Using the TLC59144EVM-008 Four-Channel Power LED Driver with Separate Channel Control

The TLC59144EVM-008 evaluation module (EVM) allows the user to control each of the 4 output channels ($\overline{OUT}$) separately via their respective enable ($\overline{PWM}$) pins. The EVM has fixed programming resistors on each of the programming pins (REXT) to set the respective outputs to 10mA, 50mA, 100mA, or 250mA. The jumpers are configured such that they can be combined to increase the output current. The user can also supply external programming resistors. The EVM can be configured to drive a 4-color LED (one color per channel) or a sting of 3 white LEDs in series. The user can supply external LEDs as well.

Contents

List of Figures

List of Tables

1 Description

The TLC59144EVM-008 evaluation module helps designers evaluate the operation and performance of the TLC59144 four-channel LED Driver. The board features the 16-pin PowerPAD package for enhanced thermal dissipation. Each channel ($\overline{\text{OUT0}}$-$\overline{\text{OUT3}}$) is enabled by its own PWM input ($\overline{\text{PWM0}}$-$\overline{\text{PWM3}}$) and has its current set through its own external resistor (REXT0-REXT3). The Status pin indicates a system fault (LED open, LED short to ground, REXT short to ground, thermal fold-back and thermal shutdown). The Open-Drain Status pin will remain active (pulled low) while a fault is present.

There are several key components on this EVM to be discussed here. U1 is the TLC59144 4-channel LED Driver. U2, U3, U4, and U5 are TPL0501-100 256 Tap Digital Potentiometers. These devices are used as an alternative (programmable) method of setting the current on each channel of the TLC59144. D4 is a 4-color LED (RGBW) which is used to demonstrate individual control of each channel (on/off and current). D1, D2, and D3 are high brightness White LEDs that are used in series to demonstrate the ability of the TLC59144 to use channels in parallel to increase the current capability of a single string. D5 is a low power LED that is used to demonstrate the Status pin functionality (lights during error).

1.1 Typical Applications

- General LED lighting applications, LED Signage, Automotive LED lighting, Gaming / Entertainment, Architectural.

1.2 Features

- Four 400mA Constant-Current Output Channels
- Combine channels to increase current (up to 1.6A)
- Output current adjusted by external resistor (1 per output)
- Constant current range: 20mA to 400mA per channel
- Automatic current fold-back at high temperature
- Thermal shutdown for over-temperature protection
- Ideal for bright white, RGBA, RGBW, RGGB applications
- Available in 16 pin PWP (HTSSOP)

2 Electrical Performance

Table 1. TLC59144EVM-008 Electrical Performance

PARAMETER	TEST CONDITIONS (25°C)	MIN	TYP	MAX	UNITS
Input Characteristics					
VDD Voltage range		3.0		5.5	V
LED Voltage range	$\overline{OUT0}$, $\overline{OUT1}$, $\overline{OUT2}$, $\overline{OUT3}$	0		47	V
$\overline{PWM}$ Voltage range	$\overline{PWM0}$, $\overline{PWM1}$, $\overline{PWM2}$, $\overline{PWM3}$	0		VDD	V
REXT Resistance range	REXT0, REXT1, REXT2, REXT3	13.6		549	kΩ
Maximum LED current				1600	mA
Electrical Characteristics					
Output Current	549 kΩ Resistor Selected on REXT		10		mA
	107 kΩ Resistor Selected on REXT		50		
	54.9 kΩ Resistor Selected on REXT		100		
	21.5 kΩ Resistor Selected on REXT		250		
Systems Characteristics					
Maximum LED Current (RGBW)	Maximum current through any of the RGBW LEDs			400	mA
Maximum LED Current (High Brightness 3-LED String)	Maximum current through the 3-String LED array			1000	mA

3 Operation

3.1 Equipment

Voltage Sources:

- Two supplies
  - VDD supply capable of supplying 3V-5.5V at 10mA.
  - VLED supply capable of supplying 3.5V – 47V at up to 1.6A.
- Supply capable of ramping voltages (function generators may be useful) can be used to drive the $\overline{PWM}$ pins. $\overline{PWM}$ pins can simply use the VDD/GND jumpers as configured.

Multimeters:

- One to three meters can be used to measure voltages (LED Forward Voltages, $\overline{OUT0}$ to $\overline{OUT3}$).
- Ammeters may be useful for measuring currents (commonly I_{OUT} per channel, I_{DD}).

Output Load:

- LED Options:
  - The EVM has jumpers for a single RGBW (Red, Green, Blue, White) LED driven by the individual outputs.
  - The EVM has jumpers for a string of 3 W (White) LEDs that can be driven by any combination of outputs.
  - The user can opt to use their own external LEDs.
- Current options:
  - The EVM has jumpers on each REXT pin to set current levels of: 10mA, 50mA, 100mA, and 250mA.
  - The REXT jumpers can be used individually or can be used in parallel to increase the current.
  - The user can opt to use their own external resistor for setting the currents.
  - The EVM has the capability to use a TPL0501-100 Digital Potentiometer to set the resistance on each output (a series resistor must be place on the board to add this parallel resistance). Control of the TPL0501-100 is though a serial (SPI-like) interface.
  - The REXT pins cannot be left floating.

Oscilloscope:

- 4 channel 100MHz to voltages as necessary ($\overline{\text{OUT}}$ pins, $\overline{\text{PWM}}$ pins, Status pin).

