MPQ7221 Tail Lamp Reference Design

Multi-Channel LED Driver for Automotive Systems

Contents

1 Overview

1.1 Description

The tail lamp dynamic requirement in automotive lighting applications is becoming increasingly demanding. This reference design showcases a holistic tail lamp proposal, including a stop lamp (SL), turn lamp (TL), and side mark lamp (SML), which uses three MPQ7221 devices to drive the LED strings.

The MPQ7221 is a 16-channel current sink LED driver that operates across a wide 4.5V to 16V input voltage (V_{IN}) range. The LED current (I_{LED}) of each channel is set by an external current-setting resistor, with a maximum current up to 80mA. The MPQ7221 integrates an I^2C interface, where 10 different I^2C addresses can be configured via an external resistor to achieve a rich dynamic effect.

The MPQ7221 is available in a QFN-24 (4mmx4mm) package with wettable flanks, and is AEC-Q100 qualified.

1.2 Features

- Wide 4.5V to 16V Input Voltage (V_{IN}) Range
- 16 Channels, 80mA/Channel Max
- LED Current (I_{LED}) Configured by an External Resistor
- 6-Bit Analog Dimming for Each Channel
- 12-Bit Pulse-Width Modulation (PWM) Dimming for Each Channel
- Selectable PWM Dimming Frequency (f_{PWM}): 220Hz, 250Hz, 280Hz, or 330Hz
- Refresh Signal Output
- I^2C Interface
- 10 Addresses, Configurable via an External Resistor
- Configurable I_{LED} Slew Rate
- 40µs Phase Shift
- Fault Indicator
- LED Open Protection
- LED Short Protection with Configurable Threshold
- Under-Voltage Lockout (UVLO)
- Over-Temperature Protection (OTP)
- Available in a QFN-24 (4mmx4mm) Package with Wettable Flanks
- Available in AEC-Q100 Grade 1

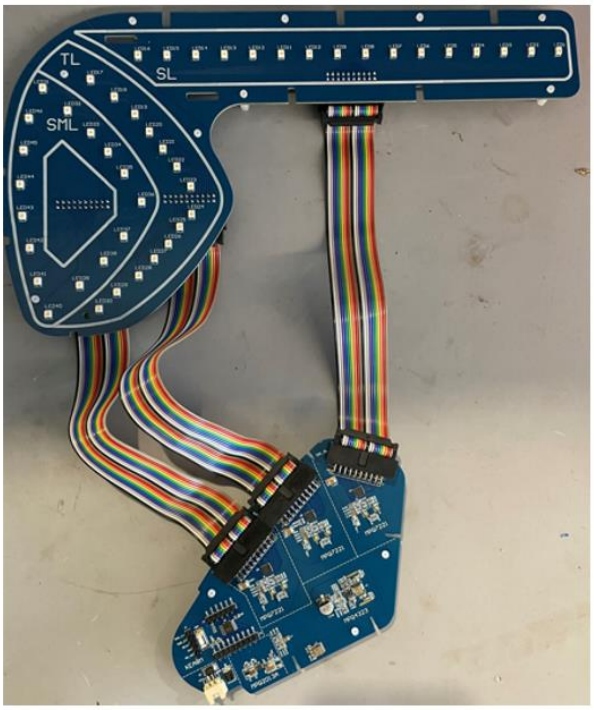


Figure 1: EVQ7221-TL-00A Tail Lamp Control Board and Tail Lamp Board

1.3 Applications

- Automotive Power Systems
- Industrial Systems
- Automotive Taillights
- Automotive Turning Lights

2 Reference Design

2.1 Block Diagram

This reference design includes one buck converter (MPQ4323), one low-dropout (LDO) regulator (MPQ2013A), three LED drivers (MPQ7221), and one microcontroller unit (MCU) (KEA8) (see Figure 2). V_{IN} is typically 12V, and the three MPQ7221 devices independently drive three different lamp types . The MCU defines the dynamic performance.

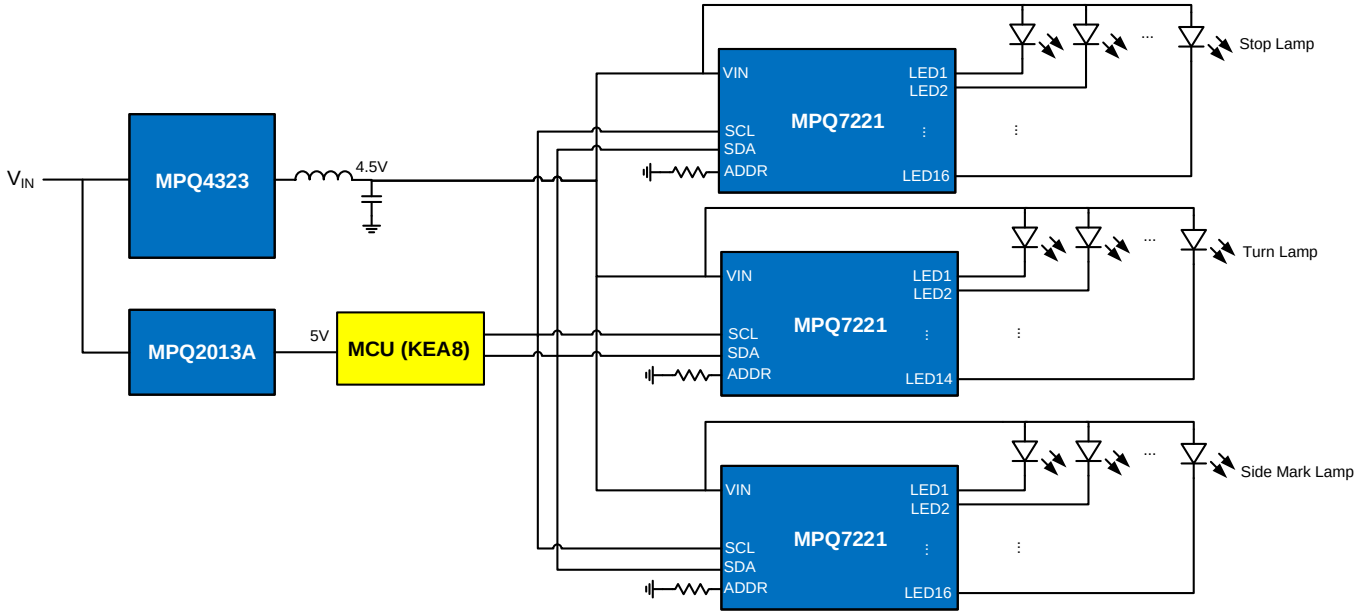


Figure 2: Block Diagram

2.2 Related Solutions

This reference design is based on the following MPS solutions:

