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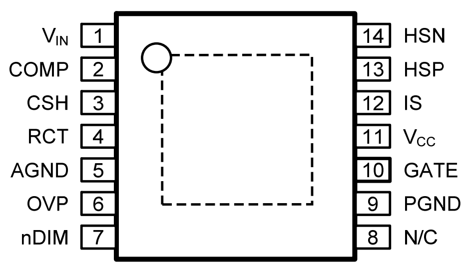
LM3429 BUCK-BOOST Nuventix

Reference design and Evaluation PCB

The demonstration board includes a LM3429 device that converts 9VDC to 36VDC input to a 700mA constant current output designed to operate a load of three to eight series LEDs. This is a 4-layer board having input voltage and ground as the two internal planes. The design has been made assuming there are analog dimming requirements.

A bill of materials below describes the parts used on this demonstration board. A schematic and layout have also been included below along with measured performance characteristics of this demo board.



LM3429

LM3429 NUVENTIX Schematic

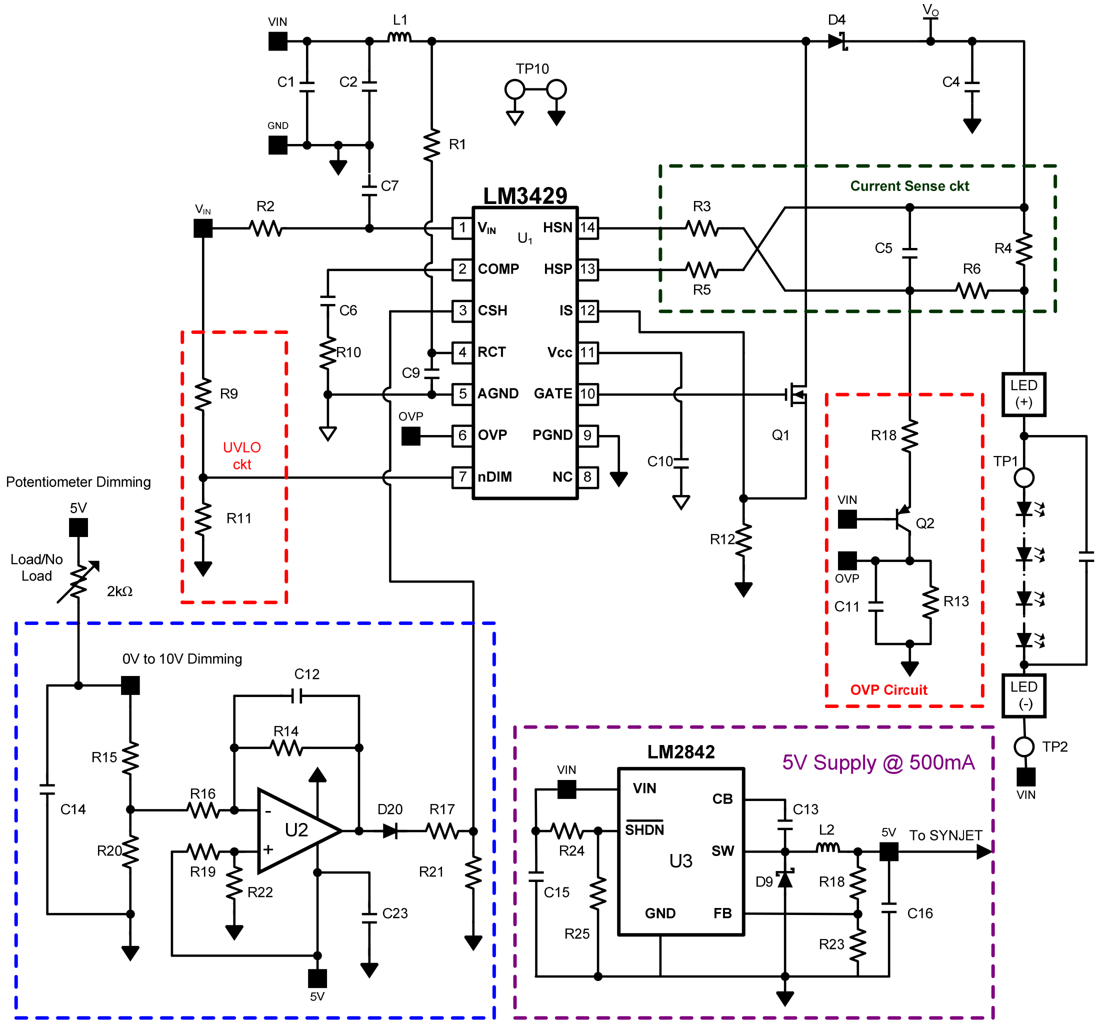


FIGURE 1: LM3429 SCHEMATIC 9VDC – 36VDC WITH ANALOG DIMMING

SETTING AVERAGE LED CURRENT

The LM3429 uses peak current-mode control to regulate the boosted output voltage. An external current sense resistor R_{SENSE} (i.e. R4) in series with the LED load is used to convert the LED current, I_{LED}, into a voltage that is sensed by HSP and HSN. HSP and HSN are the inputs to a high side sense amplifier that is used in combination with a resistor tied to CSH (pin 4) and an error amplifier to program a desired I_{LED} current.

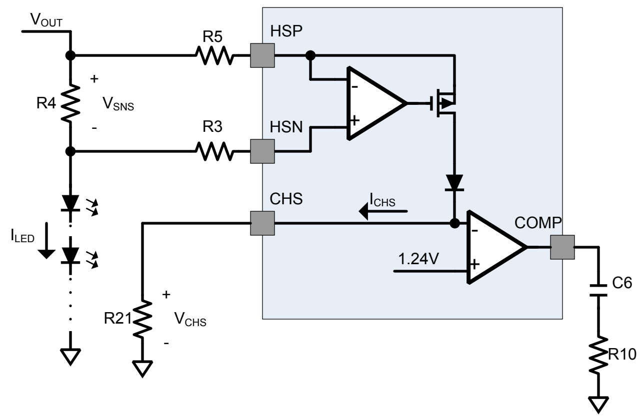


FIGURE 2: HIGH-SIDE SENSING CIRCUIT

