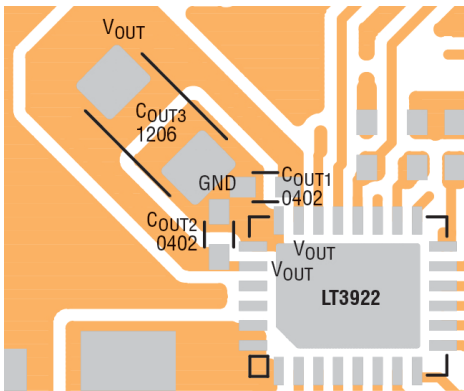


Figure 6. The dual-loop layout and high frequency 0402 split capacitors create small, opposing hot-loops that help reduce high frequency EMI

### INTERNALLY GENERATED PWM DIMMING

Analog dimming via adjustable voltage on the CTRL pin has always been easier to implement than the more accurate PWM dimming. Until now, PWM dimming required an external clock or micro signal whose duty cycle controlled the brightness via the PWM input pin. However, the LT3922 features an internally generated PWM dimming signal that only requires an external voltage on the PWM pin to set the duty cycle for 128:1 PWM dimming. The PWM period, such as 122Hz, is set by a single resistor on the RP pin.

LED current accuracy is a necessity for vehicles with redundant light clusters. The brightness of both sides must match for obvious reasons. Identically manufactured LEDs can produce different brightnesses at the same drive current. The internal dimming feature of the LT3922 can be used for brightness trimming near or just below 100% duty cycle and then set to accurate 10:1 or 100:1 ratios. This can save the light cluster manufacturer from paying extra for specially binned LEDs.

When higher dimming ratios are needed, the LT3922 can be externally dimmed in the usual manner. The high bandwidth 400kHz buck mode LED driver in Figure 2 yields a 1000:1 PWM dimming ratio at 100Hz. The 2MHz boost LED driver in Figure 1 can achieve 2000:1 dimming ratio at 120Hz as shown in Figure 7a. The same circuit can be set up for internally generated PWM dimming by placing a 122Hz frequency resistor on the RP pin and setting the PWM pin voltage between 1.0V and 2.0V for up to 128:1 dimming as shown in Figure 7b. The LT3922 can be set up to run with up to 5000:1 external PWM dimming in some applications and PWM dimming can be combined with LT3922's analog dimming for over 50,000:1 brightness control.

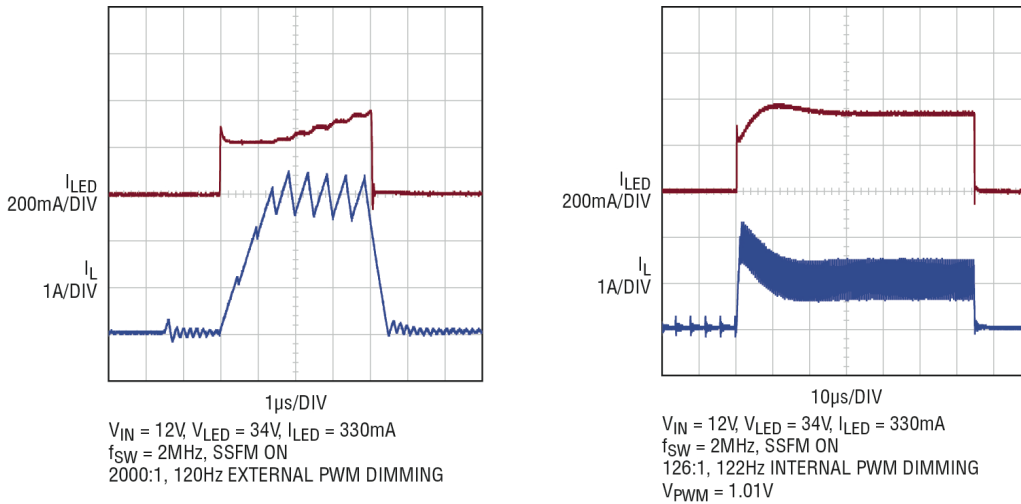


Figure 7. (a) Externally generated 2000:1 or 4000:1 PWM dimming of Figure 1 and (b) internally generated 128:1 PWM dimming of Figure 1.

## MACHINE VISION

In industrial assembly line applications, machine vision (Figure 8) provides rapid visual feedback of devices using high speed digital photography in conjunction with digital image processing. This helps rapidly identify and isolate defective products with little or no human inspection. The lighting used for machine vision systems must be synchronized with the speed of the assembly line processes while maintaining the ability to produce a consistent pulse of light for an indefinite period of off-time.

Conventional LED drivers are unable to maintain their output voltage after the PWM input signal is held low for any sustained amount of time. This is due to the gradual discharge of the output capacitor, making generic LED drivers unsuitable for these types of applications. However, the LT3922 digitally samples the output state of the converter during the falling edge of the PWM signal. It then maintains its output voltage during prolonged off-times by performing “maintenance switching” during the PWM off-time while the LEDs are disconnected by the high side PMOS. During standard PWM dimming at frequencies above 100Hz, the longest off-time is 10ms or less, and not much leakage current can be pulled off the output at that time. Machine vision and strobe applications can have long off-times between 100ms and 5s (or longer), allowing for tens to hundreds times more leakage.