Table 1: MPS Solutions

MPS Integrated Circuit	Description
MPQ2013A	40V, 150mA, low quiescent current linear regulator, AEC-Q100 qualified
MPQ4323	36V, 3A, low quiescent current, synchronous step-down converter, AEC-Q100 qualified
MPQ7221	16-channel, 80mA/ch, LED driver with separated PWM analog dimming and I^2C interface, AEC-Q100 qualified

2.3 System Specifications

Table 2: System Specifications

Parameter	Specification
Input voltage (V_{IN}) range	$5V_{DC}$ to $36V_{DC}$
Output LEDs	16 LEDs for stop lamp (SL), 14 LEDs for turn lamp (TL),16 LEDs for side mark lamp (SML)
Output current (I_{OUT})	50mA/ch for SL, 40mA/ch for TL, 8mA/ch for SML

3 Design

3.1 Schematic

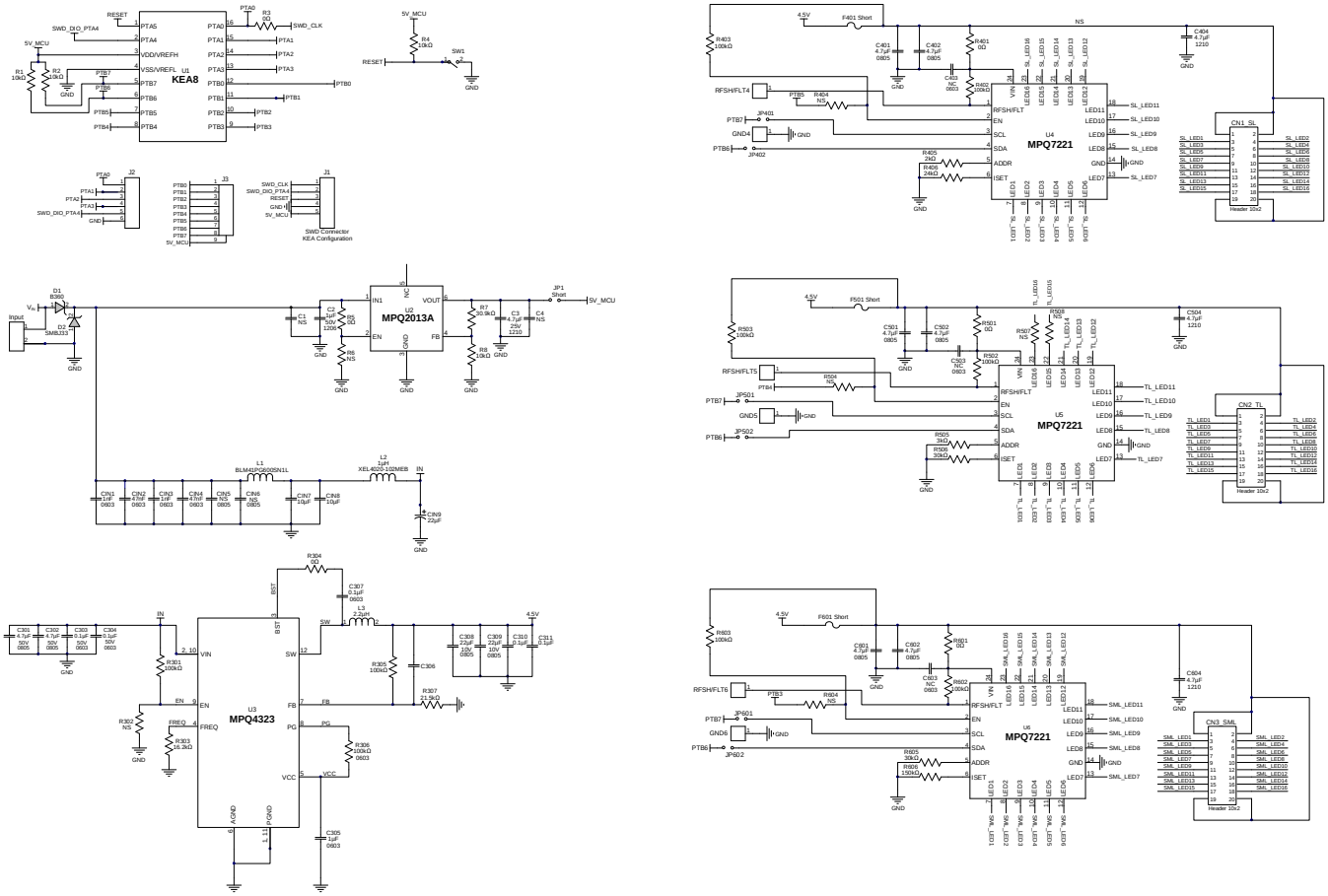


Figure 3: Control Board Schematics

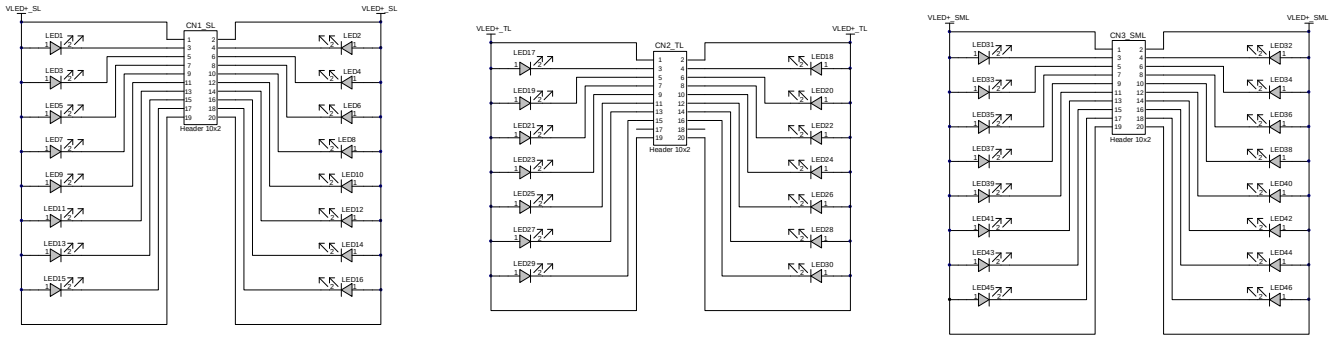


Figure 4: Lamp Board Schematics

3.2 BOM

Table 3: Control Board Bill of Materials

Qty	Ref	Value	Description	Package	Manufacturer	Manufacturer PN
2	C1, C4	NS				
1	C2	1µF	Ceramic capacitor, 100V, X7R	1210	Murata	GRM32ER72A105KA01L
4	C3, C404, C504, C604	4.7µF	Ceramic capacitor, 25V, X7R	1210	TDK	C3225X7R1E475M
8	C301, C302, C401, C402, C501, C502, C601, C602	4.7µF	Ceramic capacitor, 50V, X7S	0805	Murata	GRM21BC71H475KE11L
5	C303, C304, C307, C310, C311	0.1µF	Ceramic capacitor, 50V, X7R	0603	Murata	GRM188R71H104KA93D
1	C305	1µF	Ceramic capacitor, 16V, X7R	0603	Murata	GRM188R71C105KA12D
2	C308, C309	22µF	Ceramic capacitor, 10V, X5R	0805	Murata	GRM219R61A226MEA0D
	C306, C403, C503, C603, CIN1, CIN2	NS				
2	CIN3, CIN4	1nF	Ceramic capacitor, 50V, C0G	0603	Murata	GRM1885C1H102JA01D
2	CIN5, CIN6	47nF	Ceramic capacitor, 100V, X7R	0805	Murata	GRM21BR72A473KA01L
2	CIN7, CIN8	2.2µF	Ceramic capacitor, 50V, X7R	0805	Murata	CGA4J3X7R1H225KT000N
1	CIN9	22µF	Aluminum polymer capacitor, 50V	SMD	Panasonic	EEHZC1H220P
3	CN1_SL, CN2_TL, CN3_SML	1mm	Connector, 2x10-pin, 90°	DIP	Custom	
3	CN1_SL, CN2_TL, CN3_SML	1mm	Wiring harness, 2x10-pin	DIP	Custom	
1	D1	60V	Schottky diode, 3A	SMA	Diodes, Inc.	B360A-13-F
1	D2	33V	TVS diode	SMB	Vishay	SMBJ33AHE3_A/H
3	F401, F501, F601	63V	Fuse, 2A	1206	Bei	0685-2000-01
1	L1	240nH	Inductor, 19mΩ, 6.6A	SMD	TOKO, Inc.	DFE201612E-R24M
1	L2	1µH	Inductor	SMD	Coilcraft	XEL4020-102MEB
