Application Note

Typical Application to Achieve High Immunity to BCI

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ABSTRACT

This application note summarizes a typical schematic and layout design for 24-channel LED driver, TPS929240-Q1, to achieve high BCI (Bulk Current Injection) immunity performance with test set-up and result analysis. The test is based on TPS929240-Q1 evaluation board, which passes international standard ISO11452-4 test level IV (200mA).

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1 Introduction

1.1 Device Overview

The TPS929240-Q1 is a 24-channel, 40-V high-side automotive LED driver with FlexWire interface to address increasing requirements for pixel control of each LED string. Each of the device channels features various diagnostics including LED open-circuit, short-to-ground, single LED short-circuit detection and can support both analog dimming and PWM dimming. The internal user-programmable EEPROM allows automatic switching to FAIL-SAFE states in the case of communication loss to meet system level safety requirements. Figure 1-1 shows a typical application diagram.

Compared with traditional single ended interface, by using a CAN physical layer the UART-based FlexWire interface of the TPS929240-Q1 is much easier to accomplish long distance off-board communication without impacting EMC and BCI.

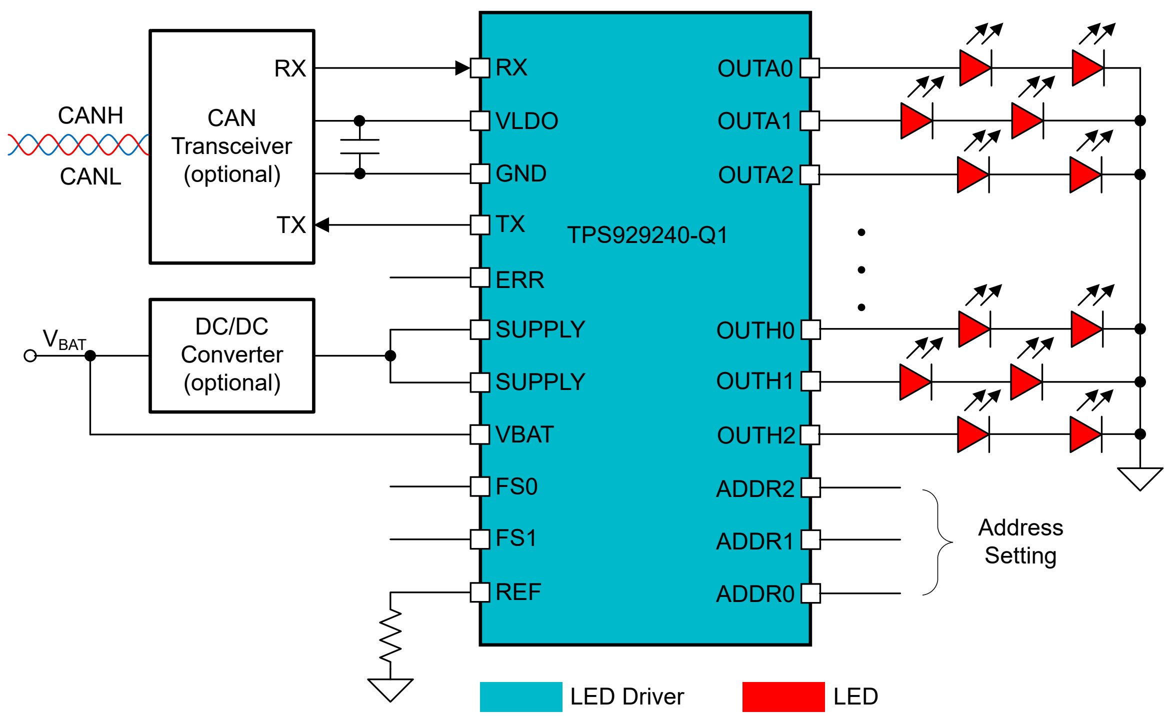

Figure 1-1. TPS929240-Q1 Typical Application Diagram

1.2 BCI Test Method

Buck Current Injection (BCI) is a method of carrying out immunity tests by inducting disturbance signals directly into the wiring harness by means of a current injection probe. In an automotive exterior lighting application, due to the long cables that connect the battery to a LED module, the noise generated by RF electromagnetic fields frequently degrades the performance of the electronic device. To simulate the effect of noise in vehicle environment, the international standard ISO11452-4 defines BCI test methods for evaluating the immunity levels of electronic devices.

