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10-Channel, Integrated, High Efficiency 120 White LED Driver

POWER MANAGEMENT

Features

- Wide input voltage range from 4.5V to 21V
- 42V maximum operating output voltage
- Programmable LED current up to 30mA per string
- +/- 1% current matching
- Integrated 3A switch
- Low current sink voltage
- Up to 91% efficiency
- Flexible LED configurations
  - Mismatched LED channels
  - Disable individual channel(s)
  - Parallel channels for high LED current
- PWM dimming capability
  - Up to 50kHz dimming frequency
  - >500:1 dimming range
- Switching frequency: 500kHz - 1MHz
- Parallel device operation with Sync Pin
- Protection features:
  - Adjustable OVP
  - Cycle-by-cycle current limit
  - LED short channel with disable /Open channnel
  - Over-Temperature protection
- MLPQ-28 lead-free package (WEEE and RoHS compliant), 4×4mm × 0.6mm

Applications

- Automotive LCD Backlighting
- Desktop monitors
- Notebook PCs
- Portable TVs

Description

The SC442 is a 10-channel, high efficiency integrated step-up (boost) driver IC capable of powering up to 120 WLEDs. The device has a wide input voltage of 4.5V to 21V with no internal regulator or bypass capacitor required. The wide input range, up to 42V output voltage and flexible implementation make it the ideal LED backlight driver solution for medium to large LCD displays. The current sink channels are programmed with an external resistor up to 30mA each.

Channel-channel current matching is +/-1% . The device disables open or shorted LEDs by disabling only the affected LED channel; thus increasing LCD panel life. Channel-channel LED mismatch voltage is accomodated by adjusting the SCPSET resistor. The current sink channels may be operated in parallel for increased LED current. Unused channels are be disabled by connecting the pin to the input voltage.

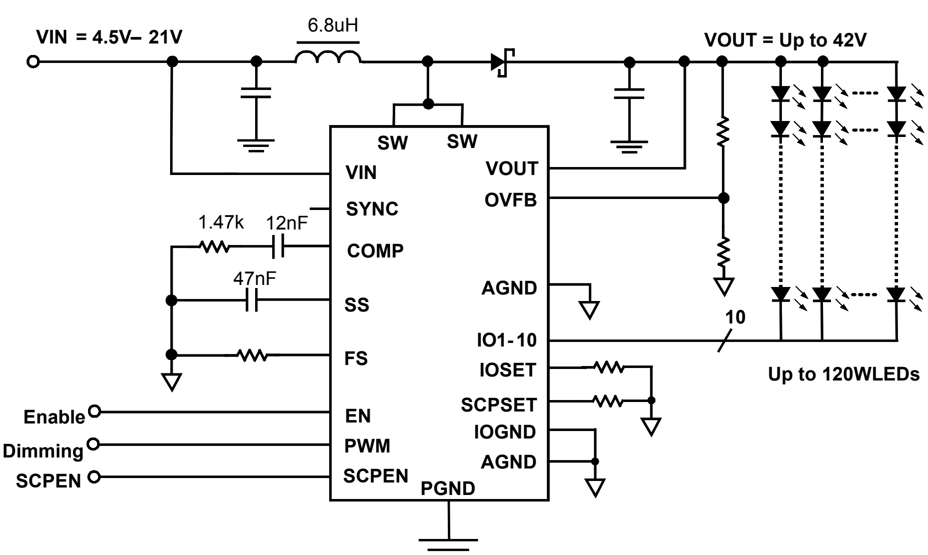
Losses in the switching device and current sinks are minimized across the operating range; yielding >90% efficiency and excellent battery life for portable systems.

The device accepts PWM dimming up to 50kHz. Maximum dimming range is greater than 500:1 with excellent linearity for optimum PWM dimming characteristics. The high frequency dimming capability (>20kHz) eliminates audio emissions and allows small ceramic output capacitors.

Switching frequency is programmable from 200kHz to 1MHz; allowing efficiency versus L/C sizing tradeoffs across the input/output voltage range. Alternatively, the SYNC pin allows the designer to synchronize the switching frequency to an external system clock and, if necessary, a parallel SC442 device - eliminating potential system intermodulation and interference problems.

Over-temperature shutdown protects the IC from over-heating under abnormal conditions. The device is available in a small 4mmx4mm MLPQ-28 pin package with 0.6mm maximum height and is fully WEEE and RoHS compliant.

Typical Application Circuit



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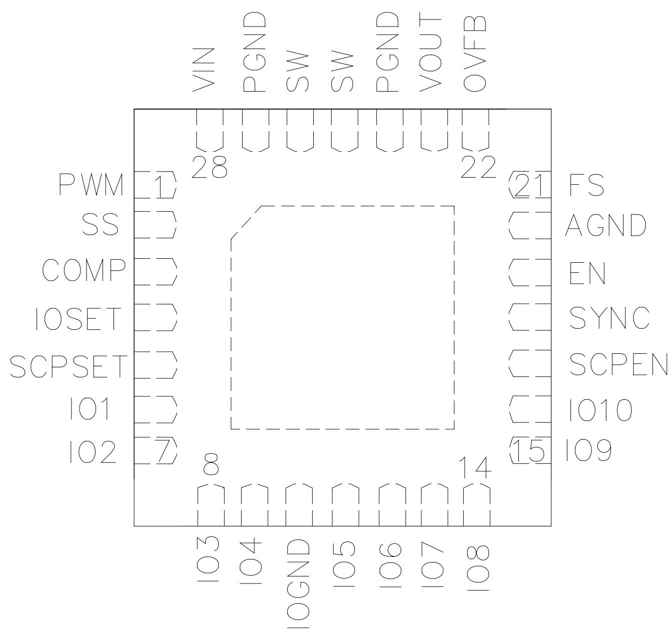
Pin Configuration



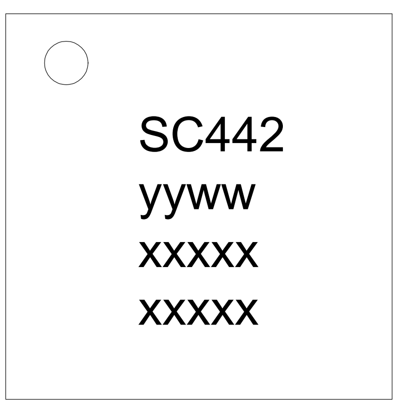
θ_{JA} = 28°C
MLPQ-UT28-4 x 4-EP1

Ordering Information

Device	Package
SC442ULTRT(1)(2)	4 x 4 x 0.6mm MLPQ-UT28
SC442EVB	Evaluation Board

Notes:
(1) Available in tape and reel only. A reel contains 3,000 devices.
(2) Available in lead-free package only. Device is WEEE and RoHS compliant and halogen free.

Marking Information



nnnnn = Part Number (Example: SC442)
yyww = Date Code (Example: 0952)
xxxxx = Semtech Lot No. (Example: E9010
xxxxx 01-10)

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Absolute Maximum Ratings

VIN Pin: Supply Voltage .... -0.3 to 25V
Maximum Output Power 12W
FS, IOSET Voltage .... -0.3 to 2V
SW, VOUT, IO1~IO10, OVFB Voltage .... 0.3V to 45V
SS, COMP Voltage .... -0.3 to 3V
SCPEN Voltage .... -0.3 to 3.5V
EN, PWM, SYNC, SCPSET ....-0.3 to V_{IN} +0.3V
PGND to AGND and IOGND............................. ± 0.3V
Peak IR Reflow Temperature .... 260°C
ESD Protection Level[2] 2kV

Recommended Operating Conditions

Supply Input Voltage .... 4.5 to 21V
Maximum Output Voltage.......................................42V
Maximum LED Current 30mA

Thermal Information

Junction to Ambient[1] ....28°C/W
Maximum Junction Temperature........................... 150°C
Storage Temperature .... -65 to +150°C

Exceeding the above specifications may result in permanent damage to the device or device malfunction. Operation outside of the parameters specified in the Electrical Characteristics section is not recommended.

NOTES-:
(1) Calculated from package in still air, mounted to 3" x 4.5", 4 layer FR4 PCB with thermal vias under the exposed pad per JESD51 standards.
(2) Tested according to JEDEC standard JESD22-A114-B.