1	L3	2.2µH	Inductor	SMD	Coilcraft	XEL4030-222MEB

14	JP1, JP401, JP402, JP501, JP502, JP601, JP602, R3, R5, R304, R401, R501, R601, R405	0Ω	Film resistor, 5%	0603	Yageo	RC0603JR-070RL
4	R1, R2, R4, R8,	10kΩ	Film resistor, 1%	0603	Yageo	RC0603FR-0710KL
9	R301, R305, R306, R402, R403, R502, R503, R602, R603	100kΩ	Film resistor, 1%	0603	Yageo	RC0603FR-07100KL
1	R303	16.2kΩ	Film resistor, 1%	0603	Yageo	RC0603FR-0716K2L
1	R307	21.5kΩ	Film resistor, 1%	0603	Yageo	RC0603FR-0721K5L
1	R406	24kΩ	Film resistor, 1%	0603	Yageo	RC0603FR-0724KL
1	R505	3kΩ	Film resistor, 1%	0603	Yageo	RC0603FR-073KL
2	R506, R605	30kΩ	Film resistor, 1%	0603	Yageo	RC0603FR-0730KL
1	R606	150kΩ	Film resistor, 1%	0603	Yageo	RC0603FR-07150KL
1	R7	30.9kΩ	Film resistor, 1%	0603	Yageo	RC0603FR-0730K9L
	R6, R302, R404, R504, R507, R508, R604	NS				
6	GND4, GND5, GND6, RFSH/FLT, RFSH/FLT, RFSH/FLT6	1mm	Golden pin	DIP	Custom	
1	INPUT	2.54mm	Connector, 2-pin	SMD	Custom	
1	J1	2.54mm	Test pin, 1x5-pin	DIP	Custom	
1	J2	2.54mm	Test pin, 1x6-pin	DIP	Custom	
1	J3	2.54mm	Test pin, 1x9-pin	DIP	Custom	
2	GND, SW1	12V	Button	DIP	Custom	KAN3511-0431C
1	U1	5.5V	Microcontroller unit	TSSOP-16	NXP Semiconductors	S9KEAZN8AMTG
1	U2	MPQ2013A	Low-I_Q linear regulator, AEC-Q100 qualified	QFN-8 (3mmx 3mm)	MPS	MPQ2013AGG
1	U3	MPQ4323	42V load dump, sync step-down converter, AEC-Q100 qualified	QFN-12 (2mmx 3mm), QFN-12 (3mmx 4mm)	MPS	MPQ4323GDE-AEC1
3	U4, U5, U6	MPQ7221	16-ch LED driver, AEC-Q100 qualified	QFN-24 (4mmx 4mm)	MPS	MPQ7221GRE-AEC1

Table 4: Lamp Board Bill of Materials

Qty	Ref	Value	Description	Package	Manufacturer	Manufacturer PN
3	CN1_SL, CN2_TL, CN3_SML	1mm	Connector, 2x10-pin, 90°	DIP	Custom	
16	LED1, LED2, LED3, LED4, LED5, LED6, LED7, LED8, LED9, LED10, LED11, LED12, LED13, LED14, LED15, LED16	2.15V	Amber LED	SMD	ams OSRAM	LA E67F-BADB-24-3A5A
14	LED17, LED18, LED19, LED20, LED21, LED22, LED23, LED24, LED25, LED26, LED27, LED28, LED29, LED30	2.15V	Yellow LED	SMD	ams OSRAM	LY E67F-ABCA-35-3B5A
16	LED31, LED32, LED33, LED34, LED35, LED36, LED37, LED38, LED39, LED40, LED41, LED42, LED43, LED44, LED45, LED46	2.15V	Red LED	SMD	ams OSRAM	LR E67F-ABCB-1-1
5	CN1_SL, CN2_TL, CN3_SML	1mm	Wiring harness, 2x10-pin	DIP	Custom	