This establishes a current gain determined by a resistor ratio consisting of R21 and R5 along with R4 as described in the equation:

$$I_{LED} = \left(\frac{R5}{R21}\right) \times \left(\frac{1.24V}{R4}\right)$$

I_{LED} current of 500mA:
R9 = 200mΩ
R5 = R3 = 1kΩ
R12 = 12.4KΩ

I_{LED} current of 700mA:
R4 = 150mΩ
R3 = R5 = 1kΩ
R21 = 11.8KΩ

Setting Switching Frequency

$$f_{SW} = \frac{25}{C_T \times R_T} = 600\text{kHz}$$

Choose C_T (C9) = 1000pF
Therefore: R_T (R1) = 41.2kΩ

Calculating Input power and input current

$$\frac{P_{OUT}}{P_{IN}} = \eta$$

Therefore:

$$\frac{V_{OUT} \times I_{LED}}{V_{IN} \times I_{IN}} = \eta$$

V_{OUT} equals $V_{LEDSTACK}$ which equals the forward voltage drop of a single LED times the number of series connected LEDs. The sense voltage across R4 (typically 100mV to 200mV) can also be added.

$V_{OUT} = V_{LEDSTACK} = (V_{FD}$ x # of LEDs + $V_{SNS})$

The input voltage range is usually known, and therefore the input current can easily be calculated.

$$I_{IN} = \frac{V_{OUT} \times I_{LED}}{V_{IN} \times \eta}$$

Efficiencies can be empirically calculated on the bench, or assumed for the initial design. Designs using the Buck-Boost topology will easily achieve efficiencies between 85% and 95% depending on external component choices.

INDUCTOR SELECTION

The inductor should be chosen so that the current ripple (Δi_L) is between 35% and 50% of the average current ($\langle I_L \rangle$) through the inductor.