The TPS929240-Q1 testing was done according to the ISO11452-4:2011 standard. Substitution method is used and the applicable frequency range is 1MHz to 400MHz. As shown in Table 1-1, according to the example of test severity levels for BCI from the standard, based on the test level IV, the highest 200mA current is injected during testing. The detailed test requirements are shown in Table 1-2.

Table 1-1. Example of Test Severity Levels (BCI)

<table>
<tr><th>Frequency Band (MHz)</th><th>Test Level I (mA)</th><th>Test Level II (mA)</th><th>Test Level III (mA)</th><th>Test Level IV (mA)</th><th>Test Level V (mA)</th></tr>
<tr><td>1 to 3</td><td>$60 \times F(MHz) / 3$</td><td>$100 \times F(MHz) / 3$</td><td>$150 \times F(MHz) / 3$</td><td>$200 \times F(MHz) / 3$</td><td rowspan="3">Specific values agreed between the users of this part of ISO 11452</td></tr>
<tr><td>3 to 200</td><td>60</td><td>100</td><td>150</td><td>200</td></tr>
<tr><td>200 to 400</td><td>$60 \times 200 / F(MHz)$</td><td>$100 \times 200 / F(MHz)$</td><td>$150 \times 200 / F(MHz)$</td><td>$200 \times 200 / F(MHz)$</td></tr>
</table>

Table 1-2. Test Requirements

<table>
<tr><th>Frequency (MHz)</th><th>Frequency Step Size (MHz)</th><th>Dwell Time (s)</th><th>Text Level (mA)</th><th>Working Voltage (V)</th><th>Probe Type</th><th>Probe Distance to DUT</th><th>Modulation</th></tr>
<tr><td rowspan="2">1 to 3</td><td rowspan="2">0.1</td><td rowspan="2">2</td><td rowspan="2">$200 \times F(MHz) / 3$</td><td rowspan="2">12</td><td rowspan="2">Open Loop</td><td rowspan="2">150 mm
450 mm
750 mm</td><td>CW</td></tr>
<tr><td>AM</td></tr>
<tr><td rowspan="2">3 to 200</td><td rowspan="2">5</td><td rowspan="2">2</td><td rowspan="2">200</td><td rowspan="2">12</td><td rowspan="2">Open Loop</td><td rowspan="2">150 mm
450 mm
750 mm</td><td>CW</td></tr>
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<tr><td rowspan="2">200 - 400</td><td rowspan="2">10</td><td rowspan="2">2</td><td rowspan="2">$200 \times 200 / F(MHz)$</td><td rowspan="2">12</td><td rowspan="2">Open Loop</td><td rowspan="2">150 mm
450 mm
750 mm</td><td>CW</td></tr>
<tr><td>AM</td></tr>
</table>

As defined in the Function Performance Status Classification (FPSC), four function performance status of the device functions are divided by whether the function can perform as designed during and after the test. So two key parameters, including supply current and LED status were monitored to measure the function performance during the whole test. The general acceptance criteria are shown in Table 1-3.

Table 1-3. Acceptance Criteria

Monitoring Parameters	Acceptance	Test Level
Supply current	Changes < ±20%	IV
LED	No flicker	IV

2 PCB Design Recommendation

This part content introduces some important recommendation for schematic and layout design to obtain good device BCI performance.

2.1 Schematic Design

Figure 2-1 is the schematic of TPS929240-Q1 EVM.

- Placing a 4.7 µF (C9) and a 100 nF (C16) decoupling ceramic capacitors close to the VBAT pin of each TPS929240-Q1 is highly recommended to obtain good EMC performance.
- Adding the same value capacitors is also required for SUPPLY input (C10 and C17) and VLDO output (C11 and C18).
  - C10 and C17 can be added after anti-reverse diode D57. D57 acts as a filter to pass positive noise and block negative noise so that the common-mode noise entering the control module decreases.
- Placing a typically 1 nF ceramic capacitor (C20) in parallel with R_{REF} close to the VREF pin to improve the noise immunity.
  - The capacitance of C20 can up to 2.2 nF.
- To achieve good EMC performance, TI recommends adding a 1 nF ceramic capacitor (C30-C53) on each of the output channels.
- TPS929240-Q1 EVM jumpers configuration during test:
  - On board buck is used to output 5.5V for SUPPLY.
  - R_{REF} is set to 6.34kΩ.