3.3 PCB Layout

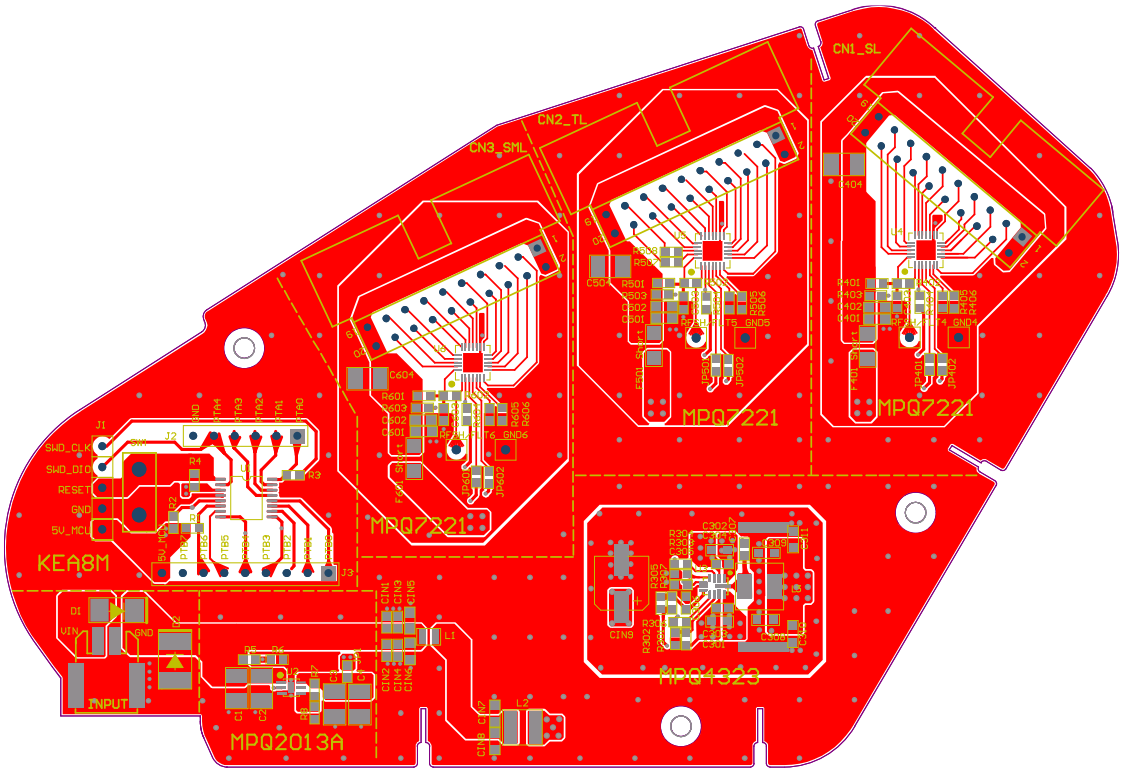


Figure 4: Top Silk and Top Layer of EVQ7221-TL-00A Tail Lamp Control Board

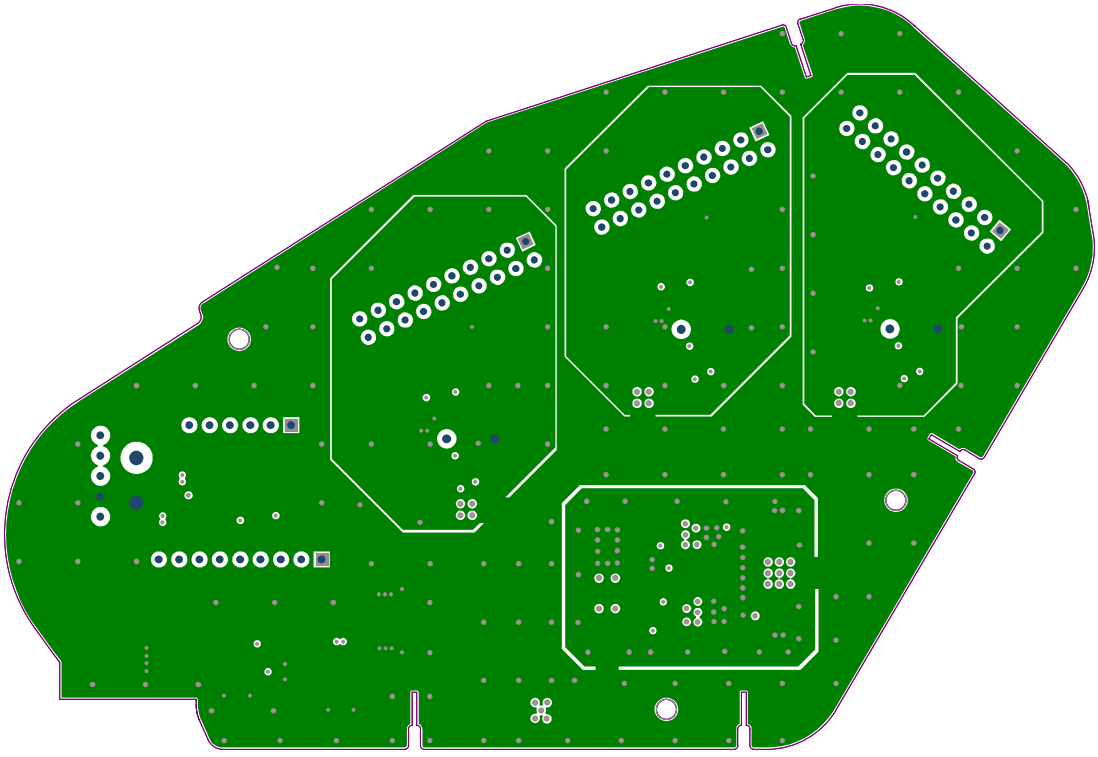


Figure 5: Mid-Layer 1 of EVQ7221-TL-00A Tail Lamp Control Board