Recommended Wire Gauge: 22 AWG

3.2 Evaluation Module Description

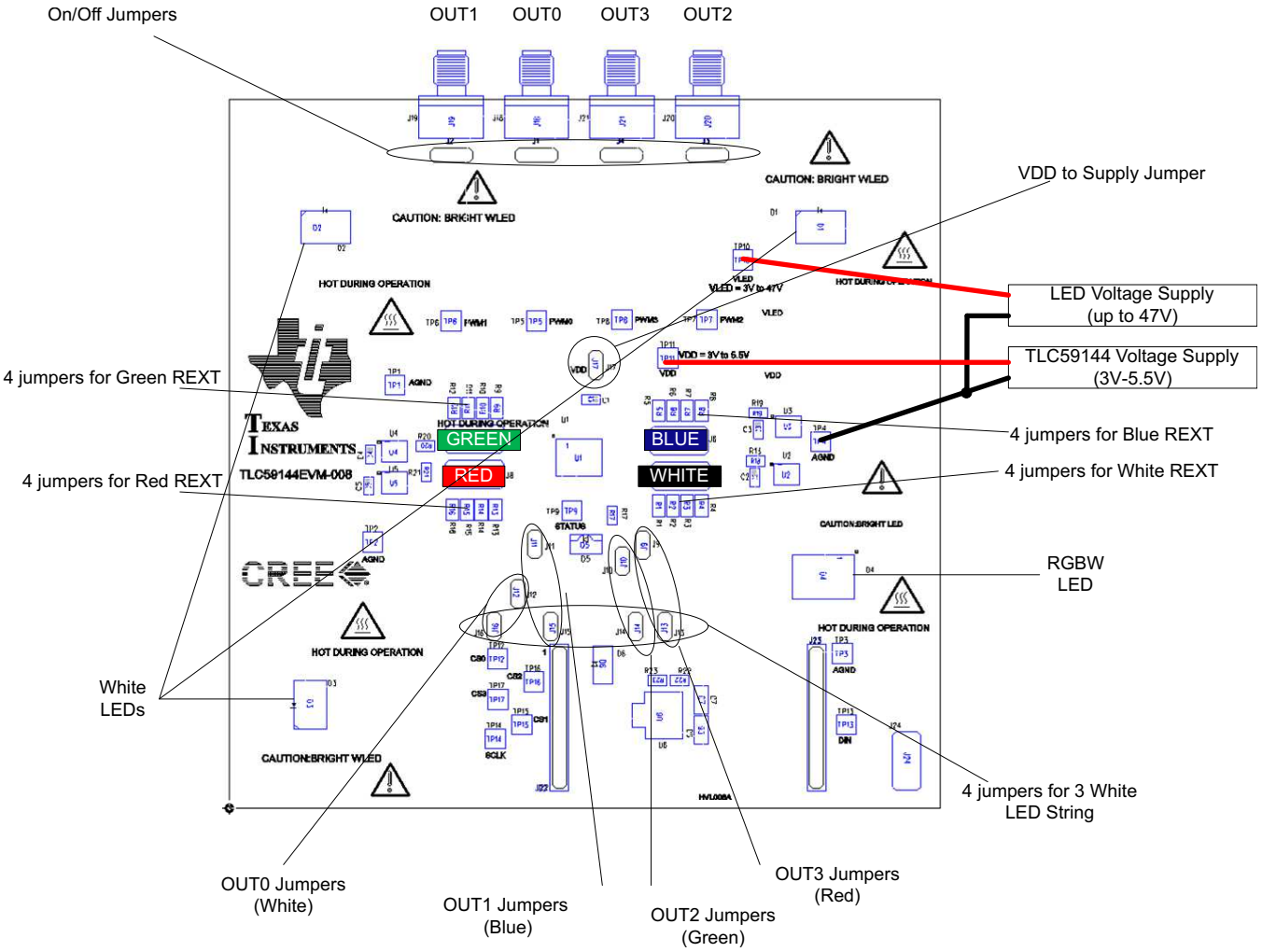


Figure 1. TLC59144EVM-008 EVM Placement

3.3 List of Test Points

Table 2. The Functions of Each Test Points

Test Points	Name	Description
TP1	AGND	System Ground
TP2	AGND	System Ground
TP3	AGND	System Ground
TP4	AGND	System Ground
TP5	$\overline{\text{PWM0}}$ (White)	Drive or monitor $\overline{\text{PWM0}}$
TP6	$\overline{\text{PWM1}}$ (Blue)	Drive or monitor $\overline{\text{PWM1}}$
TP7	$\overline{\text{PWM2}}$ (Green)	Drive or monitor $\overline{\text{PWM2}}$
TP8	$\overline{\text{PWM3}}$ (Red)	Drive or monitor $\overline{\text{PWM3}}$
TP9	STATUS	Monitor Status pin
TP10	VLED	Monitor or source LED Voltage
TP11	VDD	Monitor or source VDD Voltage
TP12	CS0	CS for DPL0501-100 (U2) for REXT0 (White)
TP13	DIN	DIN for DPL0501-100 from LaunchPad
TP14	SCLK	SCLK for DPL0501-100 from LaunchPad
TP15	CS1	CS for DPL0501-100 (U3) for REXT1 (Blue)
TP16	CS2	CS for DPL0501-100 (U4) for REXT2 (Green)
TP17	CS3	CS for DPL0501-100 (U5) for REXT3 (Red)

3.4 List of Jumper Connections

The following tables describe how each of the jumpers on the evaluation module impacts the operation of the system. The tables are organized by functions. Note that the output pins are associated with the colors of the 4-color LED, but all can also be used to drive the 3-LED string configuration as well.

Table 3 shows positions for setting currents per channel
Table 4 shows ON / OFF jumper settings for each channel by setting $\overline{\text{PWM}}$ pin low or high
Table 5 shows which external connections control each $\overline{\text{PWM}}$ pin
Table 6 shows how to control which set of LEDs is used (RGBW or 3-LED White string)
Table 7 shows the remaining jumper settings

Table 3. Current Setting Jumpers

Jumper	Pin	Output	LED Color	Position A	Position B	Position C	Position D	Open
J5	REXT0	$\overline{\text{OUT0}}$	White	549kΩ/10mA	107kΩ/50mA	54.9kΩ/100mA	21.5 kΩ/250mA	External resistor or TPL0501-100
J6	REXT1	$\overline{\text{OUT1}}$	Blue	549kΩ/10mA	107kΩ/50mA	54.9kΩ/100mA	21.5 kΩ/250mA	
J7	REXT2	$\overline{\text{OUT2}}$	Green	549kΩ/10mA	107kΩ/50mA	54.9kΩ/100mA	21.5 kΩ/250mA	
J8	REXT3	$\overline{\text{OUT3}}$	Red	549kΩ/10mA	107kΩ/50mA	54.9kΩ/100mA	21.5 kΩ/250mA	

See Figure 2 for definition of “ABCD” positions on the Current Setting Jumpers.

