デザイン・ガイド: TIDA-080008
ディスプレイ用 LED ドライバのリファレンス・デザイン

概要

このリファレンス・デザインでは、LED / レーザー・ドライバの特性、動作、使用方法について説明します。このドライバは、テキサス・インスツルメンツの TPS92641 IC を半導体ドライバ・ソリューションとして構成し、3 チャネルのレギュレーション済み電流出力を供給して、3 個の半導体デバイスを駆動します。高効率のシングル・インダクタ同期整流降圧 (バック) コンバータ方式を採用しています。このリファレンス・デザインには、ドライバの仕様、回路図、PCB レイアウトのアートワーク、推奨のテスト・セットアップ、部品表 (BOM) が付属しており、エンド・ユーザーが特定のアプリケーションでこのドライバを実装するのが容易になります。

リソース

TIDA-080008	デザイン・フォルダ
DLPC4422 コントローラ	プロダクト・フォルダ
TPS92641	プロダクト・フォルダ
DLPA100	プロダクト・フォルダ

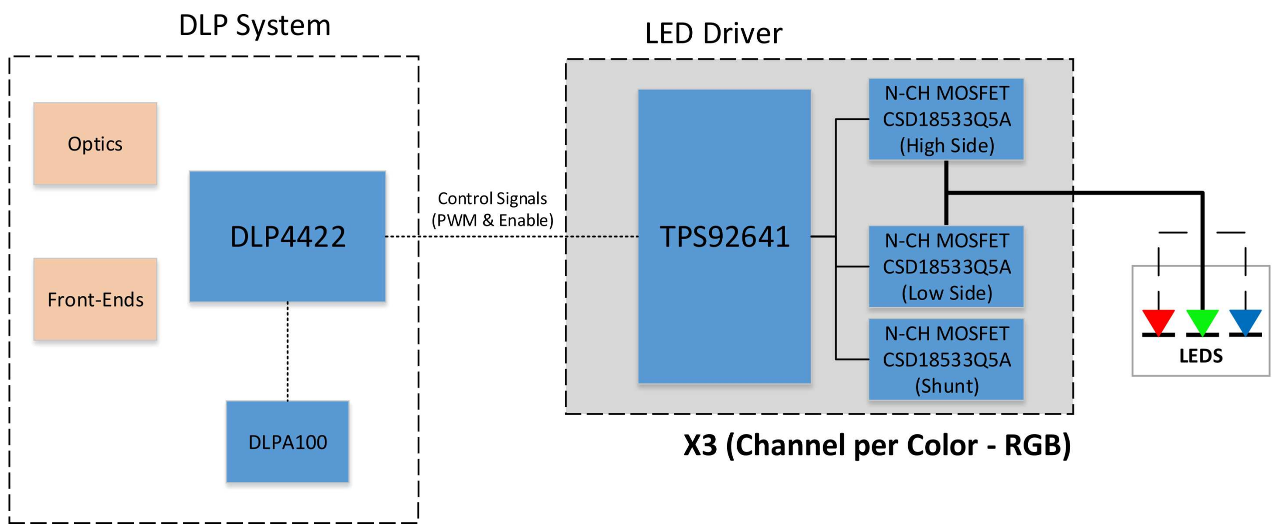
Ask our TI E2E™ support experts

特長

- 高輝度
- 低コストの BOM
- 上側ポンプ・アーキテクチャ
- 小型フォーム・ファクタ

アプリケーション

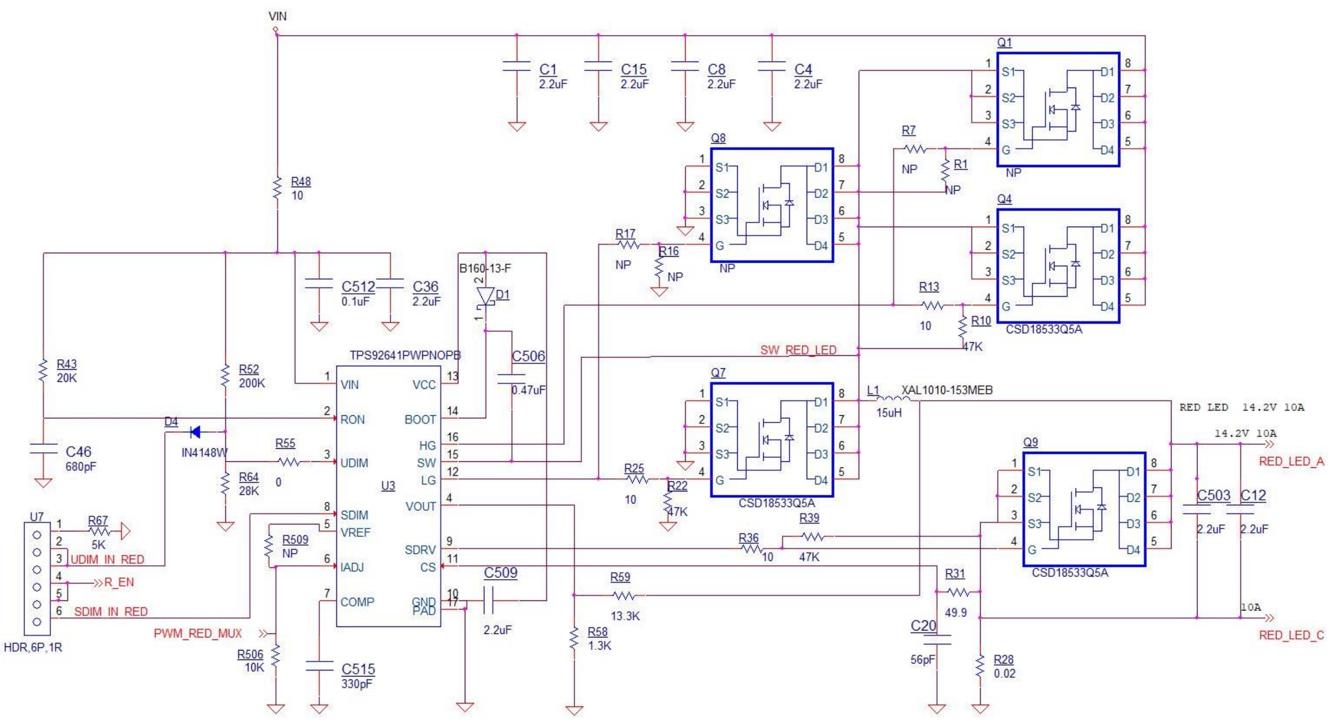
- 教室用プロジェクタ
- 企業向けプロジェクタ
- ホーム・シアター・プロジェクタ
- 産業用ディスプレイ・プロジェクタ