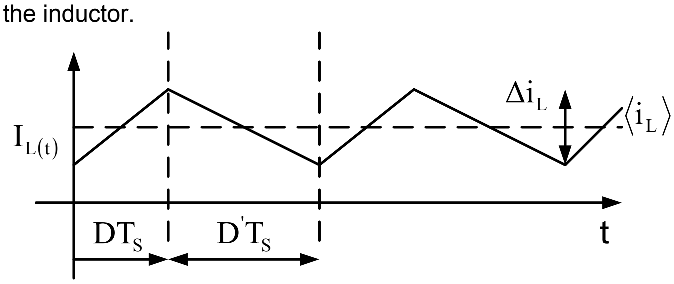


Figure 3: Inductor Current Waveform

For a given LED string voltage (V_O), the greatest peak ripple is seen when the input voltage is at its greatest magnitude. To better explain the design process of choosing an inductor, a simple example is given.

NUVENTIX - Design Example:
$V_O \approx 6 \text{ X } 3.5V = 21V$
$V_{IN\text{-}MIN} = 10V$
$V_{IN\text{-}NOM} = 16V$
$V_{IN\text{-}MAX} = 26V$
$I_{LED} = 0.70A$

Buck-Boost Conversion Ratio: $\left(\frac{V_O}{V_{IN}}\right) \approx \left(\frac{D}{D'}\right)$

Therefore: $D \approx \left(\frac{V_O}{V_{IN} + V_O}\right)$

D @ $V_{IN\text{-}MAX} \approx 0.45$
D @ $V_{IN\text{-}MIN} = 0.68$

$$f_{SW} = \left(\frac{25}{C_t \times R_t}\right) \approx 600\text{kHz}$$

$$D = \left(\frac{t_{ON}}{t_{ON} + t_{OFF}}\right) = t_{ON} \times f_{SW}$$

Calculate average input current: The average input current is equal to the average inductor current.

$$\left(\frac{P_O}{P_{IN}}\right) = \eta$$

Assume efficiency = 85%

$$\left(\frac{V_O \times I_{LED}}{V_{IN} \times I_{IN}}\right) = 0.85$$

I_{IN} AVG = 1.5A @ V_{IN} = 12V
I_{IN} AVG = 0.75A @ V_{IN} = 24V

Set inductor current ripple for 40% of average current.

ΔI_{IN} = 1.5A x 0.40 = 600mA (V_{IN} = 12V)
ΔI_{IN} = 0.75 x 0.40 = 300mA (V_{IN} = 24V)

$$V_{IN} = L\left(\frac{di}{dt}\right)$$

Therefore: $L = V_{IN}\left(\frac{dt}{di}\right) = V_{IN}\left(\frac{D}{\Delta i \times f_{SW}}\right)$

60uH @ V_{IN} = 24V
Use standard value of 47uH

PEAK CURRENT LIMIT

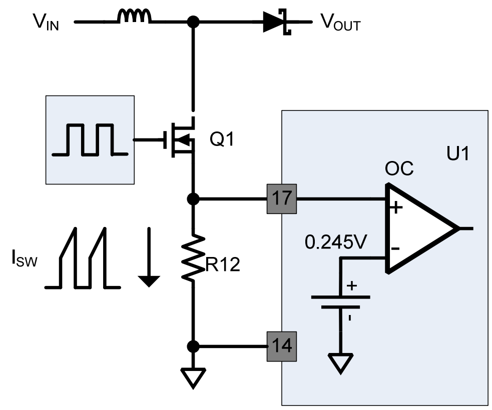


FIGURE 3: EXTERNAL R_{SENSE} I_{SW} CURRENT SENSE

$$\left(\frac{P_{OUT}}{P_{IN}}\right) = \left(\frac{V_{OUT} \times I_{LED}}{V_{IN} \times I_{IN\text{-}AVG}}\right) = \eta$$

$$I_{IN\text{-}AVG} = \left(\frac{V_{OUT} \times I_{LED}}{V_{IN} \times \eta}\right) = \left(\frac{21 \times 0.7A}{12V \times 0.85}\right) = 1.45A$$