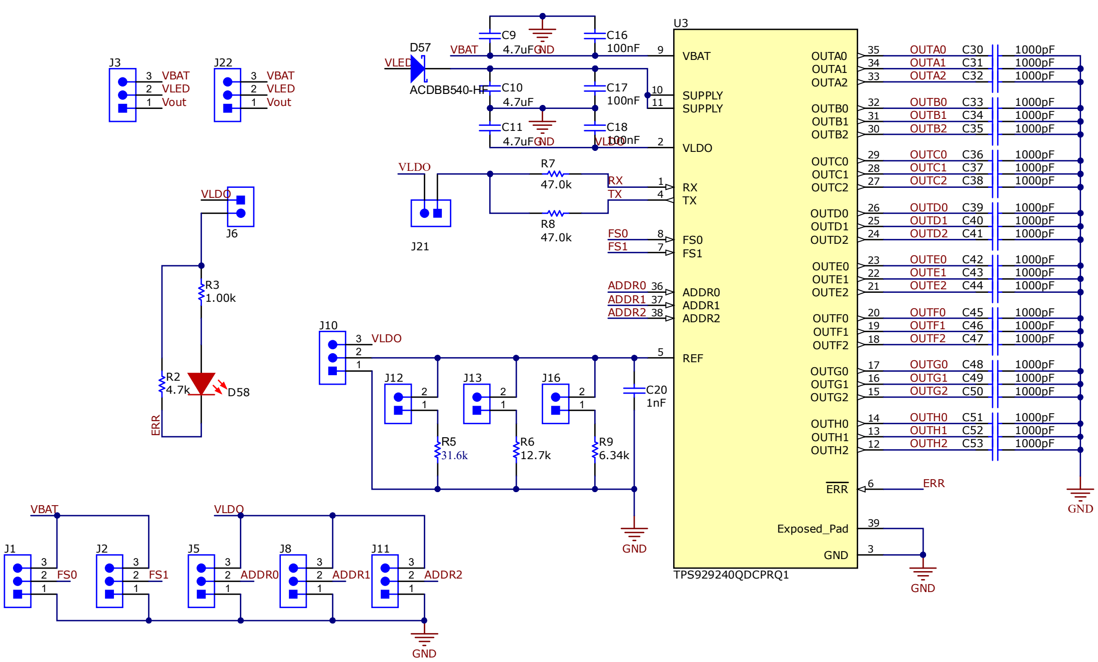

Figure 2-1. TPS929240-Q1 Schematic for PCB Design

2.2 Layout Design

Figure 2-2 shows the layout of TPS929240-Q1 EVM.

- Design large thermal dissipation area connected to thermal pads with multiple thermal vias.
- Place the capacitors (C9, C16, C10, C17, C11, C18) for VBAT, SUPPLY input and VLDO output as close as possible to the pins.
- The R_{REF} resistor needs to be placed as close as possible to the REF pin.
- Make sure the 1 nF capacitors on each output channels are close to the IC.
- The jumpers J1 to J76 are removed during the test to avoid the unexpected radiated noise coupling during the bulk current injection. The jumpers in the EVM are only for evaluation convenience, which normally are not required in a real application.