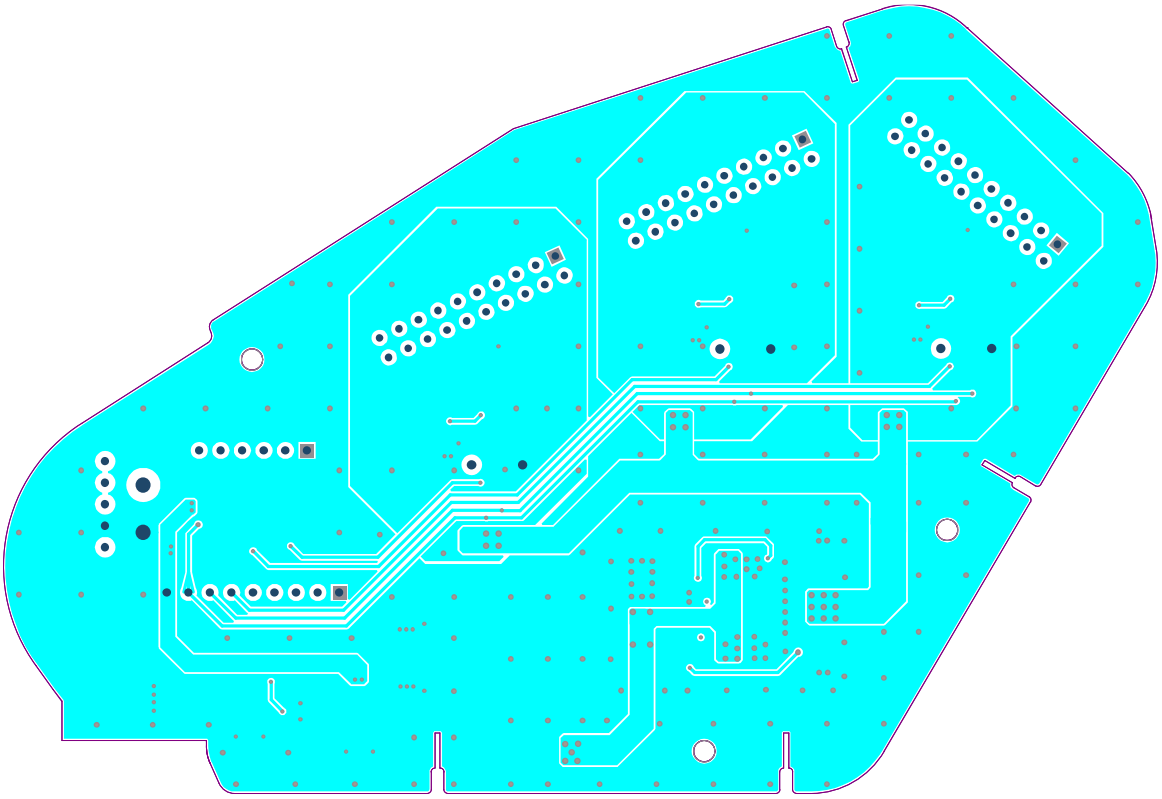


Figure 6: Mid-Layer 2 of EVQ7221-TL-00A Tail Lamp Control Board

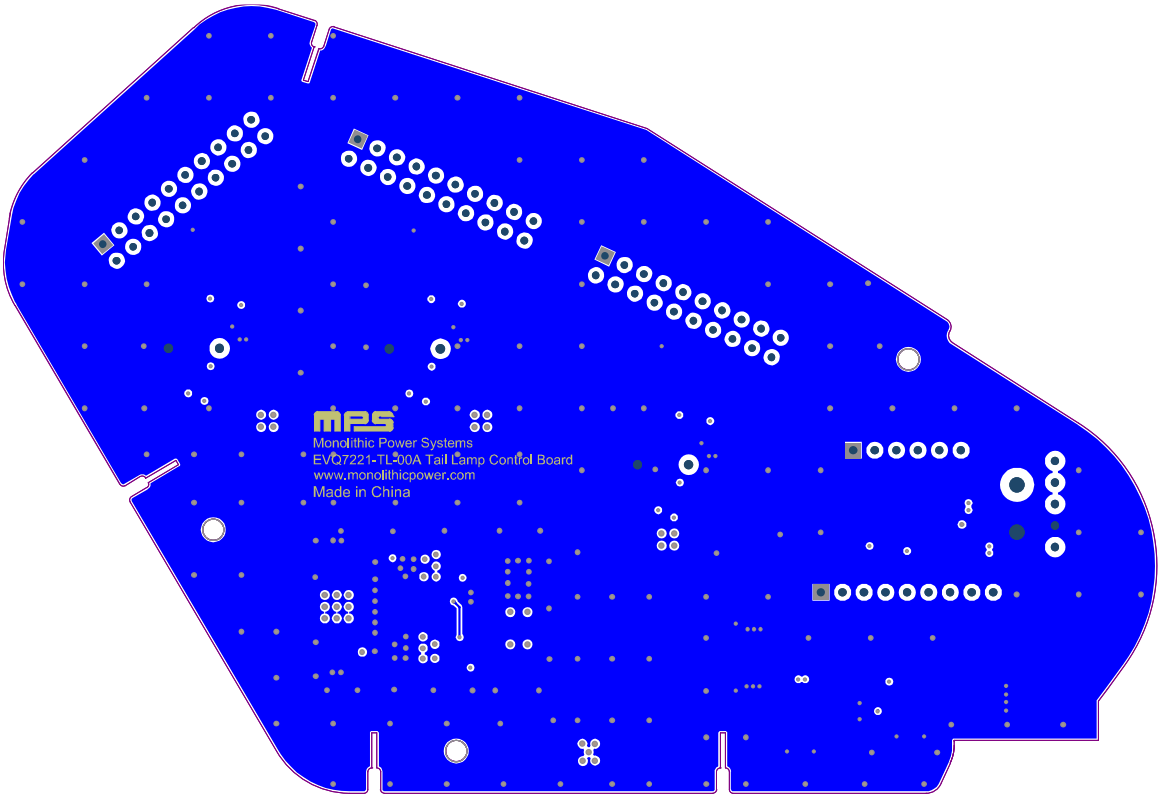


Figure 7: Bottom Silk and Bottom Layer of the EVQ7221-TL-00A Tail Lamp Control Board