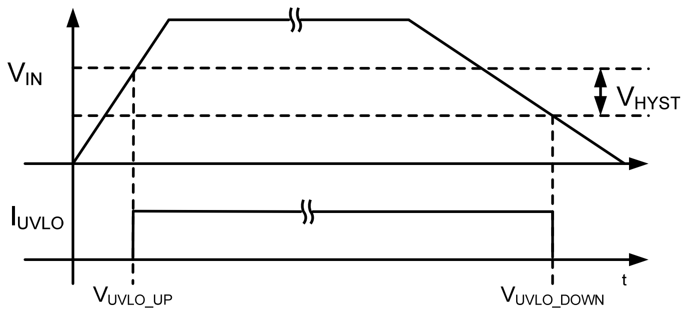
The current limit (I_{CL}) is calculated by the equation:

$$I_{CL} = \left(\frac{0.245V}{R12}\right)$$

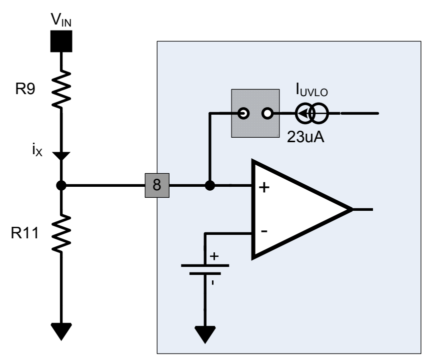
Substituting in the resistor value as listed in the board schematic (0.06Ω) gives a current limit I_{CL} of approximately 4.1A.

UNDER-VOLTAGE PROTECTION

The LM3429 can be configured for under-voltage lockout (UVLO) protection with hysteresis using the dimming input nDIM and a resistor divider from input voltage to ground. UVLO protects the power devices during power supply startup and shutdown to prevent operation at voltages less than the minimum operating input voltage. The UVLO threshold is set up by the resister divider network of R9 and R11 (see figure below).

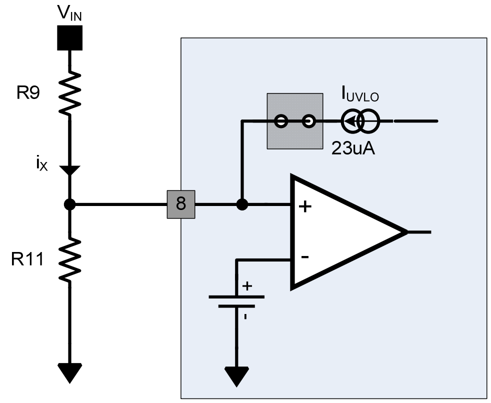


UVLO CIRCUIT SIGNATURE



UVLO CIRCUIT DURING START-UP

The UVLO threshold and hysteresis can be programmed completely independent of each other. UVLO hysteresis is accomplished with an internal 23µA current source that is switched on and off into the impedance of the UVLO set-point resistor divider. When the UVLO pin exceeds 1.24V, the current source is activated to instantly raise the voltage at the UVLO pin. When the UVLO pin voltage falls below the 1.24V threshold, the current source is turned off, causing the voltage at the UVLO pin to fall.



UVLO CIRCUIT DURING NORMAL OPERATION

Step 1: Choose V_{IN} voltage where converter starts to operate (V_{UV_UP}) and choose V_{IN} voltage where converter shuts down (V_{UV_DN}). V_{HYST} = (V_{UVLO_UP} - V_{UV_DN})

Step 2: Solve for resistor value R9 with the following equation.

$$R9 = \frac{V_{HYST}}{23uA}$$

Solve for resistor value R11 wit the following equation:

$$R11 = \left(\frac{R9 \times 1.24V}{V_{INUV\_UP} - 1.24V} \right)$$

Example Calculation of UVLO with Hysterisis:

- V_{IN} start-up = V_{UV_UP} = 7.0V
- V_{IN} shut down = V_{UV_DN} = 4.75V
- I_{UVLO} = 23_{uA}
- V_{HYST} = 7.0V – 4.75V = 2.25V
- R9 ≈ 90.9kΩ
- R11 ≈ 20.0kΩ

OVERVOLTAGE PROTECTION
An over-voltage protection (OVP) with programmable hysteresis feature is available on the LM3429 to protect the device from damage when the output voltage goes above a maximum value.

The OVP threshold is set up by the resister divider network of R11 and R18 which is referenced to the regulated output voltage (V_O). The OVP threshold and hysteresis can be programmed completely independent of each other. OVP hysteresis is accomplished with an internal 23µA current source that is switched on and off into the impedance of the OVP set-point resistor divider. When the OVP pin exceeds 1.24V, the current source is activated to instantly raise the voltage at the OVP pin. When the OVP pin voltage falls below the 1.24V threshold, the current source is turned off, causing the voltage at the OVP pin to fall.