Electrical Characteristics

Unless otherwise noted, V_{IN} = 12V, -40°C < T_A = T_J < 85°C, R_{IOSET} = 1.24k, R_{FS} = 30k.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input Supply						
Under-Voltage Lockout Threshold	U_{VLO-TH}	V_{IN} rising		4.2	4.45	V
UVLO Hysteresis	U_{VLO-H}			250		mV
V_{IN} Quiescent Supply Current	I_{IN-Q}	No switching		5		mA
V_{IN} Supply Current in Shutdown	I_{IN-S}	EN / PWM = low			1	µA
Oscillator						
Internal Switching Frequency Accuracy[1]	F_S		0.64	0.8	0.96	MHz
External Sync Frequency Range	F_{S_EXT}		1.1		1.3	Fs
Internal Switching Frequency Range[1]	F_S		200		1000	kHz
Maximum Duty Cycle[1]	D_{MAX}		90			%
Minimum Duty Cycle[1]	D_{MIN}				0	%
Minimum On-Time	T_{ON-MIN}			200		ns
Internal Power Switch						
Switch Current Limit	I_{SW}		3	3.5		A
Switch Saturation Voltage	V_{SAT}	I_{SW} = 1A		200	400	mV
Switch Leakage Current	I_{S-LEAK}	V_{SW} = 12V		0.01	1	µA

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Electrical Characteristics (continued)

Unless otherwise noted, V_{IN} = 12V, -40°C < T_A = T_J < 85°C, R_{IOSET} = 1.24k, R_{FS} = 30k.

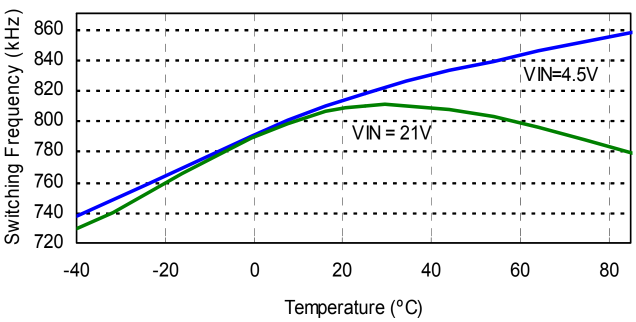
Parameter	Symbol	Conditions	Min	Typ	Max	Units
Compensation						
Sourcing Current	I_{O-H}	VCOMP = 0.5V, T_J = 25 °C		7		µA
Sinking Current	I_{O-L}	VCOMP = 2V, T_J = 25 °C		4.5		µA
Control Signals						
EN, PWM, SYNC, SCPEN High Voltage	V_{EN_H}	VIN = 4.5V to 21V	2			V
EN, PWM, SYNC, SCPEN Low Voltage	V_{EN_L}	VIN = 4.5V to 21V			0.4	V
EN, PWM, SYNC Leakage Current	I_{EN_LEAK}	VEN = VPWM = 0V to 5.0V		0.01	1	µA
PWM Dimming Frequency(1)	F_{PWM}		50		50k	Hz
PWM Dimming Minimum Duty Cycle(1)	D_{MIN_PWM}	200Hz		0.4		%
PWM Dimming Minimum Pulse Width	T_{PWM_MIN}	200Hz		10		µs
SCPEN Bias Current	I_{SCPEN}	SCPEN = 0V		33		µA
SS Source Current	I_{SS_H}	Vss = 0V		4.5		µA
SS Sink Current	I_{SS_L}	Vss = 2V at OVP or OTP		1.5		
SS Switching Threshold	V_{SS_TH}	T_J = 25°C	0.65	0.8	0.95	V
SS End Voltage	V_{SS_END}			2.5		V
Over-Voltage Protection						
OVFB Threshold Voltage	V_{OVFB_TH}		1.45	1.51	1.57	V
OVFB Leakage Current	I_{OVFB_L}	OVFB = VIN = 20V		0.1	1	µA
VOUT Internal Pull-Down in Over-Voltage Fault	I_{OVP}			0.8		mA
VOUT Leakage Current	I_{VOUT_L}	VOUT = 40V		0.1		µA
LED Short Circuit Protection						
SCPSET Current			41	51	61	µA
Max. SCPSET Threshold Voltage				V_{IN} -1		V
Current Source (IO1 ~ IO10)						
Backlight Current Accuracy	IO1~IO10	EN, PWM = 1; T_J = 25°C	28	30	32	mA
LED Current Matching		EN, PWM = 1; T_J = 25°C		+/-1	+/-3	%
Maximum LED Current	I_{O_MAX}		35			mA
IO Off Leakage Current	I_{O_LEAK}	EN = 0V, VIO1 ~ VIO10 = VIN		0.1	1	µA
Over-Temperature Protection						
Thermal Shutdown Temperature	T_{OTP}			150		°C
Thermal Shutdown Hysteresis	T_{OTP_H}			30		°C

Notes:

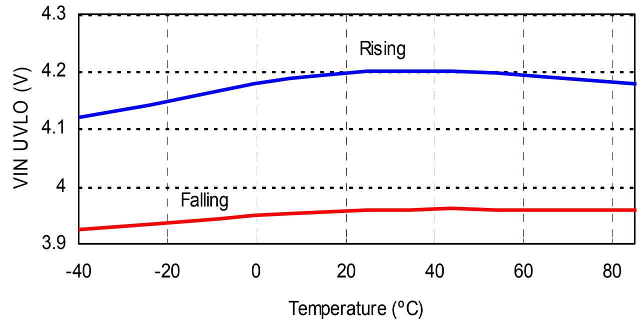
(1) Guaranteed by design.