1 System Overview

The TPS92641 is a high-voltage and synchronous NFET controller for buck-current regulators. Output current regulation is based on valley current-mode operation using on-time control architecture. This control method eases the loop compensation design and faster transient response. The PWM controller supports both analog and PWM input signals resulting in exceptional dimming control range. A linear dimmer between input command and LED current is achieved with true zero current using a low off-set error amplifier and proprietary PWM dimming logic. Protection features include cycle-by-cycle current protection, overvoltage protection, and thermal shutdown. LED driver has 3 separate driver blocks which allows for flexible color overlap schemes. As shown in 図 1 the LED driver has 3 separate driver blocks, allowing for flexible color overlap schemes.

図 1. TPS92641



1.1 Key System Specifications

表 1 provides a summary of the TPS92641EVM performance specifications. All specifications are given for an ambient temperature of 25°C.

表 1. Driver Electrical Performance Specifications

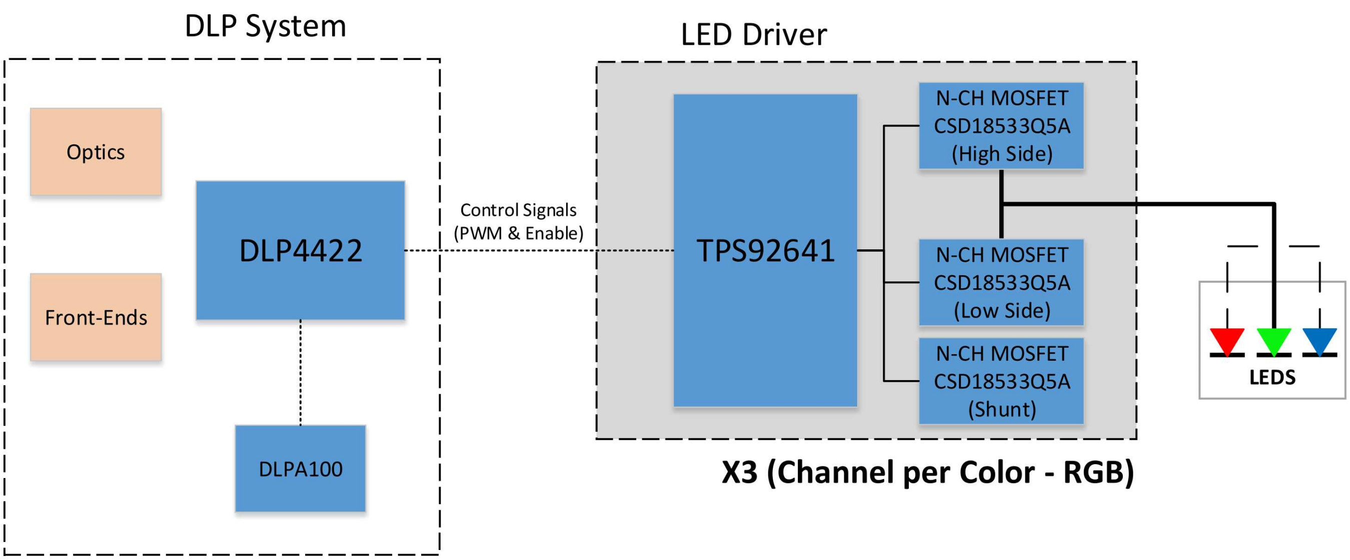
PARAMETER	NOTES AND CONDITIONS	MIN	TYP	MAX	UNIT
VIN	Input Voltage		40	48	V
VOUT	Top Side Pump Configuration for Green Channel	14.2	15.6 V	31.6 V	V
ILED		1.5		10	A
Buck Regulator Fsw			766		KHz
Dimming			50:1		
Enable Delay		7		60	uS
LED Rise Time	Based on load Capacitors value		4		uS

表 1. Driver Electrical Performance Specifications (continued)

PARAMETER	NOTES AND CONDITIONS	MIN	TYP	MAX	UNIT
LED Fall Time	Based on load Capacitors value		0.3		uS

1.2 Block Diagram

図 2. TIDA-080008 System Block Diagram



1.2 shows the LED Driver and the 3 independently controller channels, one for each color. Each channel has been configured and designed with existing series LEDS that operated at different voltage & current levels.

表 2 describes the max LED voltage and current levels that this board is configured to support.