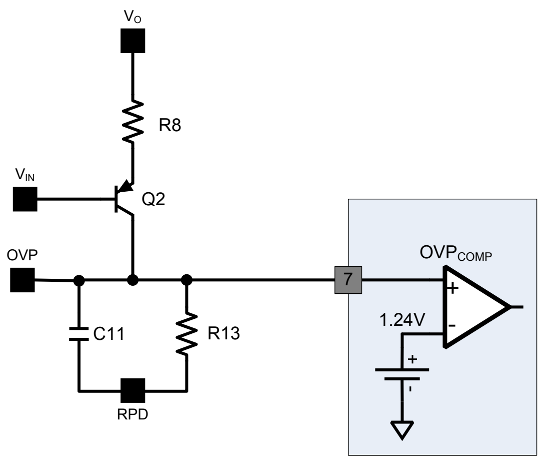


Figure 8: OVP circuit

1. Choose $V_{OVP\text{-}UP}$
2. Choose $V_{OVP\text{-}DN}$
3. Calculate OVP hysterisis $V_{HYST} = (V_{OVP\text{-}UP} – V_{OVP\text{-}DN})$
4. Calculate R8.

$$R8 = \frac{V_{HYST}}{23uA}$$

The V_O OVP release point (which includes the OVP hysteresis) is described by the equation:

$$R13 = \left(\frac{R8 \times 1.24V}{V_{OVP\_UP} - 1.24V} \right)$$

The evaluation board is already configured with OVP, and the V_O OVP threshold is programmed on the evaluation board to 26V with 4V of hysteresis.

OVP hysterisis = 4V
R8 = 174kΩ
R13 = 8.66kΩ

Main Switching MosFET
The maximum voltage seen across the switching MosFET (Q1) is equal to V_{IN} plus the LED stack voltage. One must rate the MosFET accordingly with sufficient margin.

$V_{DS} > (V_{IN}+V_{LEDSTACK})$

The MosFET current rating should be greater than the average current seen by the MosFET under worst case operating conditions with sufficient margin.

$I_{DS} > (I_{IN} \times D)$

Rectifier Diode

The output rectifier diode (D1) should be chosen accordingly.

Reverse voltage rating:
$V_{D\text{-}REV} > (V_{IN}+V_{LEDSTACK})$

Average current rating"
$I_{FD} > (I_{IN} \times D')$, or I_{LED}

Potentiometer Dimming: - Change the following values to create variable resistance dimming.

- Load 2kΩ Potentiometer
- R15, R16, R19, R22 = 2.0kΩ resistor
- R20 = 2.61kΩ resistor
- R14 change to 8.06kΩ resistor

0V to 10V Dimming: - Change the following values to create 0V to 10V dimming. 0V to 1V equals off, 8V to 10V is fully on, and everything in between is linear dimmed.

- No Load 2kΩ Potentiometer
- R14, R15, R16, R19, R20, R22 = 2.0kΩ resistor

Compensation

Compensation Design Criteria

- D = 0.68 (worst case scenario)
- V_{IN} = 12V
- V_O = 21V
- f_{SW} = 600 kHz
- C_O = 22uF (ceramic)
- C8 = 0.1uF (compensation capacitor)
- R2 = 0Ω (compensation resistor)
- R_D = 3Ω (LED dynamic resistance)
- R_{GM} = 4MΩ (internal amplifier impedance)
- L = 47uH

The internal trans-conductance amplifier resistance along with C8 forms a pole at about 0.5Hz.

$$f_{PGM} = \frac{1}{2\pi(C8 \times R_{GM})}$$

The compensation zero formed by C8 and R2 is not present due to the fact that R2 is 0.0 Ω.