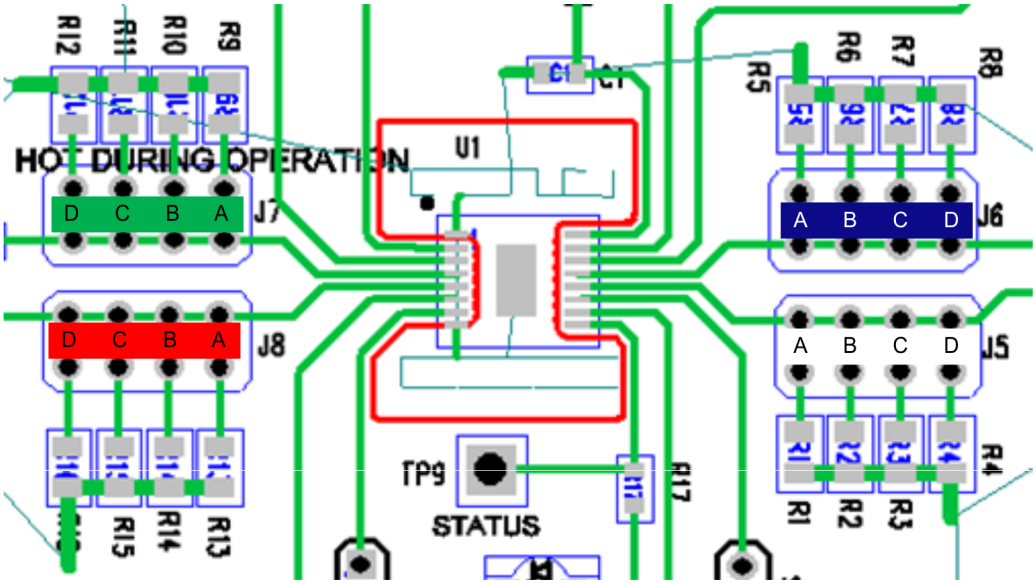


Figure 2. REXT Jumper “ABCD” Settings

Table 4. $\overline{\text{PWM}}$ Jumper Settings

Jumper	Pin	Output	LED Color	Position 1:2	Position 2:3	Open
J1	$\overline{\text{PWM0}}$	$\overline{\text{OUT0}}$	White	High / OFF	Low / ON	External control or float (OFF)
J2	$\overline{\text{PWM1}}$	$\overline{\text{OUT1}}$	Blue	High / OFF	Low / ON	
J3	$\overline{\text{PWM2}}$	$\overline{\text{OUT2}}$	Green	High / OFF	Low / ON	
J4	$\overline{\text{PWM3}}$	$\overline{\text{OUT3}}$	Red	High / OFF	Low / ON	

Figure 3 shows the definition of which pin is which function. Pin 1 is VDD. Pin 2 is the $\overline{\text{PWM}}$ for the specific channel. Pin 3 is ground.

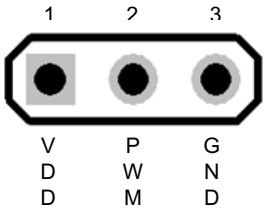


Figure 3. $\overline{\text{PWM}}$ Control Jumper Position

Table 5. External $\overline{\text{PWM}}$ Control Connections (not installed)

Connector	Pin	Output	LED Color	Note (Not populated on EVM)
J18	$\overline{\text{PWM0}}$	$\overline{\text{OUT0}}$	White	Jumper J1 must be open to use J18 to control $\overline{\text{PWM0}}$
J19	$\overline{\text{PWM1}}$	$\overline{\text{OUT1}}$	Blue	Jumper J2 must be open to use J19 to control $\overline{\text{PWM1}}$
J20	$\overline{\text{PWM2}}$	$\overline{\text{OUT2}}$	Green	Jumper J3 must be open to use J20 to control $\overline{\text{PWM2}}$
J21	$\overline{\text{PWM3}}$	$\overline{\text{OUT3}}$	Red	Jumper J4 must be open to use J21 to control $\overline{\text{PWM3}}$

Table 6. LED Selection Jumper Settings

Jumper	Pin	Installed	Not Installed
J12	$\overline{OUT0}$	White LED	Connect either jumper to drive LED Open both for Error or external LED
J16	$\overline{OUT0}$	3-LED String	
J11	$\overline{OUT1}$	Blue LED	Connect either jumper to drive LED Open both for Error or external LED
J15	$\overline{OUT1}$	3-LED String	
J10	$\overline{OUT2}$	Green LED	Connect either jumper to drive LED Open both for Error or external LED
J14	$\overline{OUT2}$	3-LED String	
J9	$\overline{OUT3}$	Red LED	Connect either jumper to drive LED Open both for Error or external LED
J13	$\overline{OUT3}$	3-LED String	

Table 7. Other Jumper Settings

Jumper	Function	Installed	Uninstalled
J17	Allow I_{DD} measurements	VDD connected to J29	Connect Ammeter
J22	Future Feature	Connection to MSP430 LaunchPad	No impact on EVM
J23	Future Feature		
J24	Future Feature		

3.5 Operation Examples

The TLC59144 allows for much flexibility in a variety of applications and the EVM can be used to demonstrate its flexibility.

Application Examples are shown in the following sections.

3.5.1 Drive Red-Green-Blue-White LED

This example (Figure 4) shows a common use of the TLC59144. The EVM is set to drive a single high-powered RGBW LED from a single 5V supply. This is set to drive 250mA through each of the LEDs. By driving the center pins of J1, J2, J3, and J4 the resulting color will change based on the duty cycle and frequency for the pins. The jumper settings for this EVM example are shown in Table 8. Alternatively, J1, J2, J3, and J4 can be used to tie their respective $\overline{PWM}$ pins high or low thereby turning the appropriate output on or off. Since the $\overline{PWM}$ pins have internal pull-ups, if they are left floating, they will be turned off.

In this configuration, the VLED and VDD test points can be tied to a single supply. The supply must be high enough to cover the forward voltage (VF) of the LEDs and the V_{OUT} of the TLC59144 (typically 4V for this EVM).

Table 8. RGBW Example

Jumper	Position	Function
J1, J2, J3, J4	Open	Use center pin for external PWM control
TP5, TP6, TP7, TP8	Test Points	Can be used instead of J1, J2, J3, J4 for PWM control
J5	D	250mA for White (21.5kΩ)
J6	D	250mA for Blue (21.5kΩ)
J7	D	250mA for Green (21.5kΩ)
J8	D	250mA for Red (21.5kΩ)
J9	Installed	Red LED for $\overline{OUT3}$
J10	Installed	Green LED for $\overline{OUT2}$
J11	Installed	Blue LED for $\overline{OUT1}$
J12	Installed	White LED for $\overline{OUT0}$
J13, J14, J15, J16	Open	Do not connect to 3-LED string
J17	Installed	VDD power
TP10	Power for RGBW LEDs	3.5V to 5.5V
TP11	Power for TLC59144	3.0V to 5.5V