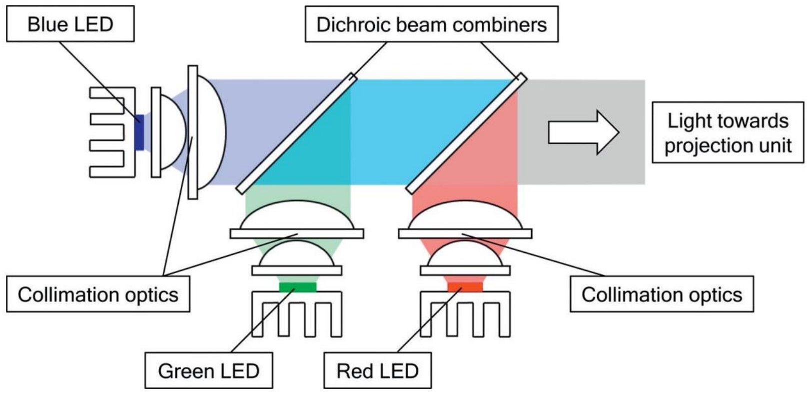
表 2. LED Operating Specs

COLOR	CURRENT (A)	VOLTAGE (V)
RED	8	14.2
GREEN	10	15.8
BLUE	10	15.8

1.3 Top Side Pump

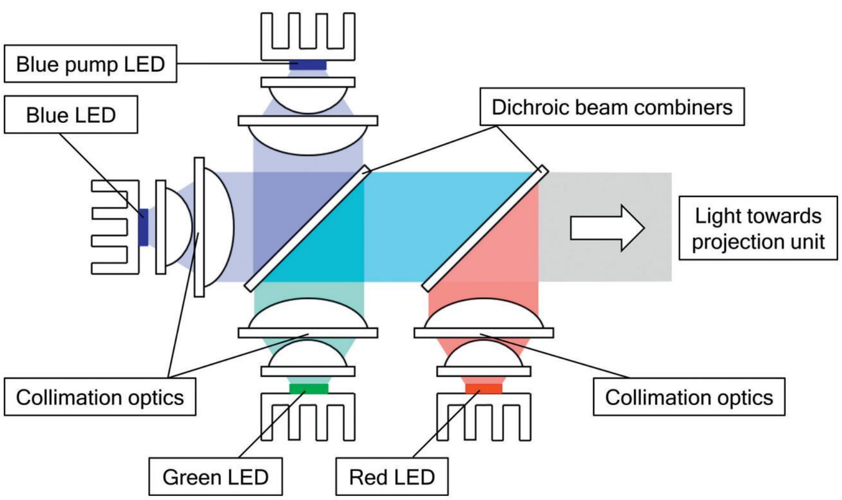
Currently LED systems are designed for a lumens level below 2000 when using the standard three channel architecture where one color (Red, green or blue) would be used per channel. As shown in 図 3, there exists a limitation from the system étendue, meaning that it is not possible increase the lumens by simply making the light emitter larger while maintaining the size of the imager (DMD) constant. This is where a new innovative concept called Top Side Pump (TSP) comes in, allowing for higher lumens with the use of a 4th LED in the system.

図 3. Three Channel Configuration



To produce a green light, manufactures take a blue LED and use a green phosphor layer to convert the blue spectrum light into green. As shown in 図 4, TSP takes advantage of this concept by adding an additional blue LED to further excite the top side of the green phosphor to have a greater green output. The result is about an enhancement of 40%, but to maintain the white point, this translates to approximately a 15% boost in lumens. The limiting factor for TSP is the red channel LED, if more red was produced, then more of the available green output could be used.

図 4. Top Side Pump Configuration



Green LED requires driving 2 diodes: Green LED and Blue pump LED together. With that in mind, here are the real voltages that are supplied for the driver to accommodate Green and Blue pump LED now requires 31.6 V to driver both diodes in series.

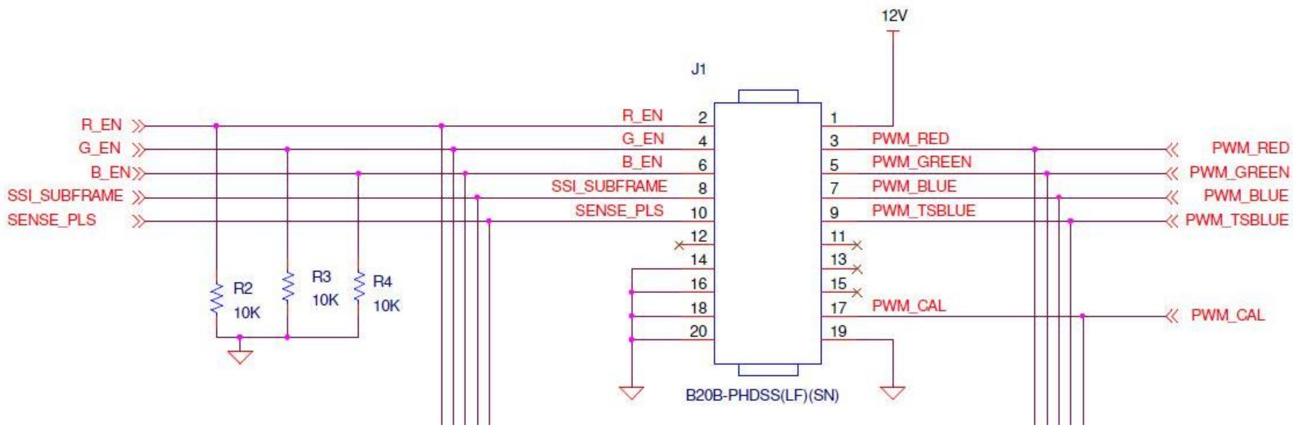
表 3. LED Operating Specs

COLOR	CURRENT (A)	VOLTAGE (V)
Red	8	14.2
GREEN	10	31.6
BLUE	10	15.8

1.4 LED Driver Input Signals

Each color receives 2 control signals ENABLE to turn LED on and off, and PWM signal which controls LED current level. Connector J1 shows all digital inputs into LED driver board including EN and PWM signals, as well as SSI_SUBFRAME, SENSE_PLS and PWM_CAL signals which are used for calibration purposes.

図 5. Driver Input Signals



1.5 LED Driver SDIM/UDIM Settings

There are 2 control signals that can be options to turn LEDs on and off – UDIM and SDIM. UDIM controls the synchronous NFET operation of the buck regulator and provides for a slower turn on of the LEDs. SDIM turns off/on shunt NFET that quickly shunts current from and to the LED providing for faster rise time. SDIM rise time is x5 faster than UDIM. SDIM fall time is x20 times faster than UDIM. LED load, as well as capacitor that is placed in parallel with the load, can influence rise/fall time of the current (current rise/fall time vs. capacitor is addressed in 2.5)

Each LED driver block has a connector that allows for flexibility of design in testing UDIM and SDIM operation. Current board is set up for SDIM operation.