Typical Characteristics

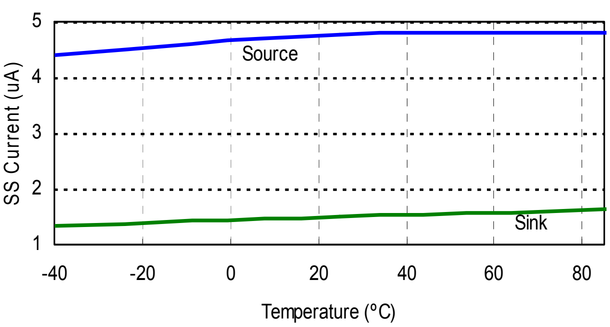
Switching Frequency vs Temperature



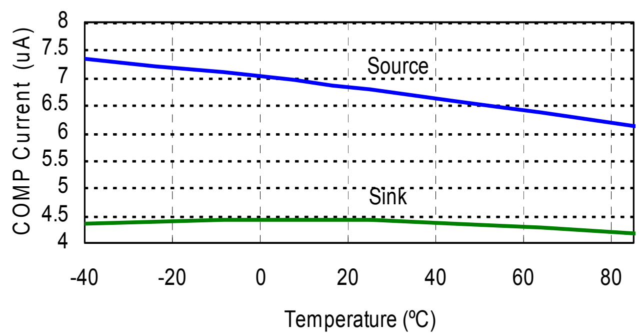
UVLO Threshold vs Temperature



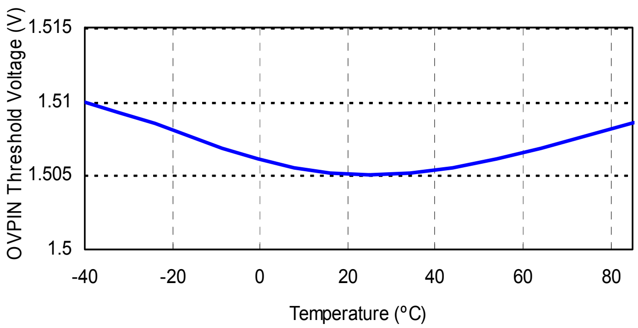
SS Current vs Temperature
VIN = 12V



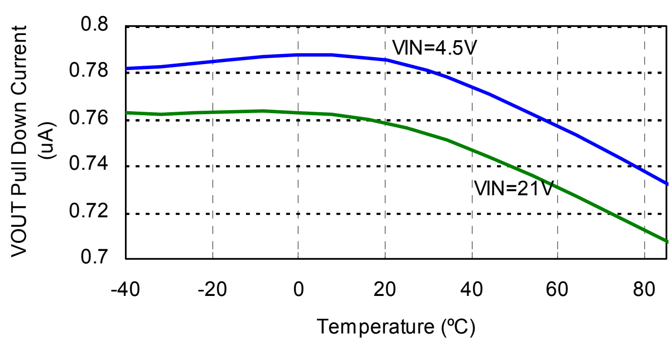
COMP Current vs Temperature
VIN=12V



OVPIN Threshold Voltage vs Temperature
VIN = 12V



VOUT Pull Down Current vs Temperature



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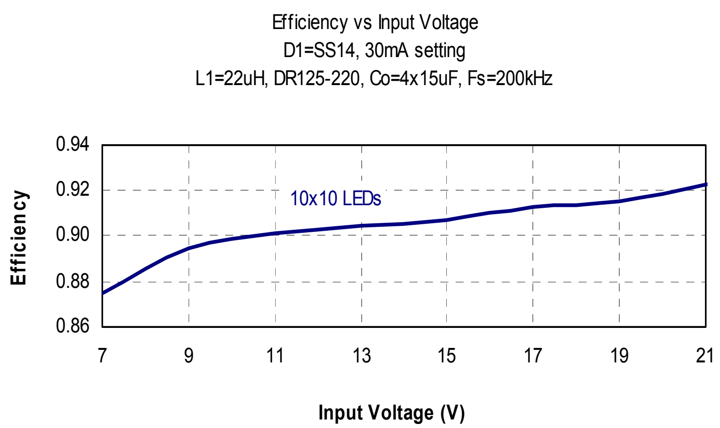
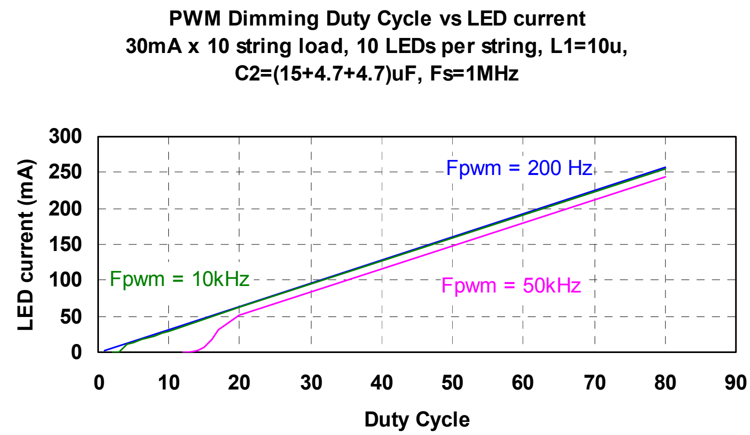
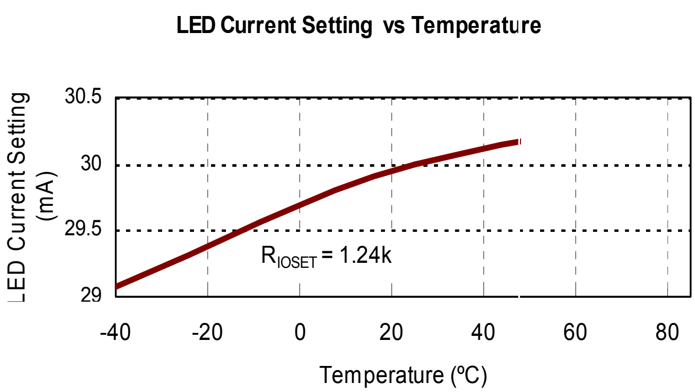
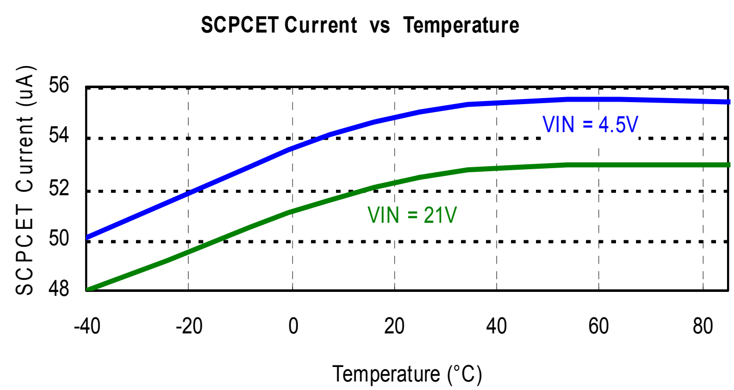
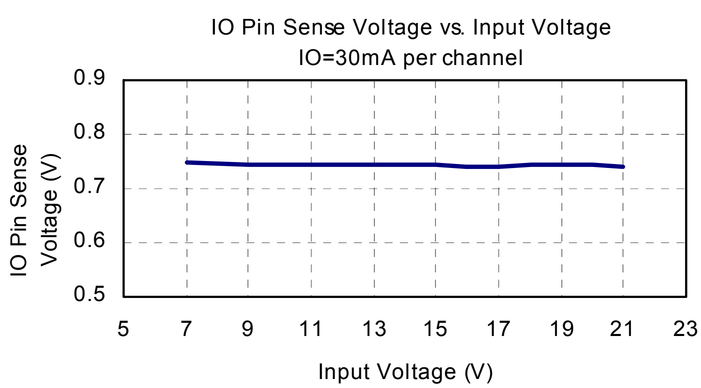
Typical Characteristics (continued)

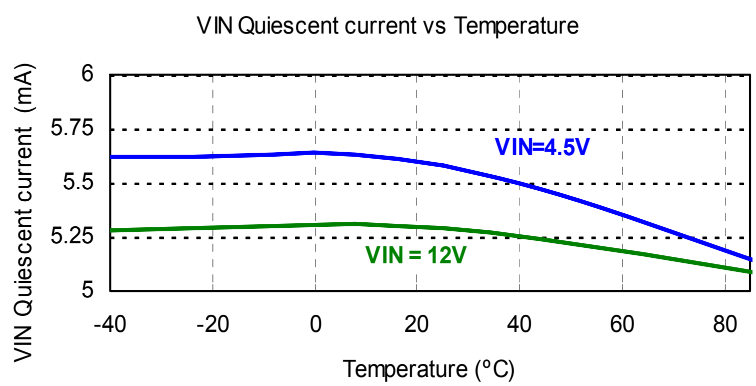




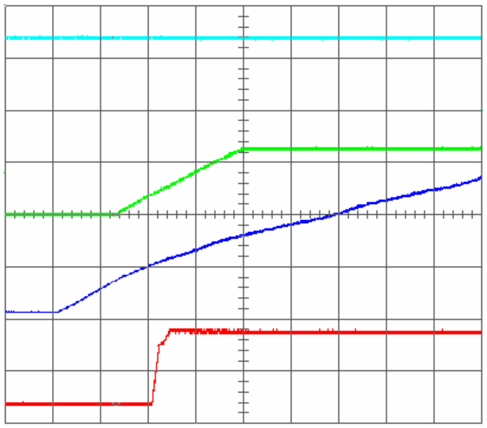








Start up



Time (50ms/DIV)
Conditions: VIN = 7V, Load = 30mA
x 10 strings, 10 LEDs per string

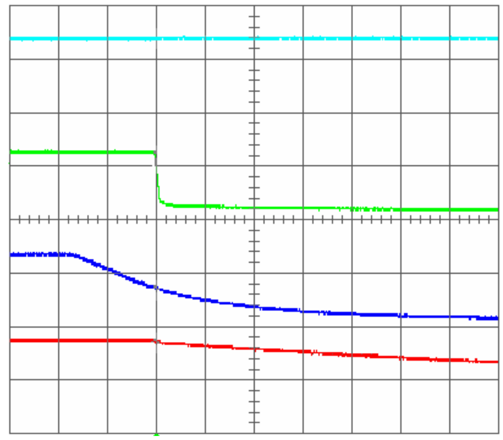
VIN
5V/DIV

SS
2V/DIV

EN
2V/DIV

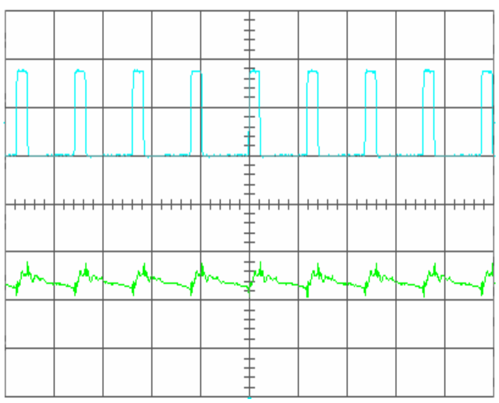
VOUT
20V/DIV

Shut down



Time (100ms/DIV)
Conditions: VIN = 7V, Load = 30mA
x 10 strings, 10 LEDs per string

Main Power Switching Waveform

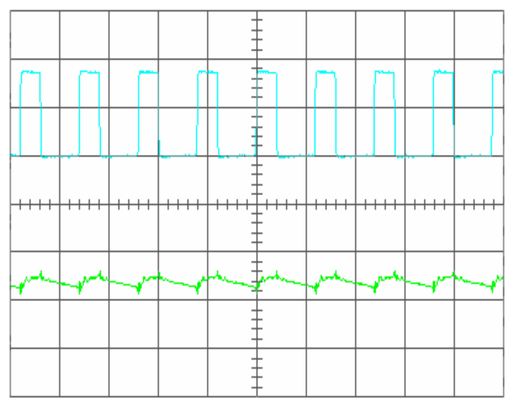


Time (1us/DIV)
Conditions: VIN = 7V, Load = 30mA
x 10 strings, 10 LEDs per string