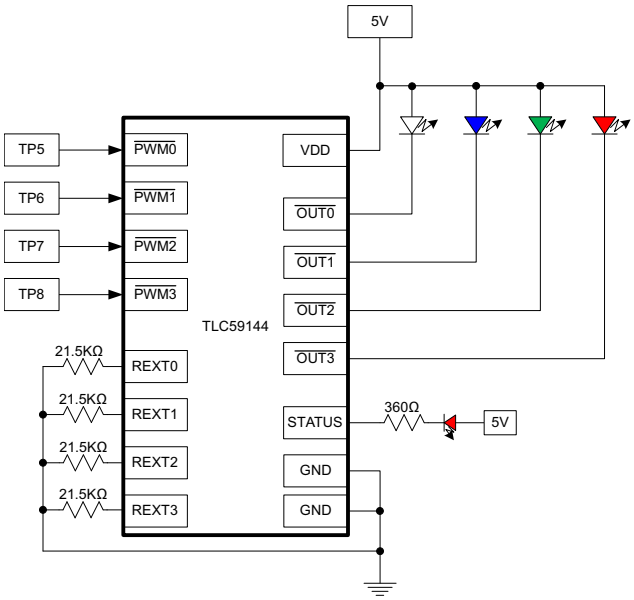


Figure 4. RGBW Color Mixing

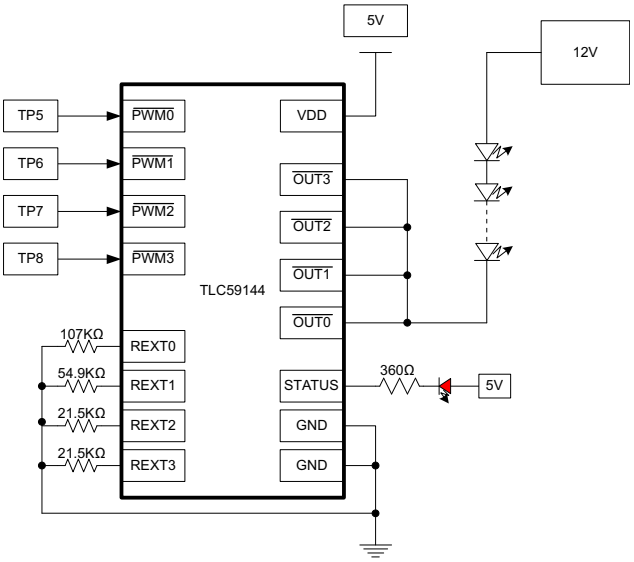


Figure 5. High Power 3-LED String

3.5.2 High Power 3-LED String

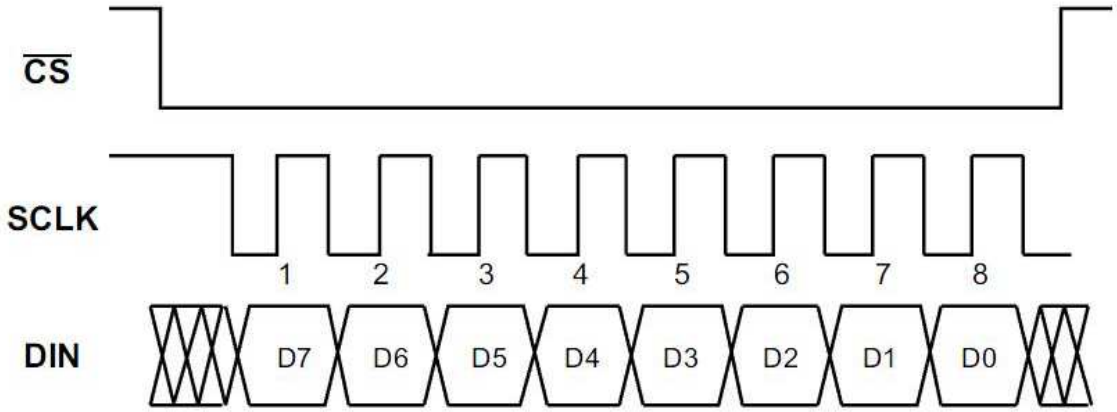
This example (Figure 5) shows the TLC59144 used to drive a single string of LEDs. All outputs are joined in parallel to increase the current through the single string. Each of the $\overline{\text{PWM}}$ pins is controlled separately. In this manner, the intensity can be changed in steps. The jumper settings for this EVM example are shown in Table 9. The maximum total current through the 3-string LED array is 1A. The $\overline{\text{PWM}}$ pins can be controlled through their respective jumpers (J1, J2, J3, and J4) or through their respective test points (TP5, TP6, TP7, and TP8). The LED voltage must be set high enough to cover the VF of the LEDs and the V_{OUT} of the TLC59144 (typically 12V for this EVM).

Table 9. Bright White LED Example

Jumper	Position	Function
J1, J2, J3, J4	Open	Allow external PWM control
TP5, TP6, TP7, TP8	Test Points	Can be used instead of J1, J2, J3, J4 for PWM control
J5	B	50mA for $\overline{\text{OUT0}}$ (107kΩ)
J6	C	100mA for $\overline{\text{OUT1}}$ (54.9kΩ)
J7	D	250mA for $\overline{\text{OUT2}}$ (21.5kΩ)
J8	D	250mA for $\overline{\text{OUT3}}$ (21.5kΩ)
J9, J10, J11, J12	Open	Do not drive RGBW LED
J13	Installed	$\overline{\text{OUT3}}$ connected to 3-LED string
J14	Installed	$\overline{\text{OUT2}}$ connected to 3-LED string
J15	Installed	$\overline{\text{OUT1}}$ connected to 3-LED string
J16	Installed	$\overline{\text{OUT0}}$ connected to 3-LED string
J17	Installed	VDD power
TP10	Power for 3 White LED string	12V
TP11	Power for TLC59144	3.0V to 5.5V

3.5.3 Output Current SPI Control

By utilizing the TPL0501-100 Digital Potentiometers, the user can vary the output current without the use of the REXT jumpers. The TPL0501-100s are set using the SCLK, DIN, and appropriate CS0-3 pin. A timing diagram for the SPI write sequence is shown below.



D7 corresponds to the MSB and D0 to the LSB. The REXT resistance value of the TPL0501-100 varies from 0-100kΩ in 256 increments. Writing a 0x00 to the TPL0501-100 sets the resistance to its 0Ω boundary and writing an 0xFF sets it to 100kΩ. All 254 values in between vary linearly. A more detailed explanation of exact resistance values can be found in the TPL0501-100 datasheet, found at http://www.ti.com/product/tpl0501-100.

The resulting output current is a direct result of the resistors added in R18-21. The equation for calculating the output current is shown below.

$$I_{OUT} = V_{REF}/R_{EXT} \times 6400 \quad (1)$$

$$V_{REF}(\text{nominal}) = 850\text{mV} \quad (2)$$

REXT is the sum of the resistance value of the TPL0501-100 and added resistance in R18-21. Note that any jumpers placed in J3-6 will put REXT in parallel with that jumper's corresponding resistance value. Without these jumpers in place, the output current can be calculated with Equation 3.

$$I_{OUT} = 5440 / (R_{TPL0501} + R_X) \quad (3)$$

For example, if the white LED output current was to be calculated, the following equation would be used.

$$I_{OUT} = 5440 / (R_{TPL0501\text{-}U2} + R_{18}) \quad (4)$$

When the device initially powers on, the resistance value of the TPL0501 is 0Ω. This means that the initial output current is:

$$I_{OUT} = 5440 / R_X \quad (5)$$

The lowest recommended value for RX is 13.7kΩ, because this results in an output of 397mA, which is very close to the maximum 400mA allowed by the device.