図 6. UDIM/SDIM Header

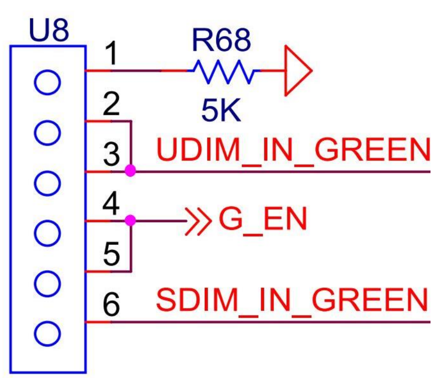


表 4. Default Jumpers

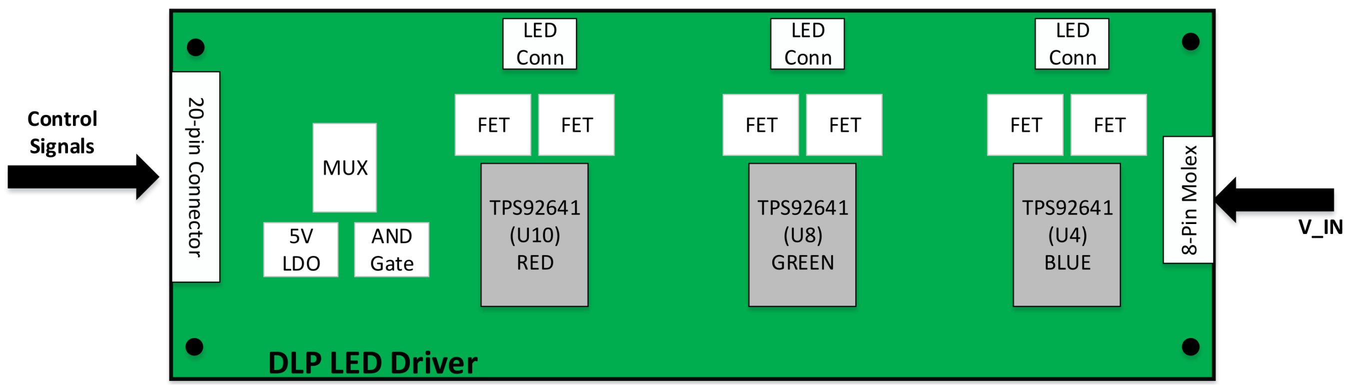
OPTIONS	CONNECTOR SETTING	OTHER REQUIREMENTS
SDIM (Default)	Jumper together pin 5 and 6	Shunt NFET must be populated
UDIM	Jumper together pin 4 and 3	Shunt NFET must be depopulated

注: **Warning:** Make sure UDIM is driven to 0 V during power up, especially when main supply that drives LEDs is on. If UDIM is left floating, it will apply constant VLED voltage/current and might damage the LED, if LED is meant to be pulsed.

1.6 TPS92641 Board Description

This reference design contains the TPS92641 IC configured as an RGB LED power solution providing three-channel regulated current output to drive red, green and blue colors with max 20 A. This application note includes a schematic diagram, PCB layouts, and a bill of materials to help the end user implement the device in their specific application.

図 7. Driver Block Diagram



1.7 Setting the LED Current and Analog Dimming

Average LED current regulation is set by using a sense resistor in-series with the LEDs. The internal error amplifier regulates the voltage across the sense resistor (VCS) to the IADJ voltage divided by 10. IADJ can be set to any value up to 2.54 V by connecting it to VREF through a resistor divider for static output current settings. IADJ can also be used to change the regulation point if connected to a controlled voltage source or potentiometer to provide analog dimming. The ILED setting is based on the equations in 式 1.

$$I_{LED} = \frac{V_{CS}}{R_{CS}}$$

$$V_{CS} = \frac{V_{IADJ}}{10} \quad (1)$$

1.8 PWM Dimming

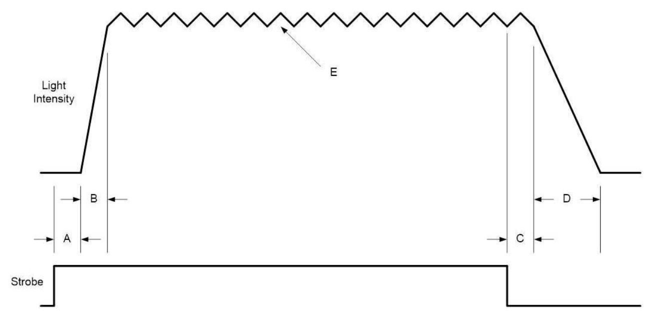
The PWM dimming can be achieved through the UDIM pin and SDIM pin. The UDIM pin can be driven with a PWM signal which controls the synchronous NFET operation. The brightness of the LEDs can be varied by modulating the duty cycle (DDIM) of the signal using a Schottky diode with anode connected to UDIM pin. The SDIM pin is controlled with an external shunt FET PWM dimming. Extremely high dimming range and linearly is achieved by shunt FET dimming operation with the SDIM and SDRV pin. When higher frequency and time resolution PWM dimming signal is applied to the SDIM pin, the SDRV pin provides an inverted signal of the same frequency and duty cycle that can be used to drive the gate of a shunt NFET directly across the LED load.

2 LED Driver Key Parameters

図 8 shows the specific characteristics of a waveform that detail the performance of any LED driver. A LED driver should be both consistent and repeatable, meaning that the light output should reach the same no matter the driver level. Referring back to the figure, we can divide a LED driver waveform to 5 main areas. The five (5) Key Parameters include the following:

- Enable Delay [A]
- Rise Time [B]
- Disable Delay [C]
- Fall Time [D]
- Ripple [E]

図 8. 5 Key Parameters



2.1 Enable and Disable Delay

Enable delay and Disable delay are the times when the driver is told to turn the light on/off and when the light actually turns on/off (typically measured with a sensor). A potential artifact from not meeting the specs is color bleed. Color bleed is when the incorrect color is being illuminated, either because the driver is too slow or too fast. An additional artifact also includes ramp smoothness issues.

2.2 Rise and Fall Time

Rise and fall times are how long it takes the light output to go from 10% to 90% and vice versa. The desired waveform should closely resemble a square wave as much as possible. The faster the time, the better the driver will perform. Keep in mind that the higher the rise time, the less margin one will have for the enable/delay. The fall time should be the same or better than the rise time. Potential issues from not having a fast rise times are ramp smoothness, PWM artifacts, CCA accuracy and dither performance.

2.3 Ripple

Lastly, the ripple is the variation of the light output. The requirements here are a little more straight forward with the max ripple equal to +/-10% and the frequency must be greater than 250 KHz. Similar artifacts as mentioned before are also possible consequences of poor ripple performance.

2.4 Performance Parameters

表 5. LED Driver Parameters

PARAMETER	MIN	MAX	IDEAL
Enable Delay	1 µS	--	1 µS

表 5. LED Driver Parameters (continued)

PARAMETER	MIN	MAX	IDEAL
Rise Time	0 µS	19 µS for LED	1 µS
Enable Delay + Rise Time	1 µS	20 µS for LED	<17 µS
Disable Delay	1 µS	--	1 µS
Fall Time	0 µS	19 µS for LED	1 µS
Disable Delay + Fall Time	1 µS	20 µS for LED	<17 µS
Ripple	>250 KHz	10 %	--

2.5 LED Load Capacitor for Rise/Fall Time

Choosing LED capacitor is very important when it comes to rise times, delay times, and current ripple. Here is a table what capacitor measurements that we made to help choose proper capacitor based on rise time and current ripple requirements. Capacitor choice might be different for Blue vs. Green LEDs. Green and top side pump are placed in parallel and are a larger load to the driver compared to just a Blue LED by itself.