SW
20V/DIV

VOUT(AC)
100mV/DIV

Main Power Switching Waveform



Time (1us/DIV)
Conditions: VIN = 12V, Load = 30mA
x 10 strings, 10 LEDs per string

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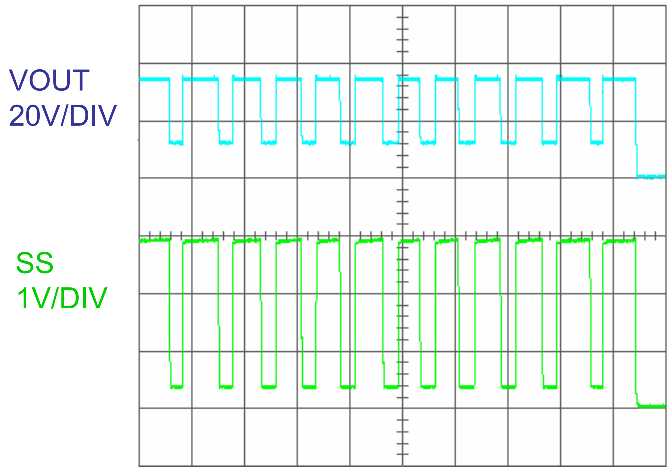
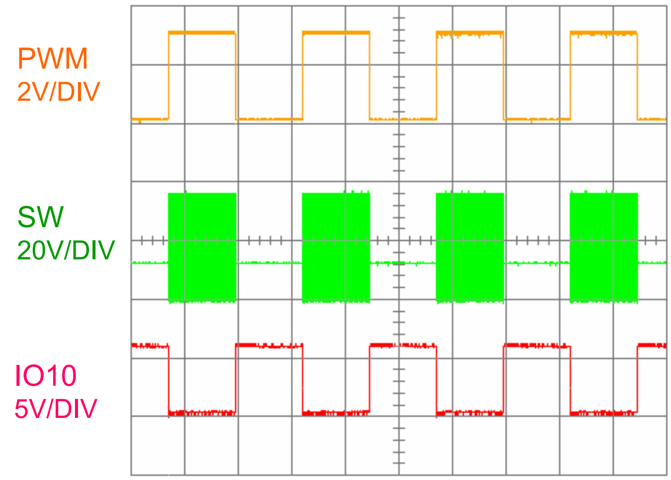
OTP and OTP Recovery



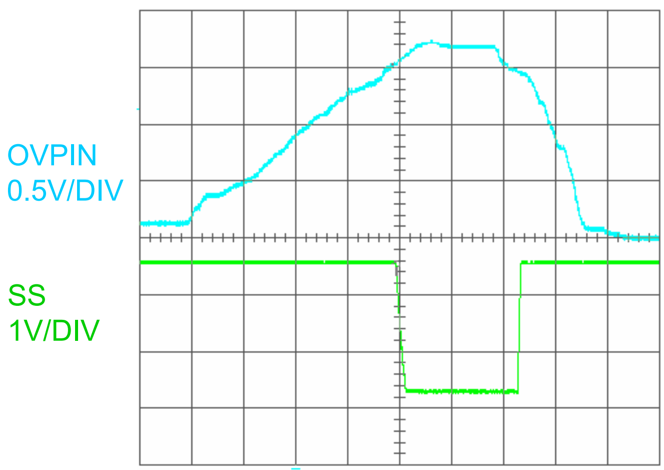
Time (2s/DIV)
Conditions: VIN = 12V, Load = 30mA
x 10 strings, 10 LEDs per string

PWM dimming



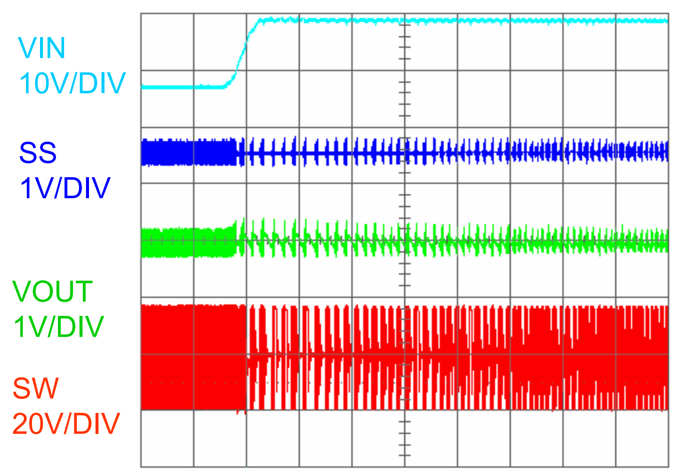
Time (5ms/DIV)
Conditions: VIN = 12V, Load = 30mA
x 10 strings, 10 LEDs per string

OVP



Time (2s/DIV)
Conditions: VIN = 12V, Load = 30mA
x 10 strings, 10 LEDs per string

VIN Adaptor Plug-in Case



Time (50us/DIV)
Conditions: VIN = 7V~18.5V, Load = 30mA
x 10 strings, 10 LEDs per string

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Pin Descriptions

Pin #	Pin Name	Pin Function
1	PWM	PWM control pin for LED backlight strings.
2	SS	Soft start pin. Connect a capacitor from 47nF to 220nF to adjust the soft-start rate.
3	COMP	The output of the internal transconductance error amplifier. This pin is used for loop compensation.
4	IOSET	Current source IO value set pin. Sets maximum current on all strings with a resistor connected from this pin GND, the corresponding maximum current on all 10 strings are set.
5	SCPSET	The voltage on this pin programs the LED Short Circuit Protection threshold (if enabled) up to Vin-1V by a resistor.
6	IO1	Provides constant current sink to LED string 1.
7	IO2	Provides constant current sink to LED string 2.
8	IO3	Provides constant current sink to LED string 3.
9	IO4	Provides constant current sink to LED string 4.
10	IOGND	LED ground.
11	IO5	Provides constant current sink to LED string 5.
12	IO6	Provides constant current sink to LED string 6.
13	IO7	Provides constant current sink to LED string 7.
14	IO8	Provides constant current sink to LED string 8.
15	IO9	Provides constant current sink to LED string 9.
16	IO10	Provides constant current sink to LED string 10.
17	SCPEN	Float high to enable LED short Circuit Protection or tie to AGND to disable.
18	SYNC	External sync frequency input. If used, must be greater than internal oscillator setting.
19	EN	Drive high to enable the IC or tie to AGND to disable the IC.
20	AGND	Analog ground.
21	FS	External resistor setting switching frequency.
22	OVFB	Over-voltage feedback pin. Use a voltage divider to adjust the OVP level.
23	VOUT	Boost output voltage pin. Internal over-voltage protection also monitors the voltage at this pin. Connect the output capacitor and the anode of the LED strings to this pin.
24	PGND	Power ground.
25, 26	SW	Collector of the internal power transistor. Connect to the boost inductor and the rectifying diode.
27	PGND	Power ground.
28	VIN	Input voltage supply for IC. Bypass with capacitors close to the pin.
T	Thermal Pad	Thermal pad for heatsinking purposes. Connect to ground plane using multiple vias. Not connected internally.

Table 1.

EN	STATUS
0	backlight disable
1	backlight enable

Note: When EN = 0; the boost is turned OFF and disabled.