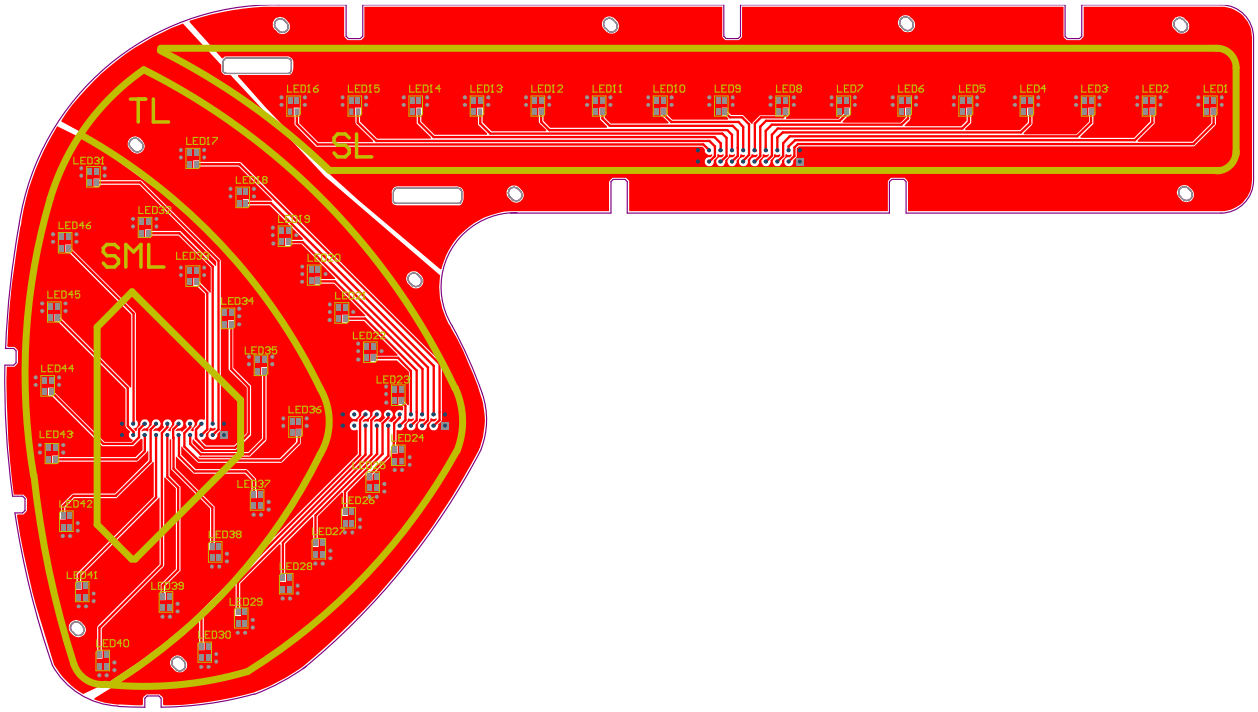


Figure 8: Top Silk and Top Layer of EVQ7221-TL-00A Tail Lamp Board

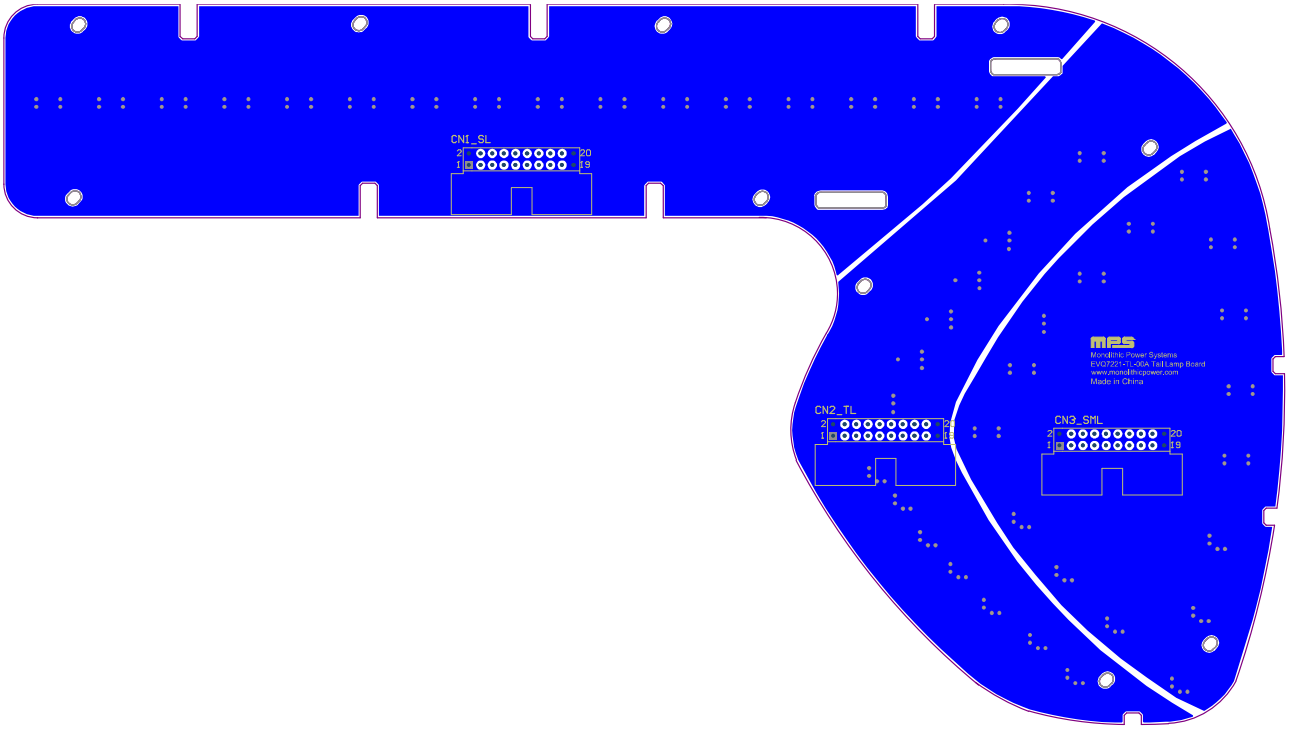


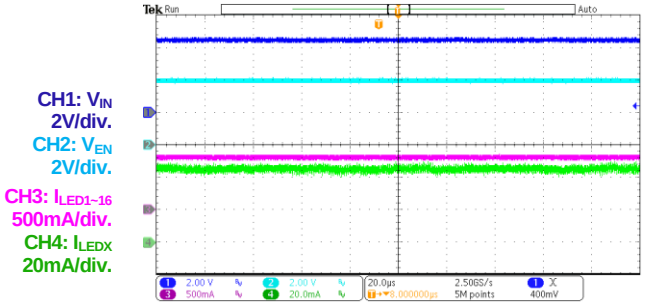
Figure 9: Bottom Silk and Bottom Layer of EVQ7221-TL-00A Tail Lamp Board

4 Test Results

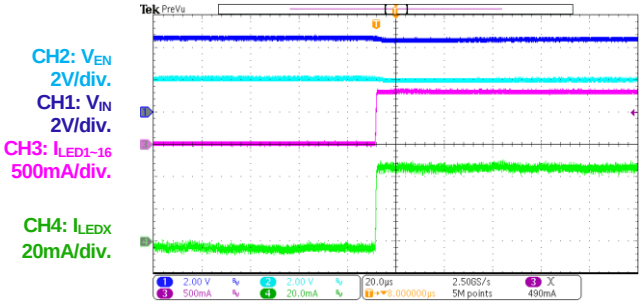
12V power supply, MPQ7221 V_{IN} = 4.5V, T_A = 25°C, unless otherwise noted. The SL, TI, and SML waveforms are similar, thus only the SL test results are shown below.