As an example, if the user wanted to send 200mA through the Red LED (I_{OUT3}) and had added an R21 of 13.7kΩ, then a value of 0x23 would be written to the TPL0501-U5. This results in a total REXT3 of 27.2kΩ and an I_{OUT3} of 200mA.

4 Operating Procedure

4.1 Powering the TLC59144 EVM

The TLC59144 Evaluation Module is set to work with independent Red, Green, Blue and White LEDs or a 3-LED string of White LEDs. The RGBW LEDs take less than 5V to operate so in this mode, the EVM can be controlled through a single 5V supply by shorting TP10 and TP11. The 3-LED String operation requires approximately 12V minimum so the VDD supply (TP11) must be separated from the LED supply (TP10, VLED). The required voltage will change with the current throught the LEDs.

4.2 Selecting the LEDs

The RGBW LEDs are selected through Jumpers J9, J10, J11, and J12. Remove the jumpers for J13, J14, J15, and J16 to disable the 3-LED string

The 3-LED String is selected through Jumpers J13, J14, J15, and J16. Remove the jumpers for J9, J10, J11, and J12 to disable the RGBW LED.

To use external LEDs jumpers J9 through J16 must be removed. The LED Supply is tied to the anode of the LEDs and the cathodes are tied to the EVM (through the open jumpers J9-J12).

4.3 Setting the LED Current

The current for each channel is set independently. To set the current for $\overline{OUT0}$, choose the corresponding resistor jumper for REXT0. Jumper J5 has 4 positions which select the resistor for REXT0. Setting the jumper in position “A” (closest to the TC59144) selects R1 (549kΩ) which sets the current to 10mA. Setting the jumper in position “B” selects R2 (107kΩ) which sets the current to 50mA. Positions “C” and “D” set 100mA and 250mA respectively.

There are a few items to note about the current settings for this EVM.

1. The 10mA setting is below the “minimum” specified in the datasheet. This indicates the driver will work below the 20mA specified in the datasheet, but may impact accuracy and Status pin functionality.
2. The resistors are in parallel, so they act independently. Adding two jumpers will effectively add the current to the output for both resistors. Using the 50mA resistor and the 250mA resistor creates a 300mA result.
3. Using all 4 resistors generates a current of 410mA. This is above the recommended datasheet maximum.
4. The TPL0501-100 Digital Potentiometers (DPOT) can be used to set the currents. In this way, the currents can be controlled off the EVM through an external software tool. In order to use this, R18 must be installed for $\overline{OUT0}$ and each of the other outputs has the same consideration (R19, R20, and R21). Note that whatever jumpers are left on the resistor jumper will be in parallel with the DPOT. On power up, the DPOT is set to 0Ω. See the Output Current SPI Control section for detailed use of the DPOTs.
5. An external resistor can also be used to program the currents. Since any resistance added from REXT to ground is in parallel with all other resistors from the same REXT, care must be taken to remove unnecessary REXT jumpers.
6. To add an external resistor simply add a connection from the desired jumper (J5, J6, J7, or J8) to the resistor and connect the other end to ground. Each resistor tied to an REXT pin is in parallel with other resistors tied to this REXT pin. Care should be taken to remove unwanted resistance to get the desired current.

4.4 Controlling the PWM Pins

The $\overline{\text{PWM}}$ pins can be used as enable pins (High or float = OFF, Low = ON) or as Pulse-Width-Modulation inputs to create color mixing. The EVM provides multiple ways to interact with the $\overline{\text{PWM}}$ pins: Test Points, Jumper Pins and optional SMA connectors. All three points are connected, so do not drive more than one. Since the TLC59144 has internal pull-up resistors on the $\overline{\text{PWM}}$ pins, those pins not actively pulled low will remain OFF.

1. Test points (TP5, TP6, TP7, and TP8) can be used to control the $\overline{\text{PWM}}$ pins. They can be connected to a function generator or other waveform generator to enable control
2. Jumper pins (J1, J2, J3, and J4) can be used to control the $\overline{\text{PWM}}$ pins. The jumpers can be set to high (OFF: short P1:P2), low (ON: short P2:P3) or float (OFF: no jumper).
3. The optional SMA connectors (J18, J19, J20, and J21) can be used to control the $\overline{\text{PWM}}$ pins. The SMA connectors can be used to connect to a waveform generator to enable control.

4.5 Status Pin

The Status pin is used as an indicator of a failure in the system. The EVM ties this open-drain pin through a resistor and LED (D5) in series to the VDD pin. When an error occurs, the LED will illuminate. When the error is removed, the LED will turn off.

Error conditions which will drive the Status pin low: LED open, LED short to ground, REXT short to ground, Thermal fold-back and Thermal Shutdown. Methods for demonstrating these error conditions are discussed below.

1. To demonstrate an LED open condition the LED must be enabled. When the LED is enabled, remove the corresponding jumper (i.e. if $\overline{\text{OUT2}}$ is being used to drive the green LED, remove jumper J10). When the jumper is removed, this causes an open on the corresponding output and the Status pin will drive low turning on the Error LED. If the output is not enabled, the Status pin will remain inactive and the LED will not turn on.
2. To demonstrate an LED short to ground the LED must be on. In this case, simply short the corresponding output to ground and the Status pin will drive low. Removing the short returns the Status pin to its inactive state.
3. Thermal fold-back can be demonstrated several ways. The simplest method is to enable all 4 channels at a high current then increase the LED voltage (VLED) above the required Forward Voltage (VF) of the LED. All excess voltage will be across the TLC59144 increasing its power dissipation. The user can monitor the current through one of the enabled LEDs. When VLED is increased enough causing high power across the TLC59144, the current will begin to fold-back and the Status pin will drive low. Reducing VLED will reduce the power and the current will return to its programmed value and the Status pin will return to its inactive state.
4. Thermal shutdown is induced in a similar method as the fold-back. Continue to increase the VLED above the thermal fold-back limit and the thermal shutdown will kick-in. Note that since the thermal fold-back is already engaged, the Status pin is already low. When thermal shutdown is triggered the LEDs will turn off. Depending on the power dissipation effectiveness, the LEDs will turn on again and continue in fold-back. This may be seen as LED blinking. The user can monitor the current during this condition and will note that the current decreases with fold-back and goes to zero with shutdown. Using a current probe is an effective method for viewing the current shut-down.

4.6 Unused Options

There are several portions of the EVM that are not populated. The option is open for self-population to enable MSP430 LaunchPad inclusion or other interaction. The unused sections are shown in Table 10.