表 6. Load Capacitor effect on performance

COLOR	CAP (UF)	ENABLE DELAY (US)	RISE TIME (US)	ENABLE DELAY + RISE TIME	RIPPLE PEAK TO PEAK (A)
Green	6.60	16.70	4.30	21.00	0.60
Green	4.40	12.40	4.40	16.80	0.80
Green	3.30	7.00	3.00	10.00	1.00
Green	2.20	6.50	2.70	9.20	0.60
Blue	10.0	11.20	3.60	14.80	0.64
Blue	6.60	11.50	4.80	16.30	0.56
Blue	4.40	8.70	3.40	12.10	0.72
Blue	3.30	5.50	3.30	8.80	0.60
Blue	2.20	4.00	1.90	5.90	0.56

2.6 LED Load Capacitor And Audible Noise

Ceramic capacitor are great when it comes to size and price, however, they can create audible noise in LED driver applications. As voltage across LED is turned on and off, capacitor flexes and vibrates the PCB, creating audible noise. There are two options to reducing this audible noise: layout considerations, as well as using an electrolytic capacitor.

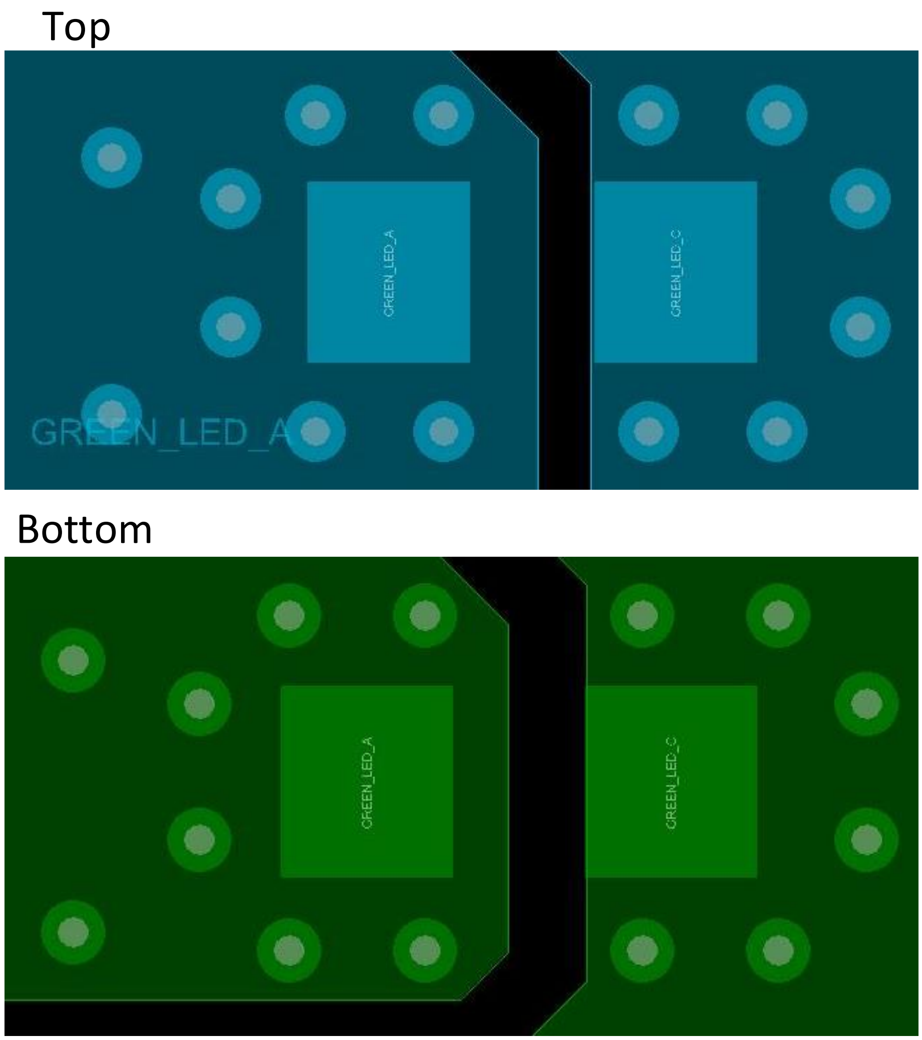
2.6.1 Layout Considerations

The two layout consideration options include:

- Place two identical capacitors directly opposite each other on the top and bottom side of the PCB. If there is only a single capacitor, it bends its middle towards the PCB and back. In doing this, the PCB is stimulated like the membrane of a loud speaker and emits acoustic waves. If two capacitors are placed opposite one another, both bend towards and away from the PCB at the same time. Thus, the PCB cannot resonate anymore.
- The second action to reduce the residual noise further is to minimize the mechanical coupling of the ceramic capacitors and the PCB. By milling holes into the PCB besides the solder points, the stimulated PCB area is reduced significantly. Figure 4 shows the read marked holes in the PCB around

the ceramic capacitors Top view.

図 9. LED Capacitor Layout



2.6.2 Electrolytic capacitor considerations

Electrolytic capacitors is less noisy because they don't vibrate the PCB due to their structure and packaging, however, they have higher resistance and inductance components, and can slow down LED current rise time and enable delay. 図 10 is an example of Green LED with 4.7µF ceramic load in parallel, 10A.