Steady State

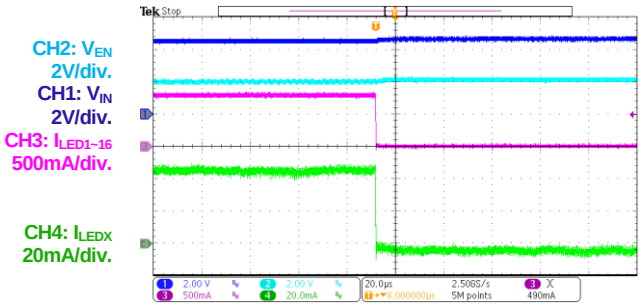
V_{IN} = 4.5V, 16P1S, 50mA/string



Start-Up via the EN Bit

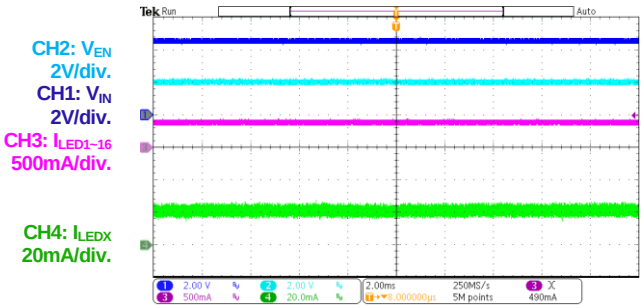


Shutdown via the EN Bit



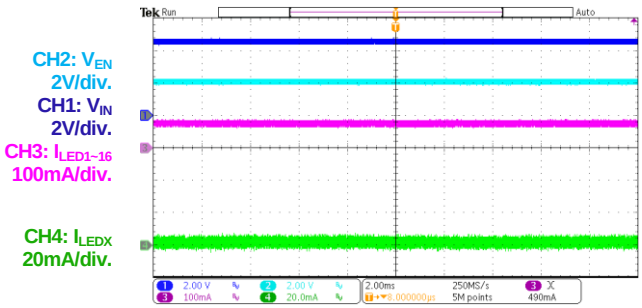
Analog Dimming

25mA/string



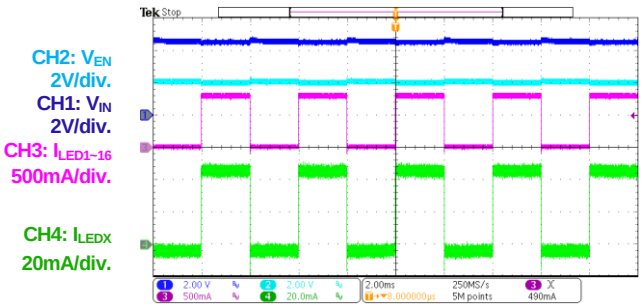
Analog Dimming

5mA/string



PWM Dimming

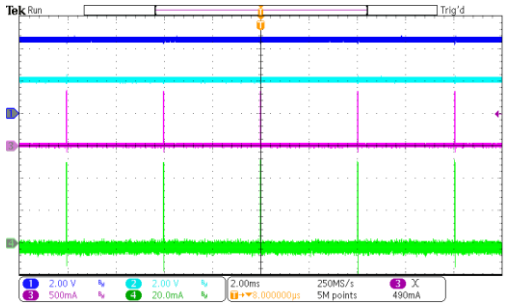
PWM duty = 50%



PWM Dimming

PWM duty = 0.5%

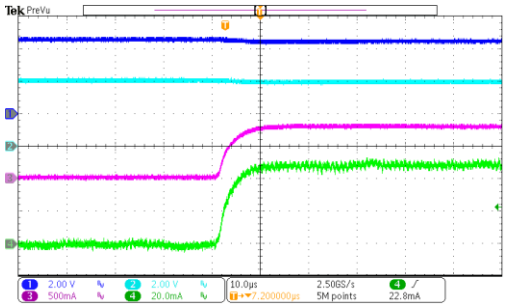
CH2: V_{EN} 2V/div.
CH1: V_{IN} 2V/div.
CH3: $I_{LED1\sim16}$ 500mA/div.
CH4: I_{LEDX} 20mA/div.



Slew Rate

PWM dimming, slew rate = 5μs

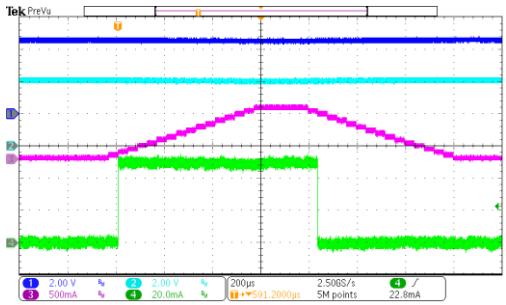
CH1: V_{IN} 2V/div.
CH2: V_{EN} 2V/div.
CH3: $I_{LED1\sim16}$ 500mA/div.
CH4: I_{LEDX} 20mA/div.



Phase Shift

PWM dimming, duty = 20%

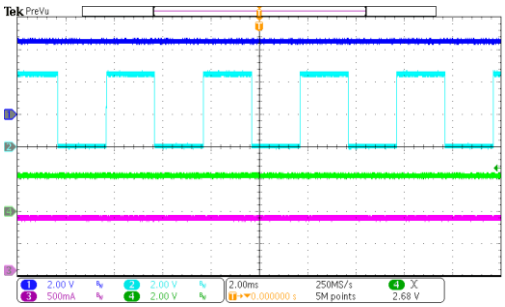
CH1: V_{IN} 2V/div.
CH2: V_{EN} 2V/div.
CH3: $I_{LED1\sim16}$ 500mA/div.
CH4: I_{LED2} 20mA/div.



Refresh Function

f_{PWM} = 250Hz, RFRSH = 0x1FF

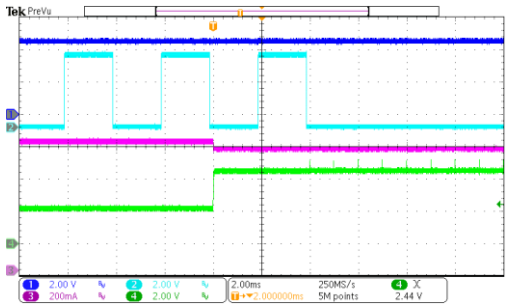
CH1: V_{IN} 2V/div.
CH2: RFSH/FLT 2V/div.
CH4: V_{LEDX} 2V/div.
CH3: $I_{LED1\sim16}$ 500mA/div.