$$f_{ZGM} = \frac{1}{2\pi(C8 \times R2)}$$

The pole associated with the output capacitor, and LED dynamic resistance is located at about 4 kHz

$$f_{P1} = \frac{(1+D)}{2\pi(C_{OUT} \times R_D)}$$

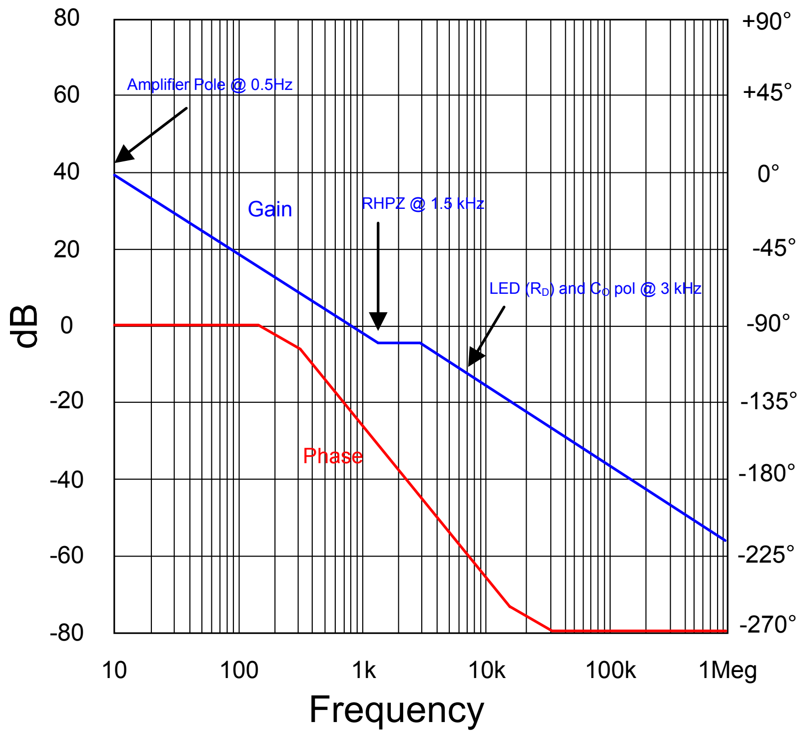
The V_{SNS} filter pole is set at about 160 kHz. At 160 kHz, it is far enough out in frequency that it wont have any bearing on the overall loop compensation.