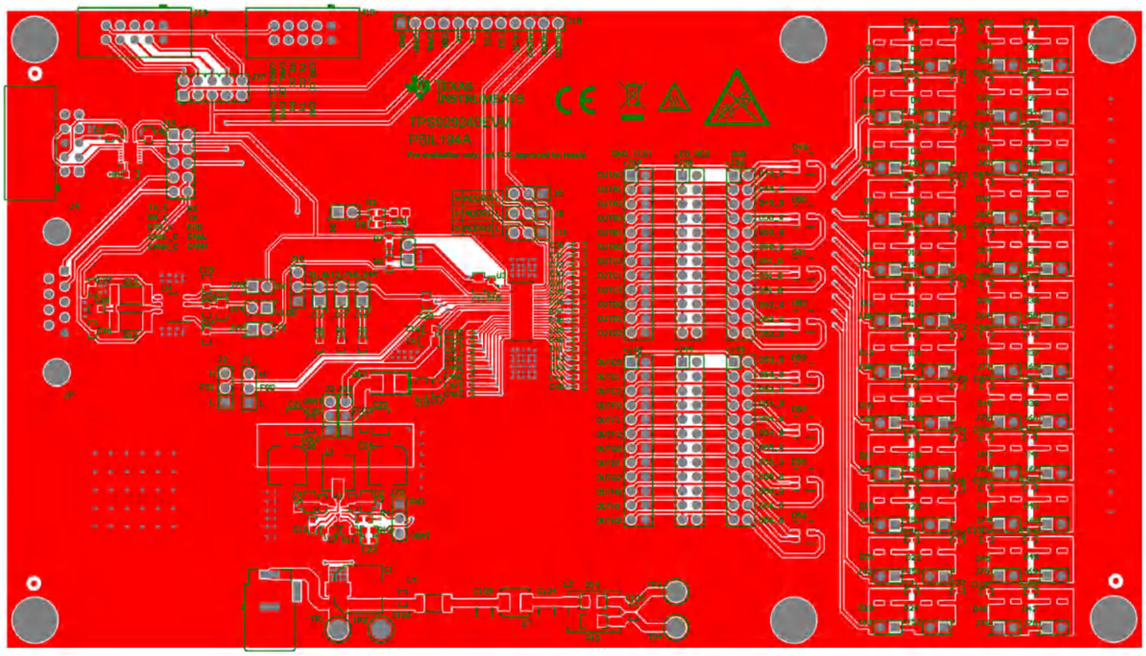

Figure 2-2. TPS929240-Q1 EVM Layout Illustration for BCI Test

3 BCI Test

3.1 Test Set-up

Figure 3-1 shows the specific hardware connections between evaluation board and test equipment. Both power supply and CAN bus wiring harnesses are included in the injection probe. In this test, connections to MSP430 microcontroller monitoring electromagnetic interference reactions of the DUT is accomplished by using fibre optics leads.

Figure 3-2 to Figure 3-5 show the equipment and EVM configuration of the BCI test.