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Block Diagram

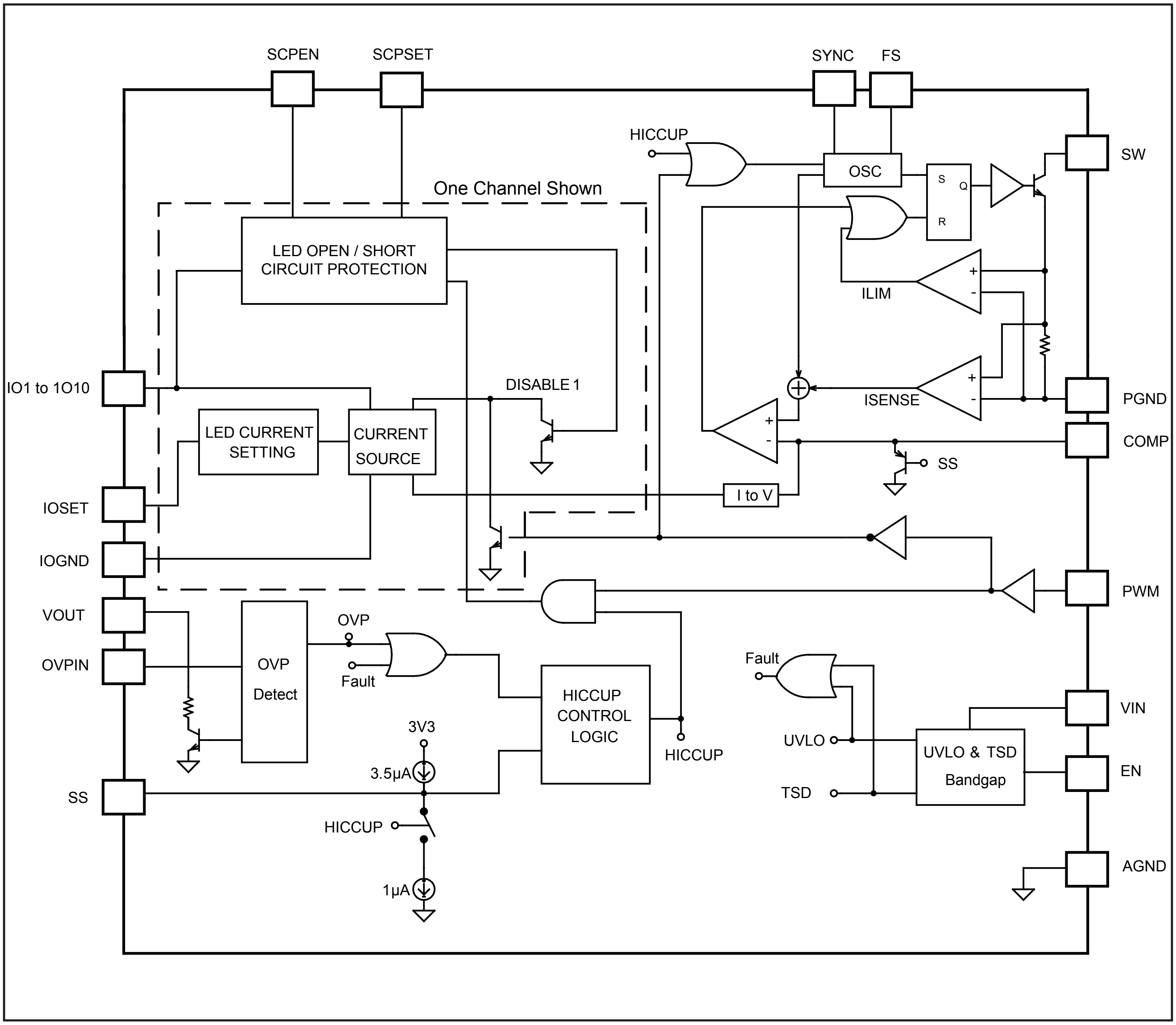

Figure 1. SC442 Block Diagram

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Applications Information

SC442 Detailed Description

The SC442 contains a high frequency, current-mode boost regulator and ten string LED current sources. The LED current for all strings is programmed by an external resistor and the PWM controller operates to maintain the output voltage at a level which will keep the current of each string regulated. A typical application would use 3-10 backlight LEDs for each string, driven with approximately 30mA.

Operation

The SC442 regulates the boost converter output voltage based on instantaneous requirements of the ten string current sources. Therefore, only a single inductor and power switch is needed to provide power to the entire lighting subsystem, increasing efficiency and reducing part count. A logic interface to output control circuit has high-bandwidth, and supports PWM dimming with 50Hz to 50kHz dimming frequency while the entire supply current is reduced to 5mA (typical) when all LED strings are off.

High frequency switching provides high output power using a 1.0mm height inductor, maximizing efficiency for space-constrained and cost-sensitive applications. Additionally, the converter and output capacitor are protected from open-LED conditions by programmable over-voltage protection.

LED Current Programming

The SC442 is a LED current programmable regulator. The LED current set point is chosen using an external resistor connected to the IOSET pin. The relationship between the programming resistor value and the LED current set point of each string can be described as follows:

$$I_{LED} = \frac{37.2}{R_{IOSET}}$$

Where, R_{IOSET} is in kΩ.

I_{LED} is the output current of each string in mA.

Start-Up

During start-up, when the VIN pin voltage reaches its UVLO threshold and both EN and PWM signals are set to high, the SS pin begins to source 4.5μA to the SS capacitor and its voltage begins to rise from 0V to its end value of (2.5V). The output voltage of the internal error amplifier (COMP) increases and clamped by the SS pin voltage. When the SS pin voltage reaches its switching threshold, the SC442 starts to switch and the output voltage increases.

Each internal LED current source (IO1 ~ IO10) tries to regulate the LED current to its set point. While the output voltage increases, a suitable amount of error information will be generated on the internal error amplifier as the COMP pin voltage keeps rising. Once each LED current reaches its set point, the error information is not generated by the LED current source. The COMP pin voltage stays at a level which keeps the LED current at its set point.

If the EN pin voltage is pulled below 0.4V and VIN reaches its UVLO, SC442 will stay at shutdown mode, drawing less than 1μA from the input power supply.

If the PWM pin voltage is pulled below 0.4V when the EN pin is pulled high and VIN reaches its UVLO, the SC442 runs in standby mode, drawing 5mA (typical) from the input power supply. Under this condition, soft-start is initiated and the SS pin voltage is raised to its end value since the EN pin is pulled high. After that, when PWM signal goes high to enable the device, the COMP pin voltage will rise as quickly as it can since it is not being limited by the SS pin. A proper capacitance (1nF ~ 100nF) is required for the COMP pin and its external RC network in order to prevent output voltage overshoot.

Shut Down

When the VIN pin voltage falls below its UVLO or EN pin voltage goes low while SC442 is at normal operation, SC442 will run in shutdown mode. The internal switch and LED current sources will be immediately turned off. The SS capacitor is discharged by SS pin internal current source and the SS pin voltage decreases to 0V. The output voltage falls to the same level as the input voltage.

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Applications Information (continued)

If PWM pin voltage goes low while the SC442 is at normal operation, the device will run in standby mode. The internal switcher and the LED current sources will be immediately turned off. The SS pin will not be affected by the PWM signal and remains at its final value.

Main Power Stage Operation

SC442 is a frequency programable, peak current-mode boost switching regulator with an integrated 3A (minimum), power transistor. The switching frequency is programmable at the FS pin by the resistor connected between the FS pin and GND as follow:

$$F_S(\text{kHz}) = \frac{24000}{R_{FS}(\text{k}\Omega)}$$

Referring to the Block Diagram on Page 10, the clock from the oscillation section resets the latch and turns on the power transistor. Switch current is sensed with an integrated sense resistor. The sensed current is summed with the slope-compensating ramp and fed into the modulating ramp input of the PWM comparator. The latch is set and the power transistor conduction is terminated when the modulating ramp intersects the error amplifier output (COMP).

The current-mode switching regulator is a dual-loop feedback control system. In the inner current loop, the EA output (COMP) controls the peak inductor current. In the outer loop, the error amplifier regulates the output voltage to keep the LED current in set point. The double reactive poles of the output LC filter are reduced to a single real pole by the inner current loop, allowing the simple loop compensation network to accommodate a wide range of input and output voltages.

Over-Current Protection

If the switch current exceeds 3A (the minimum current-limit trip point), the current-limit comparator, I_{LIM} will set the latch and immediately turn off the internal power switch. Due to separate pulse-width modulating and current limiting paths, the OCP trip point is not affected by slope compensation (i.e., trip point is not affected by switching duty cycle).

Over-Voltage Protection (OVP)

The SC442 includes an external programming over-voltage protection circuit to prevent damage to the IC and output capacitor in the event of an open-circuit condition. The output voltage of the boost converter is detected at the OVPIN pin. If the voltage at the OVPIN pin exceeds 1.5V, the boost converter will shut off and a 1mA pull down current source will be applied to the VOUT pin to quickly discharge the over-voltage capacitor. This additional level of protection prevents a condition where the output capacitor and Schottky diode must endure high voltage for an extended period of time, which can pose a reliability risk for the system. The total resistance of the divider for the OVP protection should be more than 200kΩ.

The output over-voltage trip point can be programmed by R2 and R4 resistor divider (see the schematic on page 17). The relationship can be described as follows:

$$OVP\_trip = OVPIN\_TH \cdot \frac{R2 + R4}{R4}$$

Where OVPIN_TH is 1.51V typical.