Table 10. Unpopulated EVM Components

Components	Function
J22, J23, J24, C6, C7, D6, U6, R22, R23	MSP430 LaunchPad support
R18, R19, R20, R21	DPOT connection to REXT
J18, J19, J20, J21	SMA connectors

5 EVM Layouts

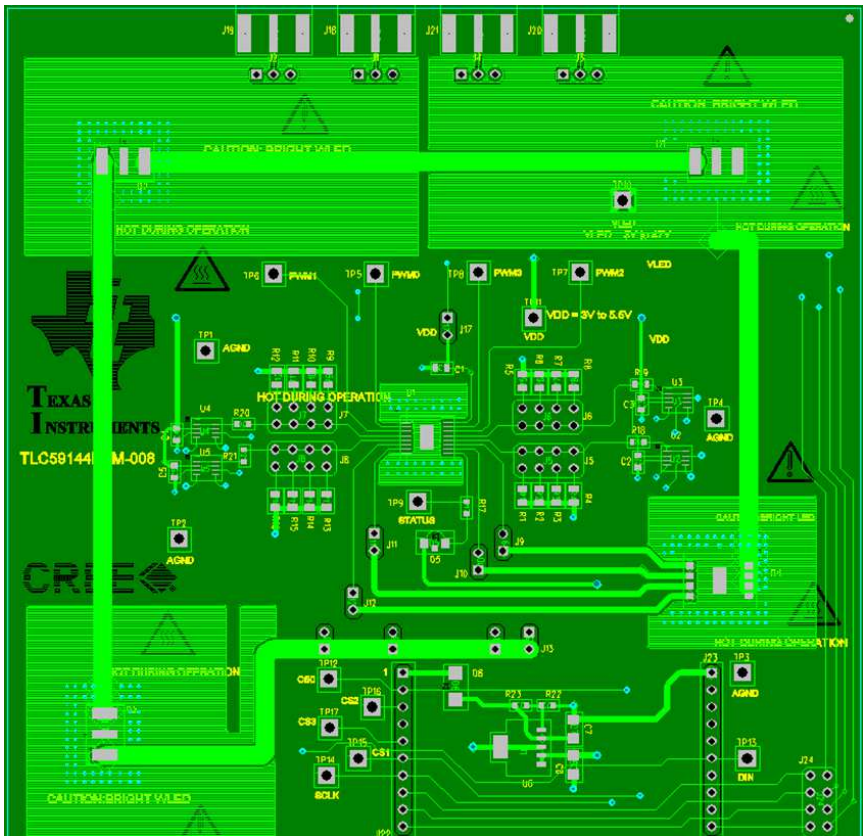


Figure 6. Top Side

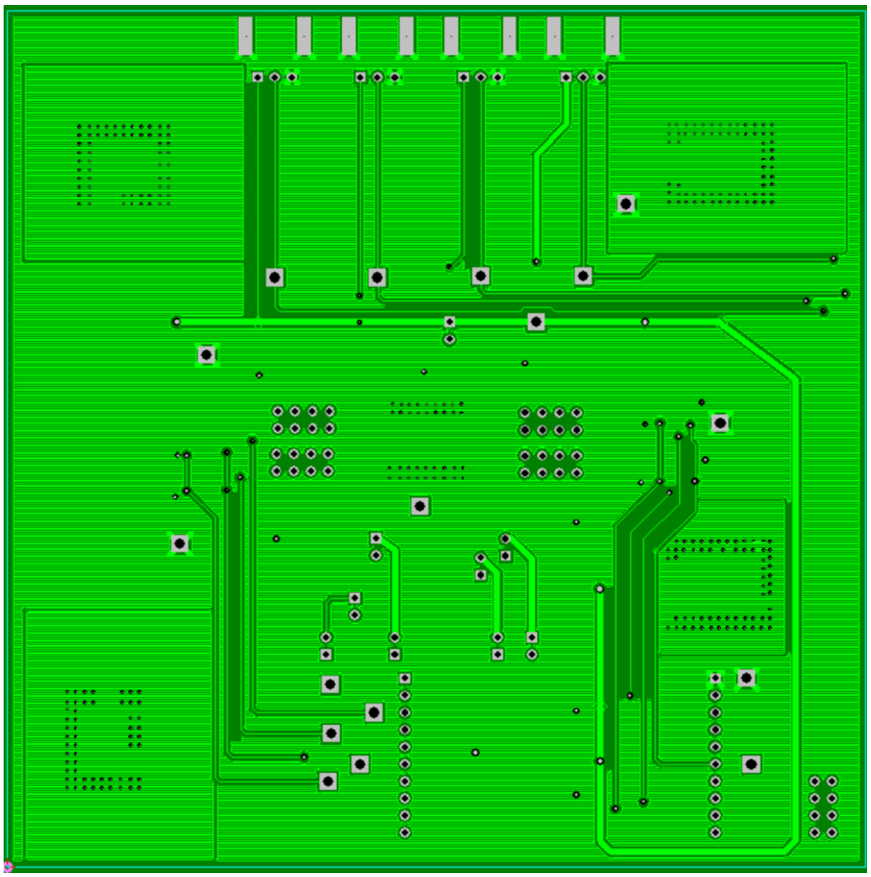


Figure 7. Bottom Side

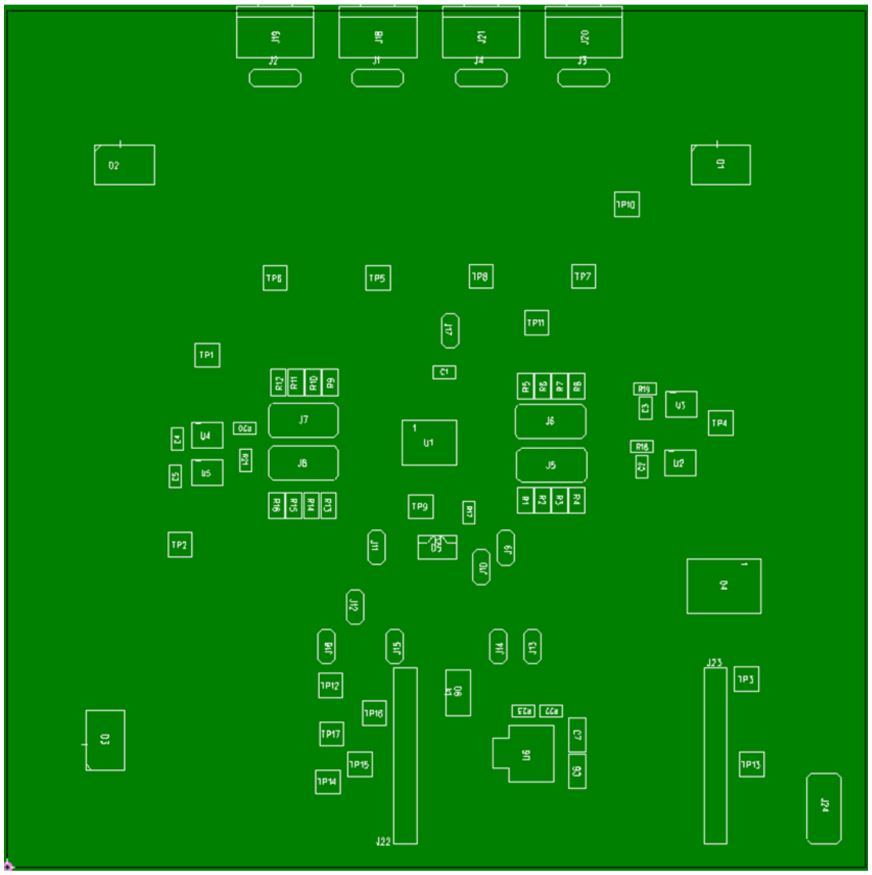
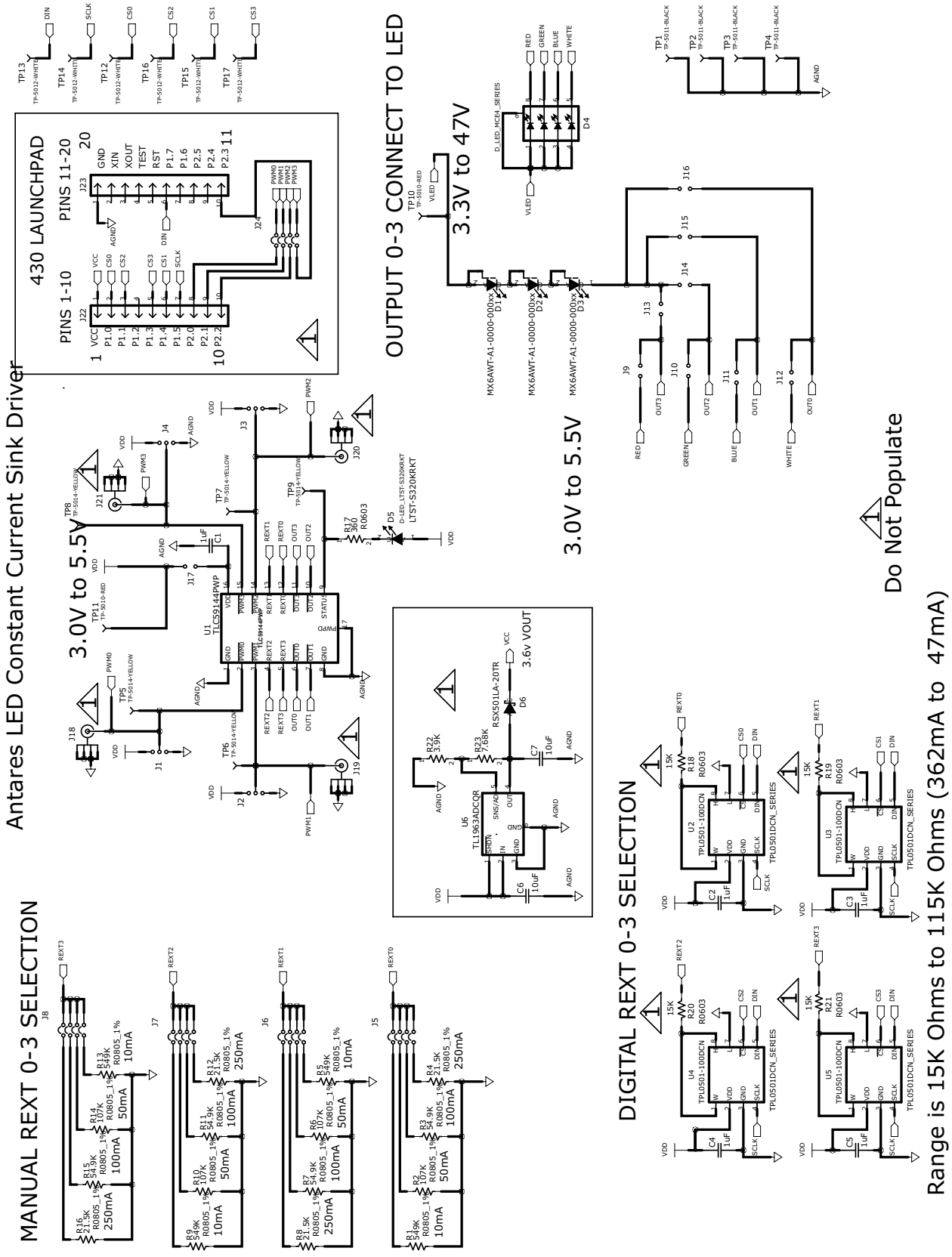


Figure 8. Top Assembly

6 Schematic



7 Bill of Materials

Count	RefDeg	Value	Description	Size	Part Number	MFR
5	C1-5	1µF	Capacitor, Ceramic, 6.3-V, X5R, 10%	0603	STD	STD
0	C6-7	10µF	Capacitor, Ceramic, 25-V, X5R, 10%	1206	STD	STD
3	D1-3	MX6AWT-A1-R250-000C51	LED, Xlamp, 1A Max, [White]	5.0 x 6.0 mm	MX6AWT-A1-R250-000C51	Cree
1	D4	MCE4CT-A2-0000-00A5AAAA1	Diode, Multi LED, [Color] 5V, 700 mA	2x5 mm	MCE4CT-A2-0000-00A5AAAA1	Cree
1	D5	LTST-S320KRKT	Diode, LED Red Side Lumination, 75mW, 30mA	0805	LTST-S320KRKT	LiteOn
0	D6	RSX501LA-20TR	Diode, Schottky, 1-A, 30-V	SMA	MBRA130LT3	Motorola
4	J1-4	PEC03SAAN	Header, Male 3-pin, 100mil spacing	0.100 inch x 3	PEC03SAAN	Sullins
0	J18-21	142-0701-801	Connector, SMA, Jack Receptacle	0.250X 0.375 inch	142-0701-801	Johnson
0	J22-23	PEC10SAAN	Header, Male 10-pin, 100mil spacing	0.100 inch x 10	PEC10SAAN	Sullins
4	J5-8 J24	PEC03DAAN	Header, 2x4, 100mil spacing	0.200x0.800 inch	PEC03DAAN	Sullins