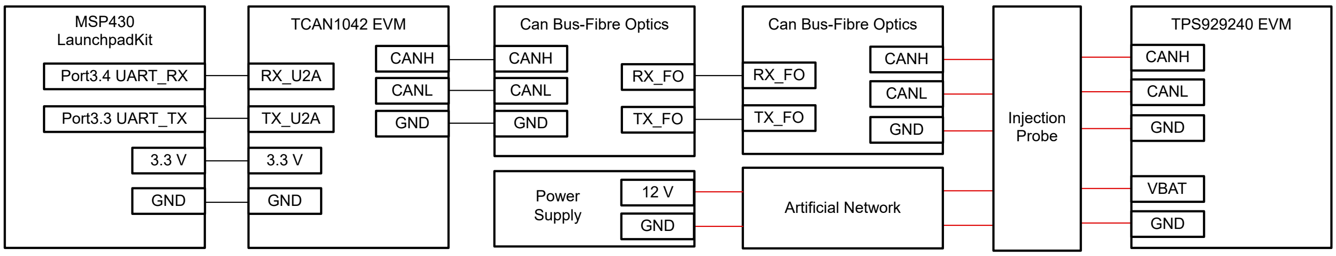

Figure 3-1. BCI Test Set-up

Figure 3-2. Overall Set-up of BCI Test

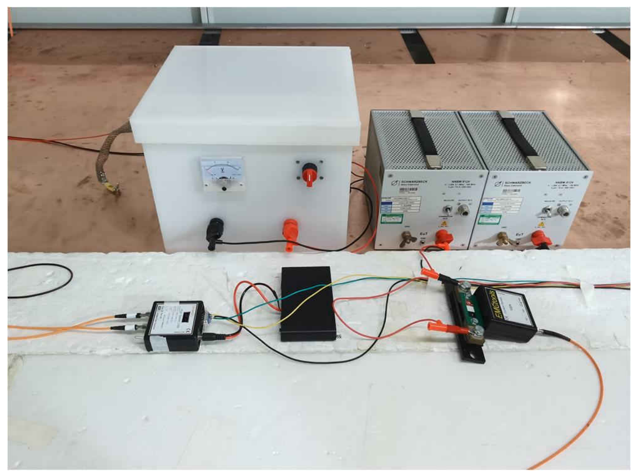

Figure 3-3. Power Supply Side of BCI Test

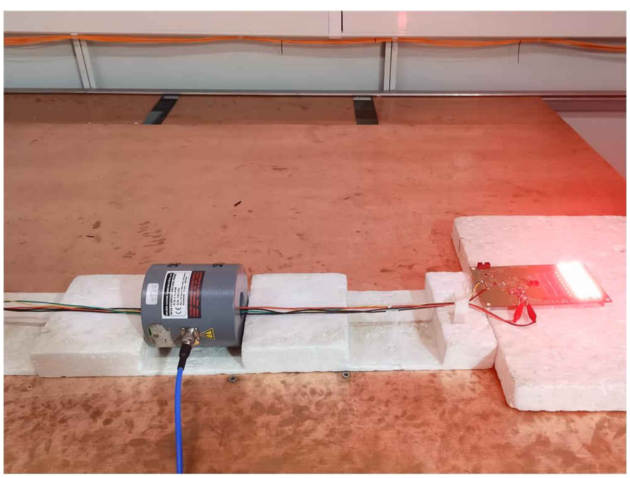

Figure 3-4. Injection Probe Side of BCI Test

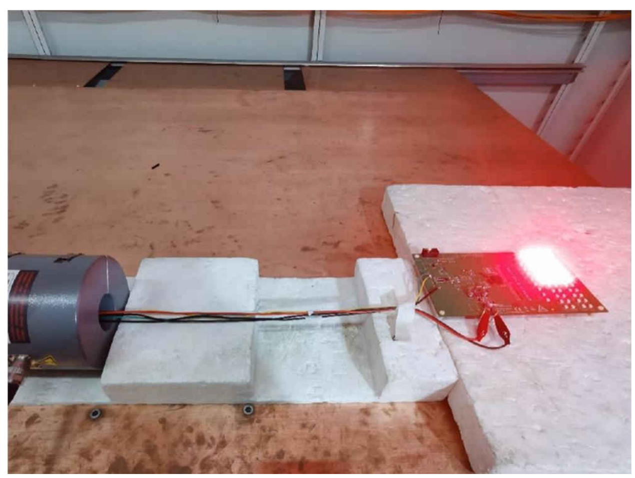

Figure 3-5. DUT Side of BCI Test

3.2 Test Results

The TPS929240-Q1 operates at two modes during the BCI test. Test mode I is animation which refers to output channels are enabled in turn with maximum output current (100mA) and 100% PWM duty cycle. Test mode II is fail-safe state which refers to all output channels are always enabled with maximum output current (100mA) and 100% PWM duty cycle.

Test results summary is shown in Table 3-1

The maximum supply current(A) deviation is:

(1.062 – 0.901) / 1.062 = 15% < ±20%

Meanwhile no visible flicker was observed during the test. Notice that during switching between CW modulation (for calibration) and AM modulation, due to the configuration of test software, there can be visible flicker. But normally this test condition does not happen in a real application.

Table 3-1. BCI Test Results

Monitoring Parameters	Acceptance	Test Results	Pass
Supply current	Changes < ±20%	15%	Y
LED	No flicker	No flicker	Y

In conclusion, the TPS929240-Q1 evaluation board passes the BCI test with function class A result. The detailed descriptions of function definition are shown in Table 3-2.

Table 3-2. BCI Test Function Definition

Class	General Definition
A	All functions of a device or system perform as designed during and after exposure to a disturbance.
B	All functions of a device or system perform as designed during exposure; however, one or more of them can go beyond the specified tolerance. All functions return automatically to within normal limits after exposure is removed. Memory function shall remain Class A.
C	One or more functions of a device or system do not perform as designed during exposure but return automatically to normal operation after exposure is removed.
D	One or more functions of a device or system do not perform as designed during exposure and do not return to normal operation until exposure is removed and the device or system is reset by a simple *operator or use* action.
E	One or more functions of a device or system so not perform as designed during and after exposure and cannot be returned to proper operation without repairing or replacing the device or system.

4 Summary

This application note introduces schematic and layout precautions of TPS929240-Q1 for better BCI immunity performance. The international standard this evaluation board passes is ISO11452-4:2011 test level IV. By following the recommended design methods, the evaluation board can pass BCI test function class A.

5 References

- Texas Instruments, *TPS929240-Q1 24-Channel,Automotive, 40-V, High-Side (O)LED Driver with FlexWire Interface*, data sheet
- Texas Instruments, *TPS929240EVM User's Guide*