An OVP event causes a fault which disables the boost converter and enables the strong pulldown. Meanwhile, the soft-start capacitor is discharged. When the soft-start capacitor voltage falls below 0.5V, SC442 enters a soft-start process.

The OVP detection circuitry provides a disconnect feature during the shutdown state to prevent any leakage from the output. The external OVP resistor divider should be connected between VOUT and OVPRTN while its central tap is connected to OVPIN. If this disconnect function is not desired, just connect the end of the OVP resistor divider directly to GND. The OVPIN pin is sensitive to noise, a proper decoupling cap (1nF ~ 10nF) is required.

LED Short-Circuit Protection

If one or more LEDs are detected as shortened, that corresponding string will be latched off if SCP_EN is floating. The voltages on all internal LED current sources (IO pins) are monitored to see if any exceeds the setting voltage (The IO voltage on abnormal LED string will rise earlier than other floating LED strings). If any IO pin voltage exceeds the setting voltage, that IO current source will be latched off. The latch can be reset if VIN falls below UVLO

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Applications Information (continued)

or recycle EN signal. Other normal LED strings remain at their normal operation. The protection will be disabled if SCP_EN is tied to GND. If all IO pin voltages reach 0.8V then the internal main switch will be off until any of the IO voltages is lower than 0.7V.
The setting voltage for SCP can be programmed by R11 (see the schematic on page 17). The relationship can be described as follows:

$$V_{SCP}(V) = 0.051 \cdot R_{11}(k\Omega)$$

Where V_{SCP} is the SCP setting voltage in Volt and R11 is in kohm.

Unused Strings
The SC442 may be operated with less than 10 strings. In this case, all unused strings should be tied to VIN and leave the SCP_EN pin floating.

LED Open-Circuit Protection
If any LED is detected as open circuit, that string will be latched off. Then the COMP pin will be driven high and the boost converter duty cycle will increase causing VOUT to rise. At some point VOUT will rise high enough to cause all the IO pin voltages of the remaining strings to reach the shorted LED detection level and those strings are latched off. Because of the open string, VOUT will continue to rise until it reaches the programmed OVP level.

When OVP is reached, the voltages on the IO pins are monitored. If any IO voltage is less than 0.2V, that string will be identified as open and will be latched off. Only VIN falling below UVLO, recycle EN signal, and thermal shutdown will reset this latch. When a hiccup cycle is initiated the SS is discharged slowly with a 1µA current source and a 1mA discharge path is turned on to pull down VOUT. When SS falls below 0.5V and VOUT falls to VIN, the shorted LED detection latches are reset and a new soft-start sequence is initiated to resume normal operation.

Thermal Shutdown (TSD)
If the thermal shutdown temperature of 150°C is reached, a hiccup sequence is initiated where the boost converter and all IO current sources are turned off. SS is discharged by a 1µA current source, and a 1mA discharge path is turned on to pull down VOUT. As temperature falls below TSD release point, the SC442 will retry once SS falls below 0.5V and VOUT falls to VIN.

PWM Dimming
The PWM input needs to be held high for normal operation. PWM dimming can be achieved by cycling the PWM input at a given frequency where a “low” on the PWM input turns off all IO current sources and a “high” turns on all IO current sources. The short and open detection latches are blanked for approximately 2µs as the PWM input transitions from low-to-high to prevent false fault detection during PWM dimming.

The PWM pin can be toggled by external circuitry to allow PWM dimming. In a typical application, a microcontroller sets a register, or counter, that varies the pulse width on a GPIO pin. The SC442 allows dimming over two decades in frequency (50Hz-50kHz) in order to allow compatibility with a wide range of devices including the newest dimming strategies that avoid the audio band by using high frequency PWM dimming. In this manner, a wide range of illumination can be generated while keeping the instantaneous LED current at its peak value for high efficiency and color temperature.

Furthermore, advanced lighting effects such as backlight dim-on can be implemented as the SC442 can resolve PWM from 10% to 90% duty at its highest frequency. Additionally, PWM dimming offers customers the ability to reduce in-rush current to the output capacitor. Simply apply the PWM signal to the device at 10% duty for a millisecond or two, and in-rush current is reduced to less than 50mA. This dim time will vary based on the number of LEDs and the size of the output capacitor, but can be easily determined on the bench and programmed into the µC firmware.

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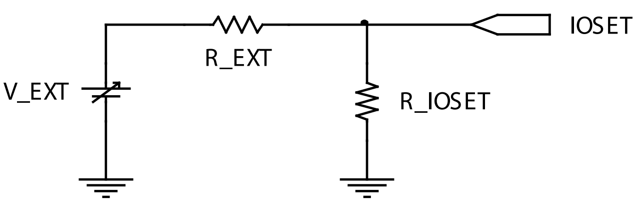
Applications Information (continued)

Linear Dimming

The linear dimming control is available for SC442 by applying an external control voltage on IOSET pin through an external resistor as shown below. External environment brightness compensation can also be achieved when the control voltage is generated by a light sensing circuit.



LED String Connection

Generally, LED strings are connected to the IO1 ~ IO10 pins through a mechanical connector which cannot support an electrical connection at times. This connection might cause noise on the IO1 ~ IO10. If this function is enabled, the SC442 LED short-circuit protection may false trip when the noise level is large enough. Certain ceramic decoupling capacitors (100pF ~ 8.2nF) on pins IO1 ~ IO10 to GND can help prevent the SC442 from entering the false protection, or, simply disable this feature by tying Pin 17 to GND.

Parallel Operation 2 External Frequency Synchronization

When two or more SC442s are operating in parallel for a large-sized panel application, audible noise may be observed due to a non-synchronous switching frequency. The ripple voltage on the input voltage rail will be modulated by the beat frequency resulting in audible noise. This situation can be resolved by using an external clock at the SYNC pin to synchronize all SC442s together.

Inductor Selection

The inductance value of the inductor affects the converter's steady state operation, transient response, and its loop stability. Special attention needs to be paid to three specifications of the inductor, its value, its DC resistance and saturation current. The inductor's inductance value also determines the inductor ripple current. The converter can operate in either CCM or DCM depending on its working conditions. The inductor DC current or input current can be calculated as,

$$I_{IN} = \frac{V_{OUT} \cdot I_{OUT}}{V_{IN} \cdot \eta}$$

I_{IN} - Input current;

I_{OUT} – Output current;

V_{OUT} – Boost output voltage;

V_{IN} – Input voltage;

η – Efficiency of the boost converter.

Then the boundary condition for CCM and DCM is,

$$D = \frac{V_{OUT} - V_{IN} + V_D}{V_{OUT} + V_D}$$

V_D = Forward conduction drop of the output rectifying diode.

When the boost converter runs in DCM ($L < L_{boundary}$), it takes advantage of small inductance and quick transient response while avoiding the bandwidth-limiting instability of the RHP zero found in CCM boost converters.

The inductor peak current is,

$$I_{L\text{-}PEAK} = \frac{V_{IN} \cdot D}{F_S \cdot L}$$

The converter will work in CCM if $L > L_{boundary}$. Generally the converter has higher efficiency under CCM and the inductor peak current is,

$$I_{L\text{-}PEAK} = I_{IN} + \frac{V_{IN} \cdot D}{2 \cdot F_S \cdot L}$$

For many applications an inductor with a value of 4.7μH to 22μH should be fine. The inductor peak current must be less than its saturation rating. When the inductor current is close to the saturation level, its inductance can decrease 20% to 35% from the 0A value depending on the vendor specifications. Using a small value inductor

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Applications Information (continued)

forces the converter into DCM, in which case the inductor current ramps down to zero before the end of each switching cycle. It also reduces the boost converter's maximum output current and produces large input voltage ripple. An inductor with larger inductance will reduce the bandwidth of the feedback loop and possibly higher DC resistance (DCR). Inductor's DCR plays a significant role for the total efficiency since the power transistor is integrated inside the SC442. Of course, there is a trade-off between the DCR and inductor size. Table 2 lists recommended inductors and their vendors.