図 10. LED Waveform with 4.7 μF Ceramic Capacitors

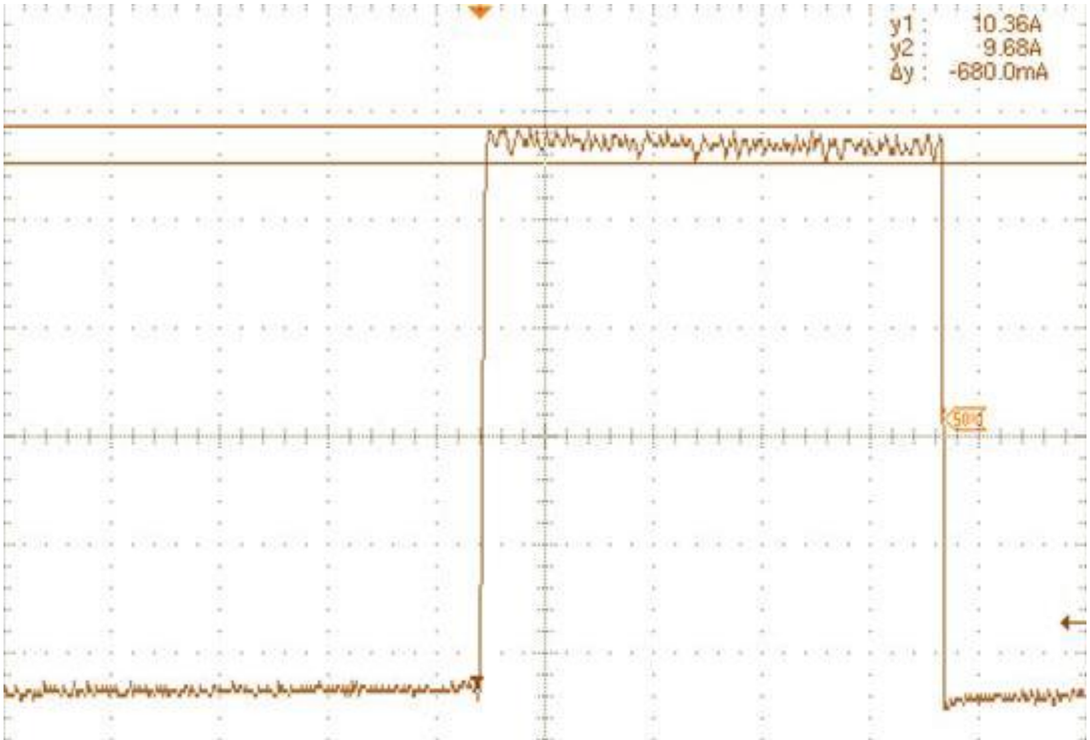


図 11 is an example of GREEN LED with 4.7μF electrolytic load in parallel, 10A.

図 11. LED Waveform with 4.7 μF Electrolytic Capacitors

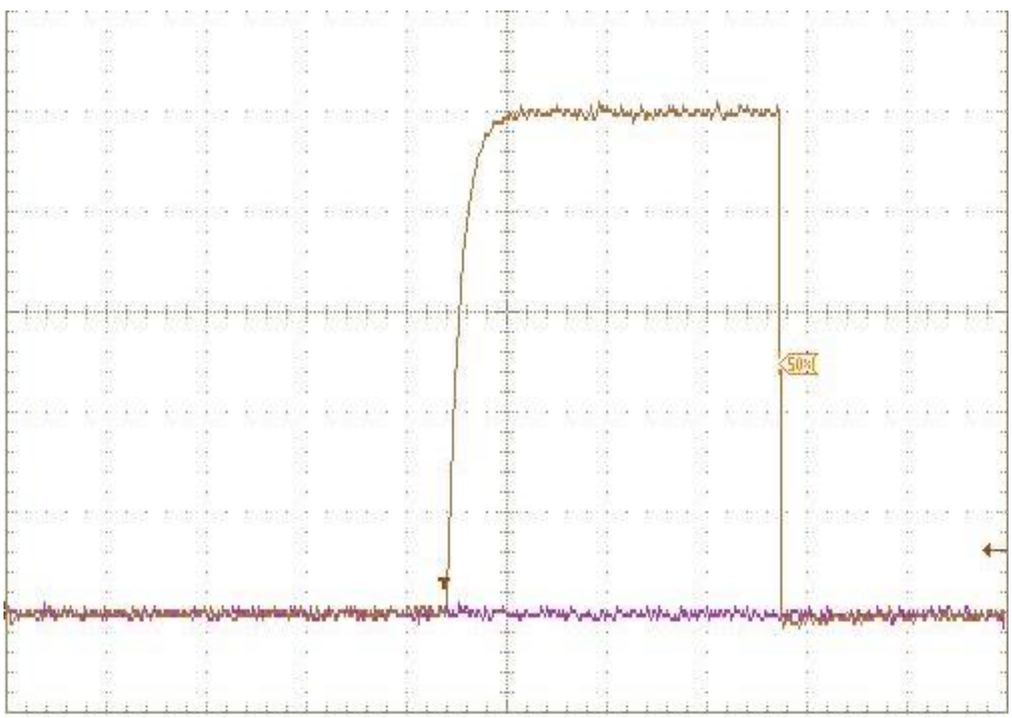


表 7 is an example of timing differences between Ceramic and Electrolytic Cap.

表 7. Driver Performance between Ceramic and Electrolytic Capacitors

COLOR	CAP VALUE (µF)	CAPACITOR TYPE	ENABLE DELAY (µS)	RISE TIME (µS)	ENABLE DELAY + RISE TIME (µS)	RIPPLE PEAK TO PEAK (A)
Green	4.70	Ceramic	9.20	3.00	12.20	1.20
Green	4.70	Electrolytic	28.00	28.50	56.50	0.40
Green	3.30	Ceramic	7.00	3.00	10.00	1.00
Green	3.30	Electrolytic	7.80	12.00	19.80	0.40
Green	2.20	Ceramic	2.70	2.70	9.20	0.60
Green	2.20	Electrolytic	10/80	10.80	15.20	0.60

2.6.3 Standoff Capacitors

For applications that have more stringent noise requirements, different capacitors can be used to mitigate any capacitor ringing that may occur at the output of the switching node. This ringing may be attributed to a piezo-electric resonant behavior with the PCB board. One solution is to use ceramic capacitors with metal terminals that physically lift the capacitor off the board.