9	J9-17	PEC02SAAN	Header, Male 2-pin, 100mil spacing	0.100 inch x 2	PEC02SAAN	Sullins
4	R1 R5 R9 R13	549kΩ	Resistor, Chip, 1/10W, 1%	0805	STD	STD
1	R17	360Ω	Resistor, Chip, 1/16W, x%	0603	STD	STD
0	R18-21	15kΩ	Resistor, Chip, 1/16W, x%	0603	STD	STD
4	R2 R6 R10 R14	107kΩ	Resistor, Chip, 1/10W, 1%	0805	STD	STD
0	R22	3.9kΩ	Resistor, Chip, 1/16W, x%	0402	STD	STD
0	R23	7.68kΩ	Resistor, Chip, 1/16W, x%	0402	STD	STD
4	R3 R7 R11 R15	54.9kΩ	Resistor, Chip, 1/10W, 1%	0805	STD	STD
4	R4 R8 R12 R16	21.5kΩ	Resistor, Chip, 1/10W, 1%	0805	STD	STD
2	TP10-11	5010	Test Point, Red, Thru Hole	0.125 x 0.125 inch	5010	Keystone
6	TP12-17	5012	Test Point, White, Thru Hole	0.125 x 0.125 inch	5012	Keystone
4	TP1-4	5011	Test Point, Black, Thru Hole	0.125 x 0.125 inch	5011	Keystone
5	TP5-9	5014	Test Point, Yellow, Thru Hole	0.125 x 0.125 inch	5014	Keystone
1	U1	TLC59144PWP	IC, 1.6A, 4-Chan Constant-Current LED Sink Driver with Error Detection	HTSSOP	TLC59144PWP	TI
4	U2-5	TPL0501-100DCN	IC, 100KΩ, 256 Taps Single Chan Digital W/SPI Interface	SOT-23	TPL0501-100DCN	TI
0	U6	TL1963ADCQR	IC, 1.5A Low-Noise FTR Low Dropout Regulator	SOT	TL1963ADCQR	TI
1	—		PCB	5 In x 5 in x 0.062 in	HVL008	Any
13	Jumper		0.1", 2 contacts black for J3, J4, J5, J6	0.100"	2-382811-1	Tyco/AMP
4	Bumpon		Rubber bumpon transparent	0.44"x 0.2"	SJ5303	3M