Table 2. Recommended Inductors

Inductor	Website
DR74, 4.7µH ~ 15µH	www.cooperet.com
IHLP-2525CZ-01, 4.7µ ~ 10µH	www.vishay.com
DS85LC, 6.8µH ~ 10µH	www.tokoam.com

Output Capacitor Selection

The next task in design is targeting the proper amount of ripple voltage due to the constant-current LED loads. The two error amplifiers that control the PWM converter sense the delta between requested current and actual current in each output current regulator. On a cycle-by-cycle basis, a small amount of output ripple ensures good sensing and tight regulation, while the output current regulators keep each LED current at a fixed value. Overall, this allows usage of small output caps while ensuring precision LED current regulation. Although the mechanics of regulation and frequency dependence may be complex, actual selection of the output capacitor can be simplified because this capacitor is mainly selected for the output ripple of the converter. Assume a ceramic capacitor is used. The minimum capacitance needed for a given ripple can be estimated by,

$$C_{OUT} = \frac{(V_{OUT} - V_{IN}) \cdot I_{OUT}}{V_{OUT} \cdot F_S \cdot V_{RIPPLE}}$$

V_{RIPPLE} – Peak-to-peak output ripple;
I_{OUT} – Output current;
V_{OUT} – Boost output voltage;
V_{IN} – Input voltage;
F_S – Switching frequency.

During load transient, the output capacitor supplies or absorbs additional current before the inductor current reaches its steady state value. Larger capacitance helps with the overshoot and undershoots during load transient, and loop stability. Recommended ceramic capacitor manufacturers are listed in Table 3.

Table 3. Recommended Ceramic Capacitor Manufacturers

Vendor	Phone	Website
Kemet	408-986-0424	www.kemet.com
Murata	814-237-1431	www.murata.com
Taiyo Yuden	408-573-4150	www.t-yuden.com

Output Rectifying Diode Selection

Schottky diodes are the ideal choice for SC442 due to their low forward voltage drop and fast switching speed. Table 4 shows several different Schottky diodes that work well with the SC442. Make sure that the diode has a voltage rating greater than the possible maximum ouput voltage, plus margin. The diode conducts current only when the power switch is turned off. A diode of 1A will be sufficient for most designs.

Layout Guidelines

The SC442 contains a boost converter and the placements of the power components outside the SC442 should follow the layout guidelines of a general boost converter. The application circuit on page 17 will be used as an example. The layout illustration diagram is shown on page 18. R5 and C7 form a decoupling filter for the SC442. C7 should be placed as close as possible to the VIN and PGND to achieve the best performance. C4 and C5 are the input power filtering capacitors for the boost converter power train. L1 is the boost converter input inductor. D1 is the output rectifying diode and it is recommended that a Schottky diode be used for fast reverse recovery.

To minimize switching noise for the boost converter, the output capacitors, C1 through C3, should be placed at the bottom, as displayed on page 16, so that the loop formed by Cout, D1, and the internal switch, is the small-

Applications Information (continued)

est. The output of the boost converter is used to power up the LEDs. R6, C9 and C10 (open, not used), form the compensation network for the boost converter. C9 should return to analog ground.

Table 4. Recommended Rectifying Diodes

Part	Vendor
SS13 SS14	Vishay www.vishay.com
10BQ015	International Rectifier www.irf.com

C8 determines the soft-start time and should be connected to analog ground. R8 is the output current programming resistor for IO1 through IO10 and should return to analog ground. IOGND should also be connected to AGND.

Since there is pad at the bottom of the SC442 for heat dissipation, a copper area right underneath the pad is used for better heat spreading. On the bottom layer of the board another copper area connected through vias to the top layer, is used for better thermal performance. The pad at the bottom of the SC442 should be tied to the analog ground. The analog ground should be connected to the power ground at one point for better noise immunity.

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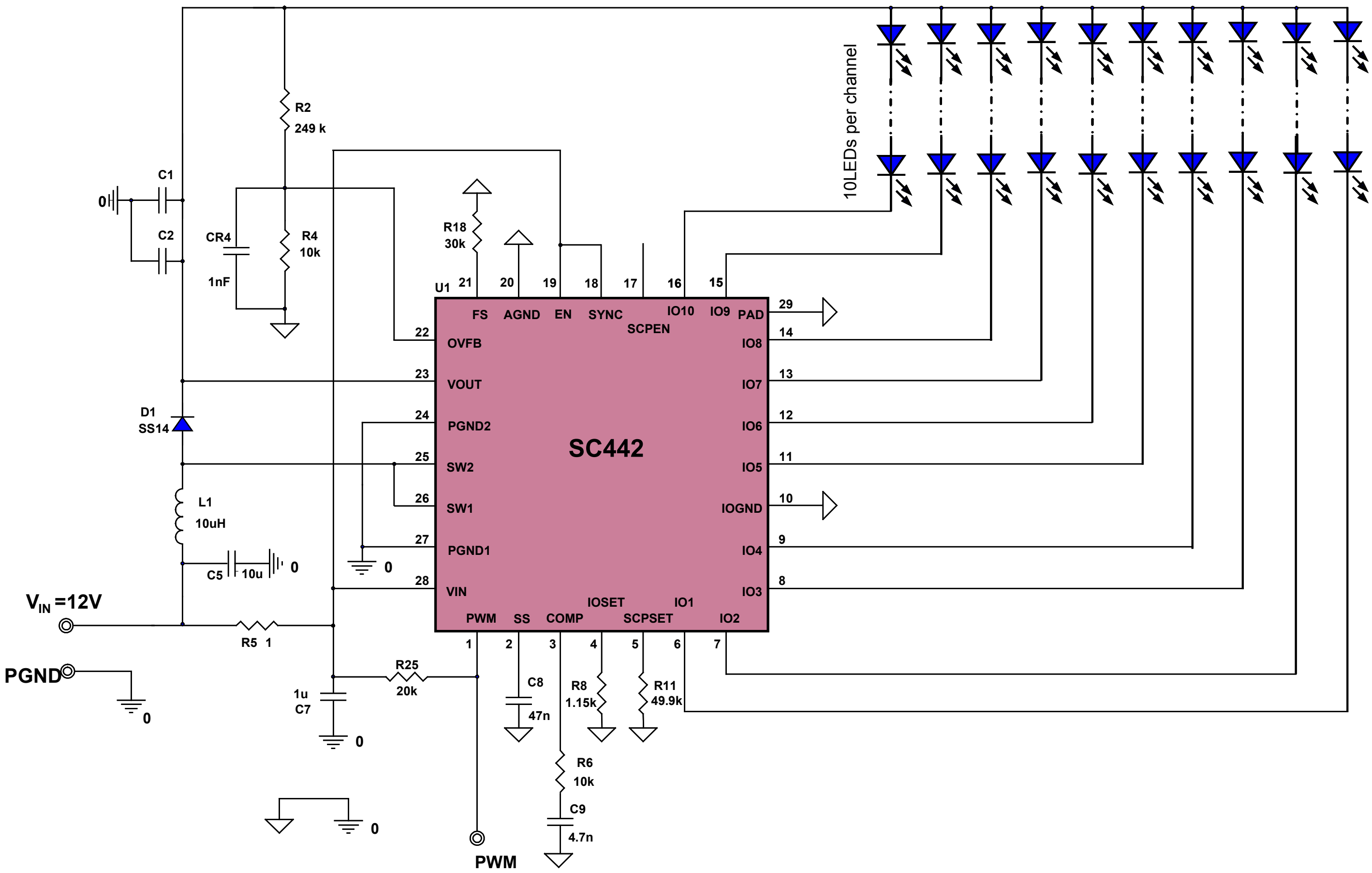
Case 1: Schematic for 10 strings 10 LED per string application



Item	Quantity	Reference	Part
1	1	U1	SC442, high efficiency, integrated, 120 LED driver IC, Semtech
2	1	CR4	1nF
3	2	C2, C1	4.7uF, 50V, 1210, Murata
4	1	C5	10u, 35V, 1206, Murata
5	1	C7	1u, 50V, 0805, Murata
6	1	C8	47n
7	1	C9	4.7n
8	1	D1	SS14
9	1	L1	10u/vishay,IHLP2525CZ1
10	1	R2	249 k
11	1	R25	20k
12	2	R4, R6	10k
13	1	R8	1.15k
14	1	R11	49.9k
15	1	R5	1
16	1	R18	30k