LEDx Short Entry

RFSH/FLT fault enabled, f_{PWM} = 250Hz, RFRSH = 0x1FF

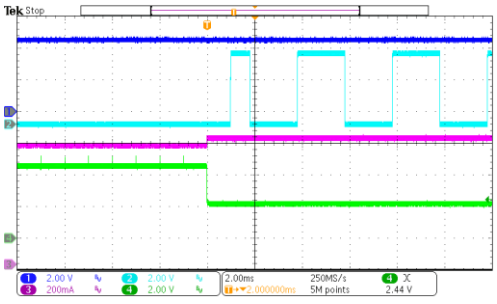
CH1: V_{IN} 2V/div.
CH2: RFSH/FLT 2V/div.
CH4: V_{LEDX} 2V/div.
CH3: $I_{LED1\sim16}$ 200mA/div.



LEDx Short Recovery

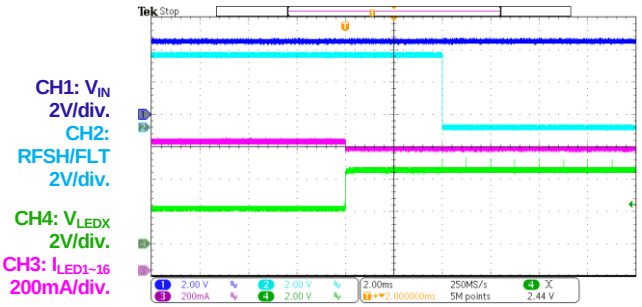
RFSH/FLT fault enabled, f_{PWM} = 250Hz, RFRSH = 0x1FF

CH1: V_{IN} 2V/div.
CH2: RFSH/FLT 2V/div.
CH4: V_{LEDX} 2V/div.
CH3: $I_{LED1\sim16}$ 200mA/div.



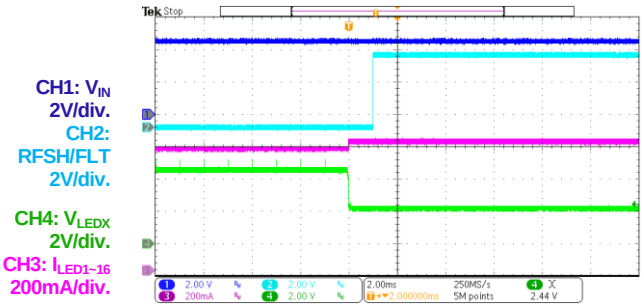
LEDx Short Entry

RFSH/FLT fault enabled, f_{PWM} = 250Hz, RFRSH = 0x000



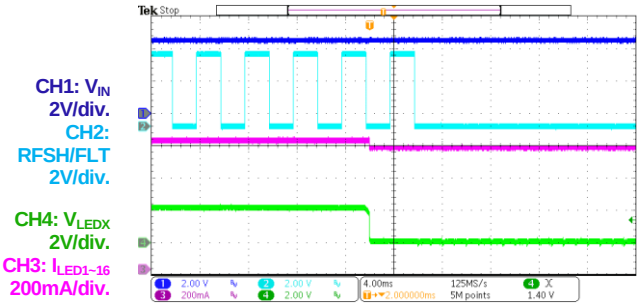
LEDx Short Recovery

RFSH/FLT fault enabled, f_{PWM} = 250Hz, RFRSH = 0x000



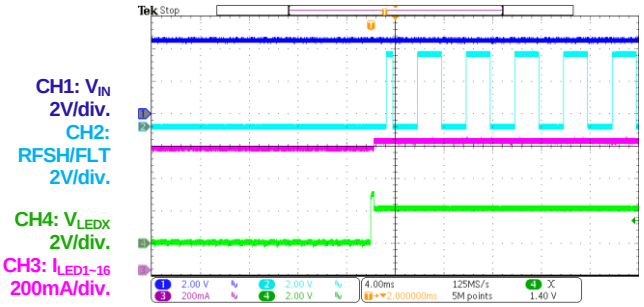
LEDx Open Entry

RFSH/FLT fault enabled, f_{PWM} = 250Hz, RFRSH = 0x1FF



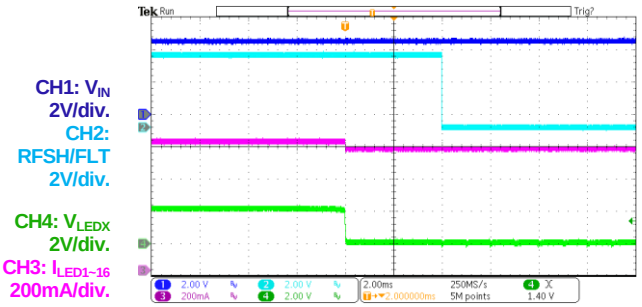
LEDx Open Recovery

RFSH/FLT fault enabled, f_{PWM} = 250Hz, RFRSH = 0x1FF



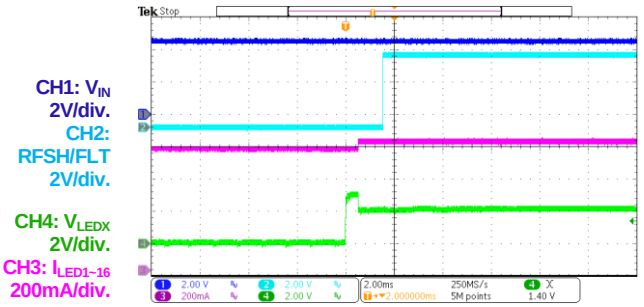
LEDx Open Entry

RFSH/FLT fault enabled, f_{PWM} = 250Hz, RFRSH = 0x000



LEDx Open Recovery

RFSH/FLT fault enabled, f_{PWM} = 250Hz, RFRSH = 0x000



5 Start-Up

1. Preset the power supply output between 5V and 36V, then turn off the power supply.
2. Connect the power supply output's positive and negative terminals to the INPUT connector's positive and negative terminals, respectively.
3. Turn the power supply on. The three MPQ7221 devices should automatically start up. The board should run the stop lamp (SL), turn lamp (TL), and side mark lamp (SML) dynamic performance.

6 Disclaimer

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Questions concerning potential risk applications should be directed to MPS.

MPS semiconductors are typically used in power supplies in which high voltages are present during operation. High-voltage safety precautions should be observed in design and operation to minimize the chance of injury.

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	8/25/2022	Initial Release	-