EVALUATION BOARD/KIT/MODULE (EVM) ADDITIONAL TERMS

Texas Instruments (TI) provides the enclosed Evaluation Board/Kit/Module (EVM) under the following conditions:

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. THE FOREGOING LIMITED WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please visit www.ti.com/esh or contact TI.

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REGULATORY COMPLIANCE INFORMATION

As noted in the EVM User's Guide and/or EVM itself, this EVM and/or accompanying hardware may or may not be subject to the Federal Communications Commission (FCC) and Industry Canada (IC) rules.

For EVMs **not** subject to the above rules, this evaluation board/kit/module is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION OR EVALUATION PURPOSES ONLY and is not considered by TI to be a finished end product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC or ICES-003 rules, which are designed to provide reasonable protection against radio frequency interference. Operation of the equipment may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

General Statement for EVMs including a radio

User Power/Frequency Use Obligations: This radio is intended for development/professional use only in legally allocated frequency and power limits. Any use of radio frequencies and/or power availability of this EVM and its development application(s) must comply with local laws governing radio spectrum allocation and power limits for this evaluation module. It is the user's sole responsibility to only operate this radio in legally acceptable frequency space and within legally mandated power limitations. Any exceptions to this are strictly prohibited and unauthorized by Texas Instruments unless user has obtained appropriate experimental/development licenses from local regulatory authorities, which is responsibility of user including its acceptable authorization.

For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant

Caution

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

For EVMs annotated as IC – INDUSTRY CANADA Compliant

This Class A or B digital apparatus complies with Canadian ICES-003.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Concerning EVMs including radio transmitters

This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concerning EVMs including detachable antennas

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication.

This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Cet appareil numérique de la classe A ou B est conforme à la norme NMB-003 du Canada.

Les changements ou les modifications pas expressément approuvés par la partie responsable de la conformité ont pu vider l'autorité de l'utilisateur pour actionner l'équipement.

Concernant les EVMs avec appareils radio

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

【Important Notice for Users of this Product in Japan】

This development kit is NOT certified as Confirming to Technical Regulations of Radio Law of Japan

If you use this product in Japan, you are required by Radio Law of Japan to follow the instructions below with respect to this product:

1. Use this product in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use this product only after you obtained the license of Test Radio Station as provided in Radio Law of Japan with respect to this product, or
3. Use of this product only after you obtained the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to this product. Also, please do not transfer this product, unless you give the same notice above to the transferee. Please note that if you could not follow the instructions above, you will be subject to penalties of Radio Law of Japan.

Texas Instruments Japan Limited
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http://www.tij.co.jp

EVALUATION BOARD/KIT/MODULE (EVM)
WARNINGS, RESTRICTIONS AND DISCLAIMERS

For Feasibility Evaluation Only, in Laboratory/Development Environments. Unless otherwise indicated, this EVM is not a finished electrical equipment and not intended for consumer use. It is intended solely for use for preliminary feasibility evaluation in laboratory/development environments by technically qualified electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems and subsystems. It should not be used as all or part of a finished end product.

Your Sole Responsibility and Risk. You acknowledge, represent and agree that:

1. You have unique knowledge concerning Federal, State and local regulatory requirements (including but not limited to Food and Drug Administration regulations, if applicable) which relate to your products and which relate to your use (and/or that of your employees, affiliates, contractors or designees) of the EVM for evaluation, testing and other purposes.
2. You have full and exclusive responsibility to assure the safety and compliance of your products with all such laws and other applicable regulatory requirements, and also to assure the safety of any activities to be conducted by you and/or your employees, affiliates, contractors or designees, using the EVM. Further, you are responsible to assure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard.
3. You will employ reasonable safeguards to ensure that your use of the EVM will not result in any property damage, injury or death, even if the EVM should fail to perform as described or expected.
4. You will take care of proper disposal and recycling of the EVM's electronic components and packing materials.

Certain Instructions. It is important to operate this EVM within TI's recommended specifications and environmental considerations per the user guidelines. Exceeding the specified EVM ratings (including but not limited to input and output voltage, current, power, and environmental ranges) may cause property damage, personal injury or death. If there are questions concerning these ratings please contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, some circuit components may have case temperatures greater than 60°C as long as the input and output are maintained at a normal ambient operating temperature. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors which can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during normal operation, please be aware that these devices may be very warm to the touch. As with all electronic evaluation tools, only qualified personnel knowledgeable in electronic measurement and diagnostics normally found in development environments should use these EVMs.

Agreement to Defend, Indemnify and Hold Harmless. You agree to defend, indemnify and hold TI, its licensors and their representatives harmless from and against any and all claims, damages, losses, expenses, costs and liabilities (collectively, "Claims") arising out of or in connection with any use of the EVM that is not in accordance with the terms of the agreement. This obligation shall apply whether Claims arise under law of tort or contract or any other legal theory, and even if the EVM fails to perform as described or expected.

Safety-Critical or Life-Critical Applications. If you intend to evaluate the components for possible use in safety critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, such as devices which are classified as FDA Class III or similar classification, then you must specifically notify TI of such intent and enter into a separate Assurance and Indemnity Agreement.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

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