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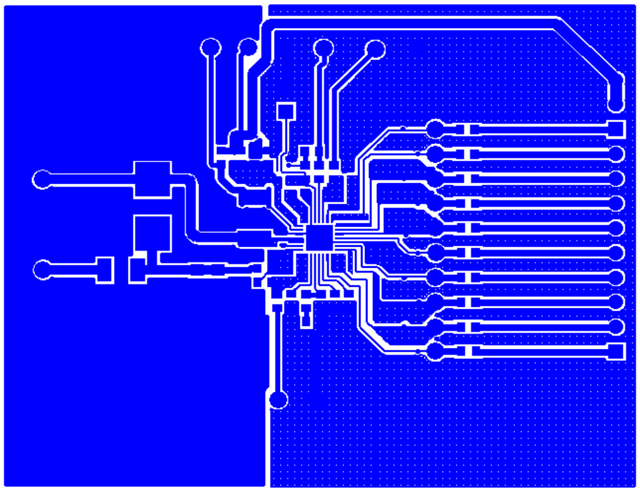
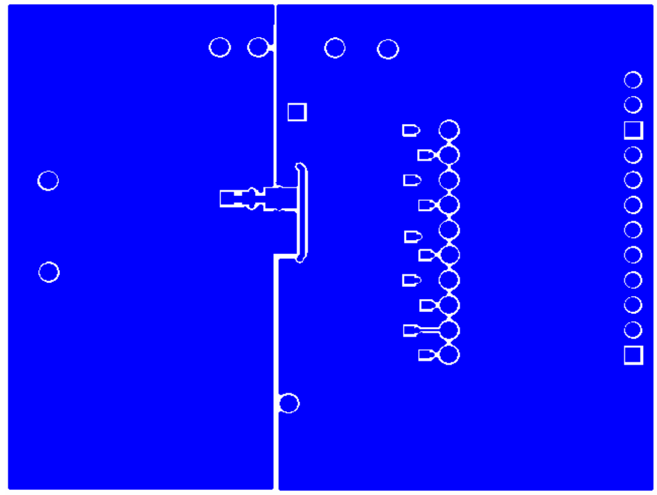
Layout Illustration Diagrams

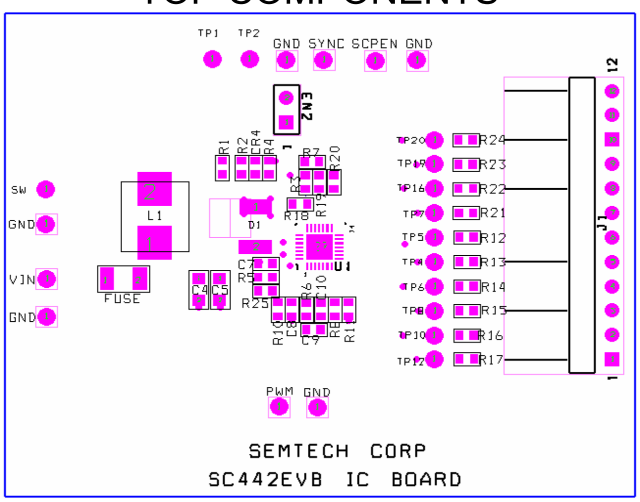
TOP LAYOUT



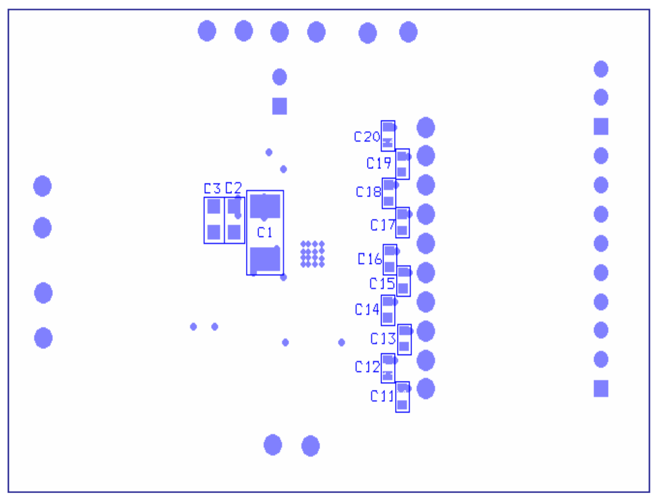
BOTTOM LAYOUT



TOP COMPONENTS



BOTTOM COMPONENTS



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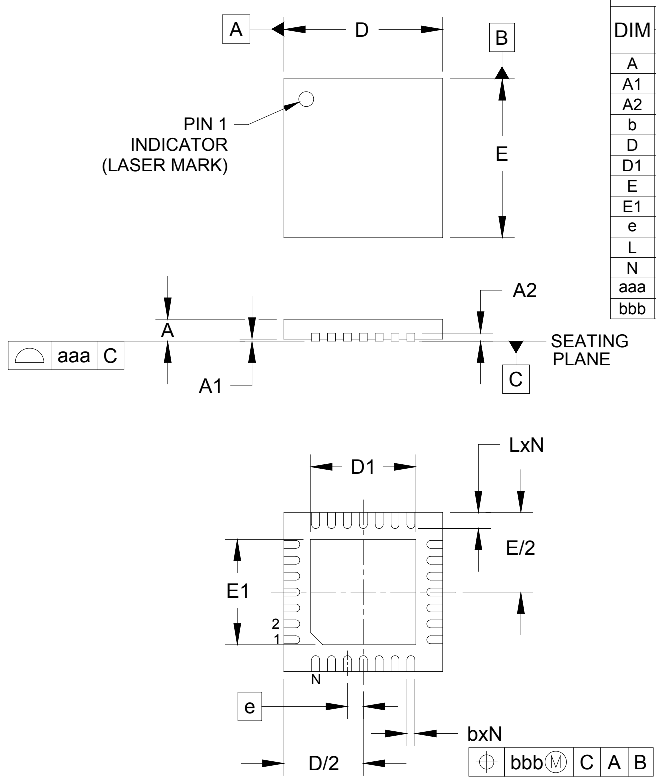
Outline Drawing - MLPQ-UT28, 4mm x 4mm x 0.6mm



DIM	DIMENSIONS					
	INCHES			MILLIMETERS		
	MIN	NOM	MAX	MIN	NOM	MAX
A	.020	-	.024	0.50	-	0.60
A1	.000	-	.001	0.00	-	0.02
A2	(.006)			(0.152)		
b	.006	.008	.010	0.15	0.20	0.25
D	.154	.157	.161	3.90	4.00	4.10
D1	.100	.104	.108	2.55	2.65	2.75
E	.154	.157	.161	3.90	4.00	4.10
E1	.100	.104	.108	2.55	2.65	2.75
e	.016 BSC			0.40 BSC		
L	.012	.016	.020	0.30	0.40	0.50
N	28			28		
aaa	.003			0.08		
bbb	.004			0.10		

NOTES:

1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS (ANGLES IN DEGREES).
2. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

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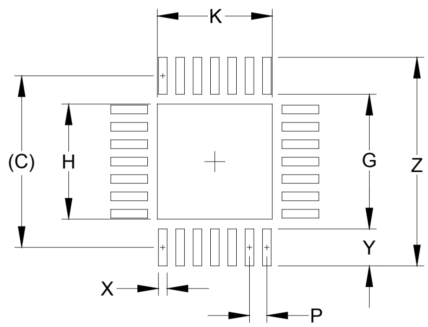
Land Pattern - MLPQ-UT28, 4mm x 4mm x 0.6mm



DIMENSIONS		
DIM	INCHES	MILLIMETERS
C	(.156)	(3.95)
G	.122	3.10
H	.104	2.65
K	.104	2.65
P	.016	0.40
X	.008	0.20
Y	.033	0.85
Z	.189	4.80

NOTES:

1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS (ANGLES IN DEGREES).
2. THIS LAND PATTERN IS FOR REFERENCE PURPOSES ONLY. CONSULT YOUR MANUFACTURING GROUP TO ENSURE YOUR COMPANY'S MANUFACTURING GUIDELINES ARE MET.
3. THERMAL VIAS IN THE LAND PATTERN OF THE EXPOSED PAD SHALL BE CONNECTED TO A SYSTEM GROUND PLANE. FAILURE TO DO SO MAY COMPROMISE THE THERMAL AND/OR FUNCTIONAL PERFORMANCE OF THE DEVICE.
4. SQUARE PACKAGE-DIMENSIONS APPLY IN BOTH X AND Y DIRECTIONS.

Contact Information

Taiwan	Tel: 886-2-2748-3380 Fax: 886-2-2748-3390	Switzerland	Tel: 41-32-729-4000 Fax: 41-32-729-4001
Korea	Tel: 82-2-527-4377 Fax: 82-2-527-4376	United Kingdom	Tel: 44-1794-527-600 Fax: 44-1794-527-601
Shanghai	Tel: 86-21-6391-0830 Fax: 86-21-6391-0831	France	Tel: 33-(0)169-28-22-00 Fax: 33-(0)169-28-12-98
Japan	Tel: 81-3-6408-0950 Fax: 81-3-6408-0951	Germany	Tel: 49-(0)8161-140-123 Fax: 49-(0)8161-140-124

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