Maintenance switching ensures that the output capacitor maintains the voltage recorded during the LT3922's previous sample cycle. The digital sample of the state of the converter is stored indefinitely, assuming uninterrupted input power is provided to the IC. This allows the LT3922 to have a consistent output current waveform for any given off-time, as demonstrated in Figure 9.

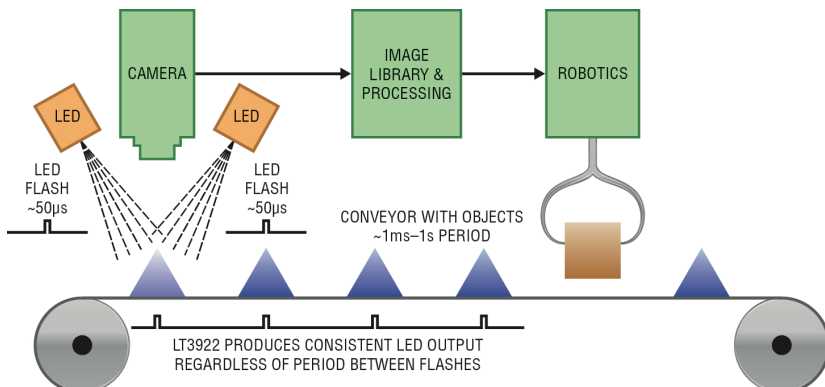


Figure 8. Assembly line system overview with machine vision application

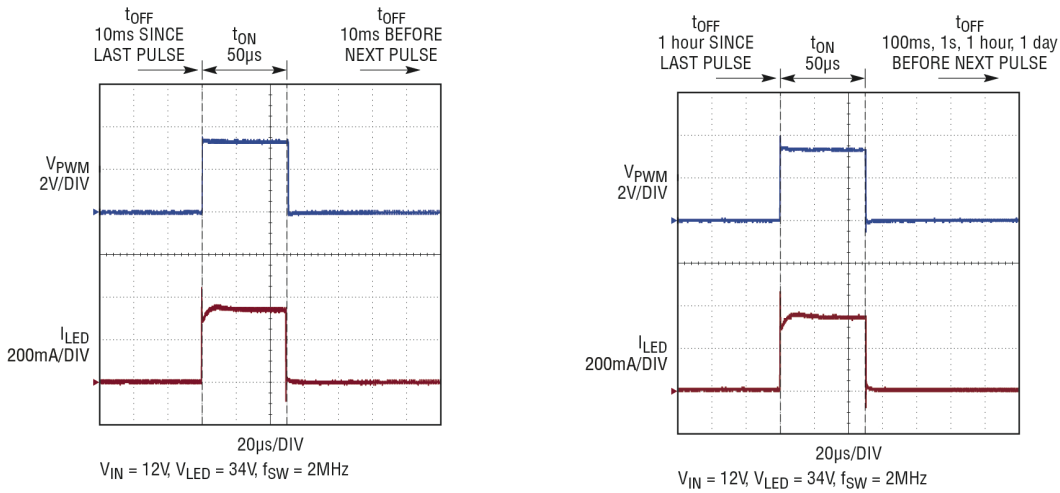


Figure 9. Camera flash waveform looks the same regardless of idle or down time. Waveforms show pulse after 10ms and after one hour. The flash looks the same after sitting idle for one hour as it does after 10ms. These results are for the circuit shown in Figure 1.

## CONCLUSION

The LT3922 36V LED driver with internal, synchronous, 2A switches is a compact and versatile LED driver. It can be easily used in boost, buck and boost-buck topologies. Regardless of topology, all of its features are available, including high PWM dimming capability and internally generated PWM dimming. Low EMI is easily achievable with its Silent Switcher layout and SSFM. Its compact and synchronous switches maintain high efficiency, even at frequencies up to 2MHz. With robust fault protection, this IC easily meets the requirements of automotive other demanding applications. ■

**Table 1. Wide input range LED drivers**

	LT3922	LT3795	LT8391	LT3952	LT3518
VIN Range	2.8V–36V	4.5V–110V	4V–60V	3V–42V	3V–30V (40V transient)
Synchronous	☑		☑		
Frequency Range	200kHz–2.5MHz	100kHz–1MHz	150kHz–650kHz	200kHz–3MHz	250kHz–2.5MHz
Peak Switch Current	2A	10A+	10A+	4A	2.3A
SSFM	☑	☑	☑	☑	
TG PWM	☑	☑	☑	☑	☑
Internal PWM Dimming	☑		☑	☑	
Short-Circuit Proof	☑	☑	☑	☑	
Package	4mm × 5mm QFN	28-Lead TSSOP	4mm × 5mm QFN	28-Lead TSSOP	4mm × 4mm QFN
Power Switches	two internal	single external	four external	single internal	single internal