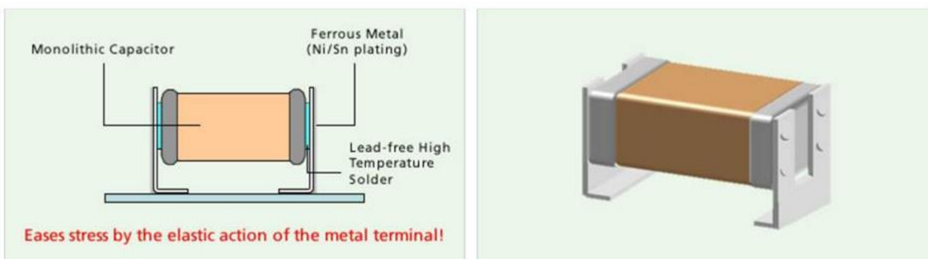
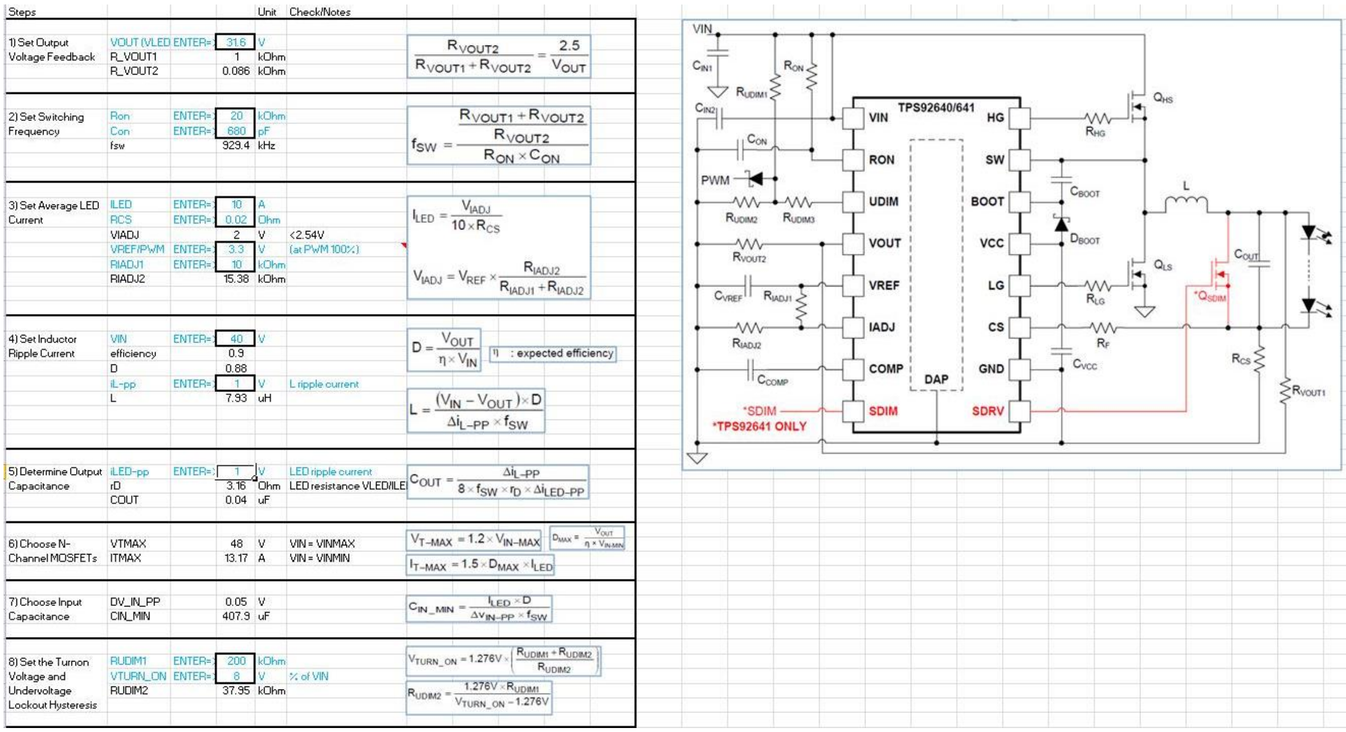


図 12. Standoff Capacitors

2.7 LED Driver Calculator Tool

If LED driver has changes based on different LED specifications or even Lasers, you can use LED Driver Components Calculator. LED driver components calculator is an excel-based calculator that allows customers to calculate various components values based on led driver specifications in tab Component Values. You can enter values in blue such as LED voltage signal, LED current and others, and the calculator will calculate the rest of the values needed for the driver to work as shown in 図 13.

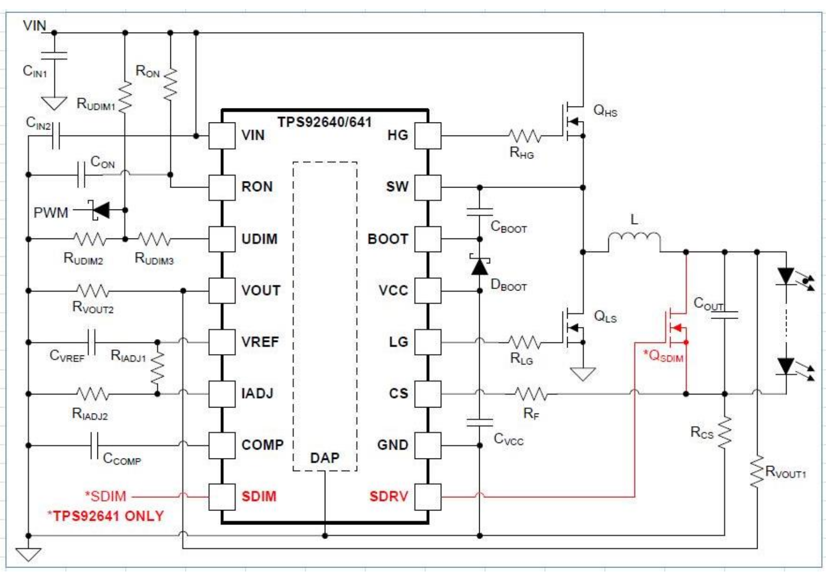
図 13. Driver Component Calculator Tool



Second tab ComponentRatings tab shown in 図 14 calculates various component ratings based on selected specs from ComponentValues tab. This should help customers choose appropriate power and voltage ratings.