$$f_{P\text{-}FLT} = \frac{1}{2\pi(C12 \times R20)}$$

The right half plane zero frequency location is calculated to be at 1.5 kHz

$$f_{RHPZ} = \frac{(D'^2 R_D)}{2\pi(DL)}$$

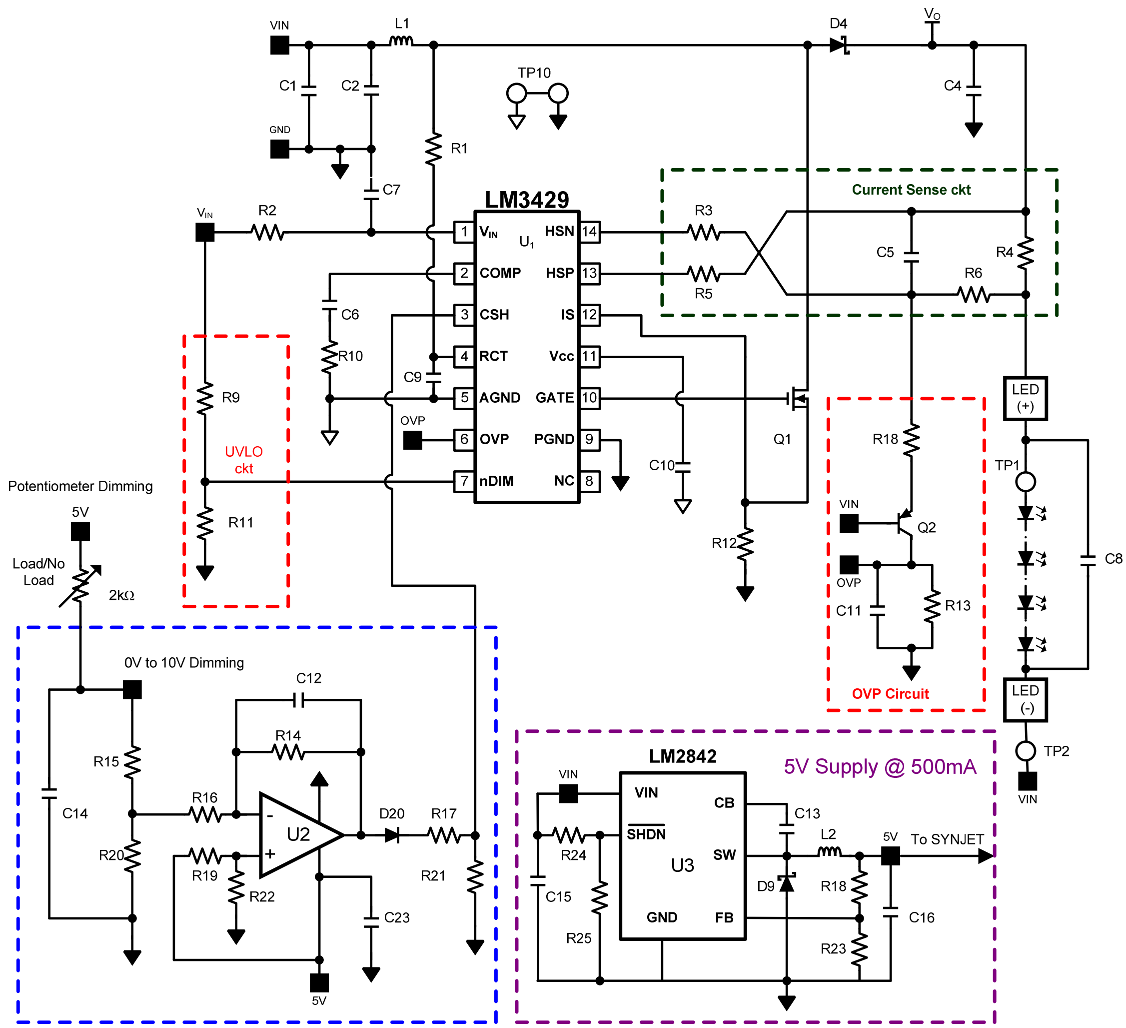
The plot below shows the Gain/Phase plot for this application.



From the illustration above the loop bandwidth is 900 Hz, and the phase margin is about 40°.

One could simply drop the amplifier pole by a slight amount to gain 45° or more of phase margin. Another solution would be to decrease the inductor value slightly to push out the RHPZ.

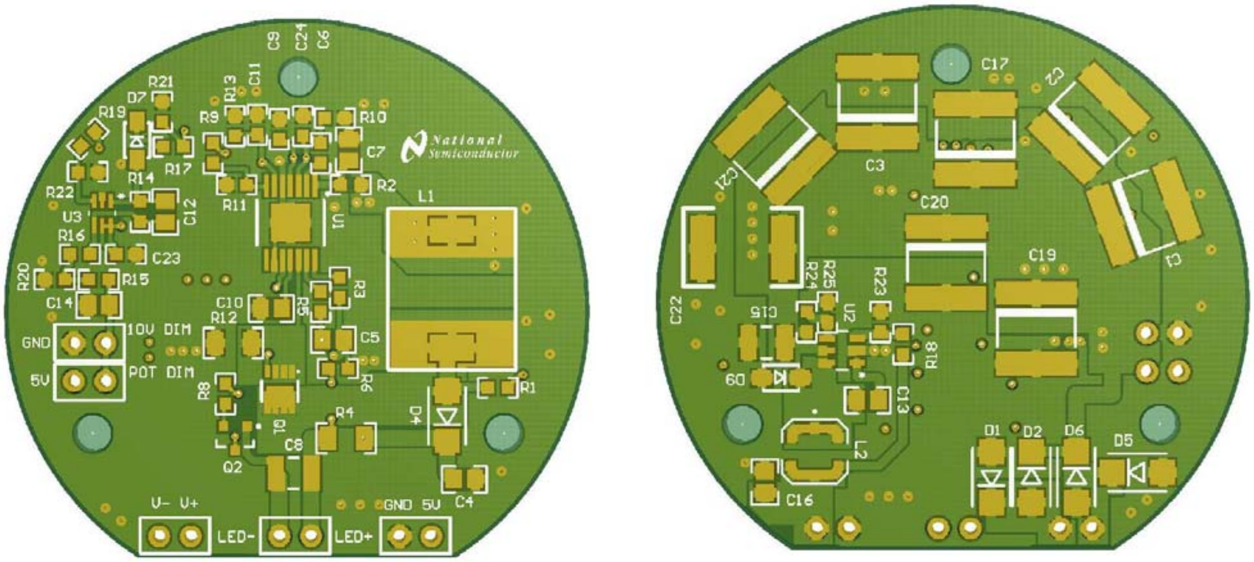
LM3429 LED driver, Dimming, Nuventix cooler schematic