図 14. Component Ratings Tool

Component	Value	Unit	Rating Name	Rating Value	Rating Unit
CIN1	407.91	uF	VIN	40	V
CIN2	10	uF	VIN	40	V
RON	20	kOhm	POWER	0.002	W
CON	680	uF	VIN	40	V
RUDIM1	200	kOhm	POWER	0.0057	W
RUDIM2	37.95359905	kOhm	POWER	0.0011	W
RVOUT1	1	kOhm	POWER	0.8468	W
RVOUT2	0.085910653	kOhm	POWER	0.0728	W
RADJ1	10	kOhm	POWER	0.0002	W
RADJ2	15.38461538	kOhm	POWER	0.0001	W
CCOMP	0.1 - 0.47	uF	VOLTAGE	25	V
RHG/RLG	4-10	Ohm	POWER	0.1	W
CBOOT	0.47	uF	VOLTAGE	48.5	V
DBOOT			VOLTAGE	48.5	V
COUT	0.04	uF	VOUT	31.6	V
RCS	0.02	Ohm	POWER	2	W
CVCC	2.2uF	uF	VCC	8.5	V
L	7.93	uH	ILpeak	25.5	A



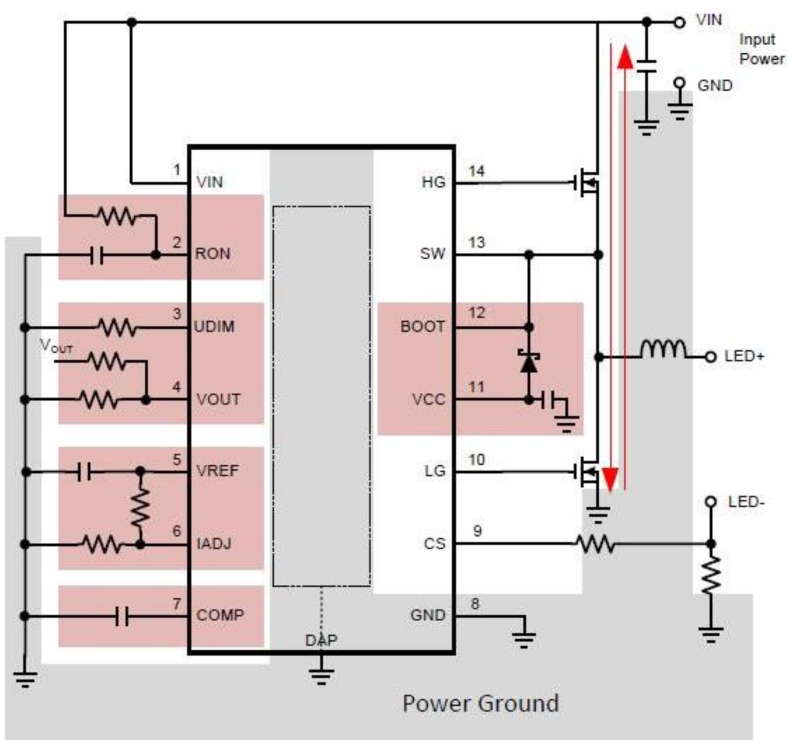
3 Layout

図 15 shows the layout guidelines taken from the TPS92641 Synchronous Buck Controllers for Precision Dimming LED Drivers data sheet.

Discontinuous currents are the most likely to generate EMI, therefore take care when routing these paths. The main path for discontinuous current in the TPS92640 and TPS92641 buck converters contain the input capacitor (CIN), the low side MOSFET (QLS), and the high side MOSFET (QHS). This loop should be kept as small as possible and the connections between all three components should be short and thick to minimize parasitic inductance. In particular, the switch node (where L, QLS, and QHS connect) should be just large enough to connect the components without excessive heating from the current it carries. The current sense trace (CS pin) should be run along with a ground plane or have differential traces run for CS and ground.

In some applications, the LED or LED array can be far away (several inches or more) from the circuit, or on a separate PCB connected by a wiring harness. When an output capacitor is used and the LED array is large or separated from the rest of the converter, the output capacitor should be placed close to the LEDs to reduce the effects of parasitic inductance on the AC impedance of the capacitor.

図 15. TPS92641 Layout Guidelines



4 Related Documentation

1. Texas Instruments, *Getting Started With TI DLP® Display Technology Application Report*
2. Texas Instruments, *TI DLP® Display & Projection Chipset Selection Guide*
3. Texas Instruments, *TI DLP® System Design: Brightness Requirements and Tradeoffs Application Report*
4. Texas Instruments, *Low-Latency, High-Speed TI DLP® Digital Projection Reference Design*
5. Texas Instruments, *4K UHD display chip sub-system Reference Design featuring DLP660TE and DLPC4422*

4.1 商標

TI E2E is a trademark of Texas Instruments.
すべての商標および登録商標はそれぞれの所有者に帰属します。

4.2 Third-Party Products Disclaimer

TI'S PUBLICATION OF INFORMATION REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE AN ENDORSEMENT REGARDING THE SUITABILITY OF SUCH PRODUCTS OR SERVICES OR A WARRANTY, REPRESENTATION OR ENDORSEMENT OF SUCH PRODUCTS OR SERVICES, EITHER ALONE OR IN COMBINATION WITH ANY TI PRODUCT OR SERVICE.

TIDUEW9 翻訳版 — 最新の英語版資料 http://www-s.ti.com/sc/techlit/TIDUEW9

重要なお知らせと免責事項

TI は、技術データと信頼性データ (データシートを含みます)、設計リソース (リファレンス・ デザインを含みます)、アプリケーションや設計に関する各種アドバイス、Web ツール、安全性情報、その他のリソースを、欠陥が存在する可能性のある「現状のまま」提供しており、商品性および特定目的に対する適合性の黙示保証、第三者の知的財産権の非侵害保証を含むいかなる保証も、明示的または黙示的にかかわらず拒否します。

これらのリソースは、TI 製品を使用する設計の経験を積んだ開発者への提供を意図したものです。(1) お客様のアプリケーションに適した TI 製品の選定、(2) お客様のアプリケーションの設計、検証、試験、(3) お客様のアプリケーションに該当する各種規格や、その他のあらゆる安全性、セキュリティ、規制、または他の要件への確実な適合に関する責任を、お客様のみが単独で負うものとします。

上記の各種リソースは、予告なく変更される可能性があります。これらのリソースは、リソースで説明されている TI 製品を使用するアプリケーションの開発の目的でのみ、TI はその使用をお客様に許諾します。これらのリソースに関して、他の目的で複製することや掲載することは禁止されています。TI や第三者の知的財産権のライセンスが付与されている訳ではありません。お客様は、これらのリソースを自身で使用した結果発生するあらゆる申し立て、損害、費用、損失、責任について、TI およびその代理人を完全に補償するものとし、TI は一切の責任を拒否します。

TI の製品は、TI の販売条件、または ti.com やかかる TI 製品の関連資料などのいずれかを通じて提供する適用可能な条項の下で提供されています。TI がこれらのリソースを提供することは、適用される TI の保証または他の保証の放棄の拡大や変更を意味するものではありません。

お客様がいかなる追加条項または代替条項を提案した場合でも、TI はそれらに異議を唱え、拒否します。

郵送先住所：Texas Instruments, Post Office Box 655303, Dallas, Texas 75265