LM3429 Buck-Boost: High Side Current Sense (2kΩ Potentiometer Dimming)

Part ID (DESC)	Part Value	MFG	Part Number
U1	Buck-Boost controller, TSSOP14	NSC	LM3429MH
C1, C2	10uF, X7R, 50V	TDK	C5750X7R1H106
C4, C5, C7	0.1uF, 0805	TDK	C2012X7R1H104K
C6	0.22uF, 0603	TDK	C1608X5R0J225K
C8 (Output Cap)	22uF 25V, 1210	Panasonic	GRM32ER61E226KE15L
C9	1000pF, 0603	TDK	C1608X7R1H102K
C10 (Vcc Cap)	2.2µF, 16V	TDK	C2012X5R1C225K
C11	47pF, 50V 0603	Panasonic	ECJ-1VC2A470J
D4	60V 2A SMA	ST Micro	STPS2L60A
L1	47uH	Coilcraft	MSS1038-473MLB
Q1	Power-PAK 60V	Vishay	SI7414DN
Q2	PNP Small Signal XSTR SOT23	Fairchild	MMBT3906
R1 (RCT Res)	41.2kΩ, 0603, 1%	Vishay	CRCW06034122F
R2, R6, R10	10Ω, 0603, 1%	Vishay	CRCW060310R0F
R3, R5 (HSP, HSN)	1kΩ, 0603, 1%	Vishay	CRCW06031001F
R4 (I_{LED} SNS Res)	0.15Ω, 1206	Vishay	WSL1206R1500FEA
R8 (OVP Res)	174kΩ, 0603, 1%	Vishay	CRCW06031743F
R9 (UVLO Res)	90.9kΩ, 0603, 1%	Vishay	CRCW06039092F
R11 (UVLO Res)	20.0kΩ, 0603, 1%	Vishay	CRCW06032002F
R12 (Mosfet SNS Res)	0.06Ω, 1206	Vishay	WSL2512R0600FEA
R13 (OVP)	8.66kΩ, 0603, 1%	Vishay	CRCW06038661F
R21 (CSH Res)	11.82kΩ, 0603, 1%	Vishay	CRCW060311822F
Dimming Circuit			
U2	SOT23-6	NSC	LMH6723MF
C12,C14,C23	0.1uF, 0805	TDK	C2012X7R1H104K
C24	No load		
D20	SOD123	Diodes Inc	1N4148W-7-F
R14	8.06kΩ, 0603, 1%	TDK	CRCW06038061F
R15, R16, R19, R22	2.0kΩ, 0603, 1%	TDK	CRCW06032001F
R17	22.1kΩ, 0603, 1%	TDK	CRCW06032212F
R20	2.61kΩ, 0603, 1%	TDK	CRCW06032611F
LM2842 Circuit			
U3	TSOT (1.25MHz), 600mA	NSC	LM2842YMK-ADJL
D9	40V 1A SMA	Diodes Inc	B140 -13
C15	4.7uF 1210, 50V	Murata	GRM32ER71H475KA88L
C16	47uF 6.3V	Kemet	C0805C476M9PACTU
C13	0.1uF, 0603, 16V	TDK	C1608X7R1C104K
L2	600mA	Coilcraft	LPS4018-153
R18	5.62kΩ, 0603, 1%	TDK	CRCW06035621F
R23	1.02kΩ, 0603, 1%	TDK	CRCW06031021F
R24	69.8kΩ, 0603, 1%	TDK	CRCW06036982F
R25	10.0kΩ, 0603, 1%	TDK	CRCW06031002F
V_{IN}, GND, LED+, LED-	Connector	Keystone	575-8
Test Points	Connector	Keystone	1502-2
J1, J3	Jumper	Molex	22-28-4023

Top and Bottom Layers



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