RS3703-Q1 Three-Channel High-Side LED Driver with Thermal Sharing and Off-Board Binning

1 FEATURES

- **RS3703-Q1 AEC-Q100 Qualification is Ongoing**
- **Wide Input Voltage Range: 4.5 V to 40 V**
- **Thermal Sharing by External Shunt Resistor**
- **Low Supply Current in Fault Mode**
- **Three High-Precision Current Regulation:**
  - **Up to 150mA Current Output for Each Channel**
  - **±5% Accuracy Over Full Temperature Range**
  - **Independent Current Setting by Resistor**
  - **Independent PWM Pin for Brightness Control**
  - **Support Off-Board Brightness Binning Resistor**
  - **Support External NTC for Current Derating**
- **Low Dropout Voltage:**
  - **TYP Dropout: 315 mV at 150 mA**
- **Diagnostics and Protection**
  - **LED Open-Circuit with Auto-Recovery**
  - **LED Short-to-GND with Auto-Recovery**
  - **Single LED Short-Circuit Detection with Auto-Recovery**
  - **Diagnostic Enable with Adjustable Threshold**
  - **Fault Bus Configurable as either One-Fails–All-Fail or Only-Failed-Channel Off (N-1)**
  - **Thermal Shutdown**
- **Operation Junction Temperature Range: –40°C to 150°C**

2 APPLICATIONS

- **General-Purpose LED Driver Applications**

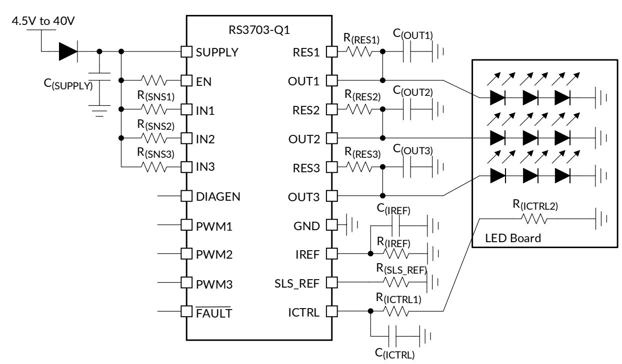
3 DESCRIPTIONS

The RS3703-Q1 three-channel LED driver includes an unique thermal management design to reduce temperature rising on the device. The RS3703-Q1 is a linear driver to output full current loads up to 150 mA per channel. External shunt resistors are leveraged to share output current and dissipate power out of the driver. The RS3703-Q1 also drives LED units and off-board brightness binning resistors to simplify the manufacturing process and lower whole system cost. Its full-diagnostic capabilities include LED open, LED short-to-GND circuit and single LED short circuit detection.

Device Information (1)

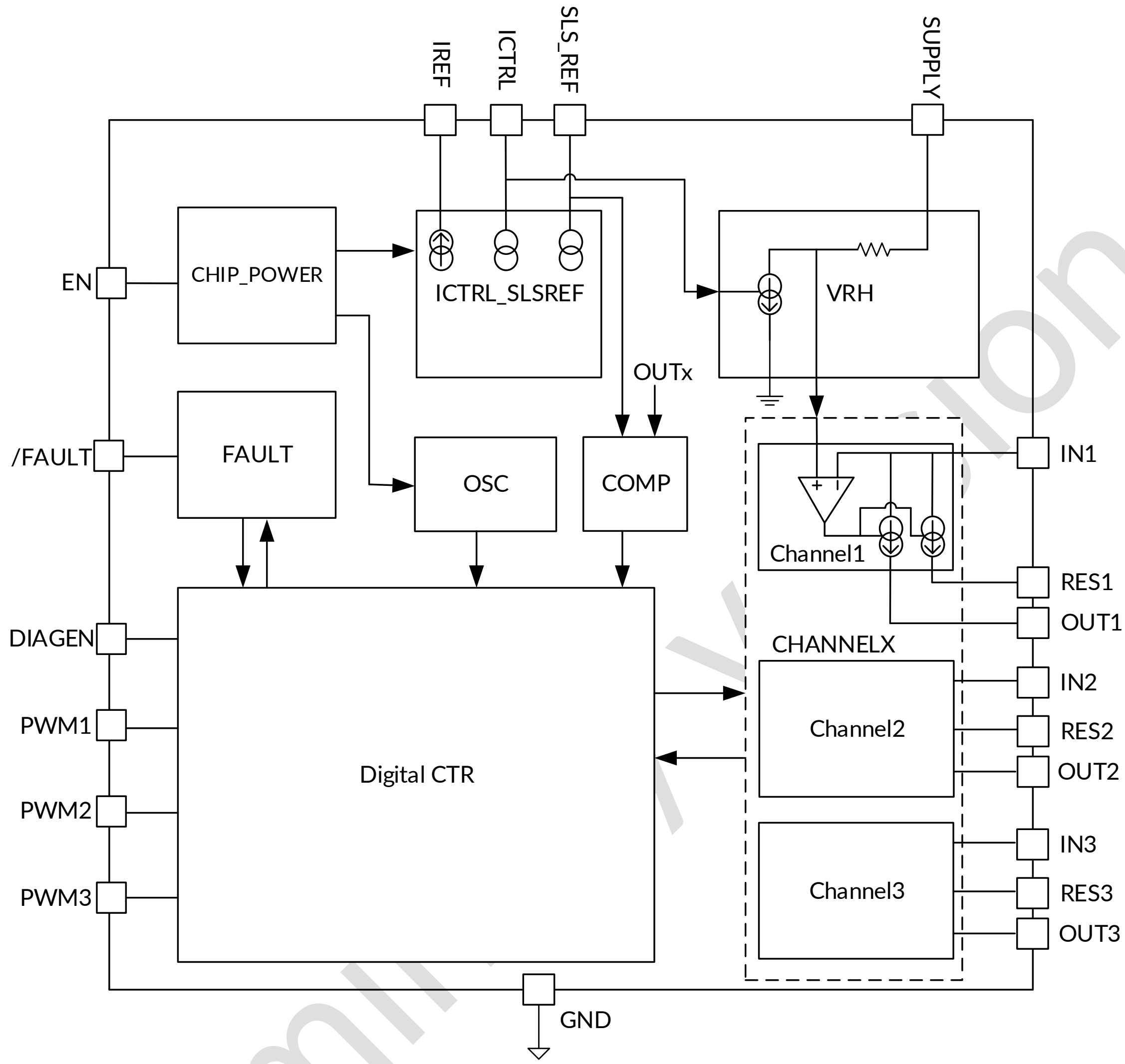
PART NUMBER	PACKAGE	BODY SIZE (NOM)
RS3703-Q1	ETSSOP20	6.50mm×4.40mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.



Typical Application Diagram

4 FUNCTIONAL BLOCK DIAGRAM



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5 REVISION HISTORY

Note: Page numbers for previous revisions may different from page numbers in the current version.

Version	Change Date	Change Item
A.0	2025/02/19	Preliminary version completed

6 PACKAGE/ORDERING INFORMATION (1)

PRODUCT	ORDERING NUMBER	TEMPERATURE RANGE	PACKAGE LEAD	Lead finish/Ball material (2)	MSL Peak Temp (3)	PACKAGE MARKING (4)	PACKAGE OPTION
RS3703-Q1	RS3703XE TSS20-Q1	-40°C ~+125°C	ETSSOP20	SN	TBD	RS3703	Tape and Reel, 4000

NOTE:

(1) This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the right-hand navigation.

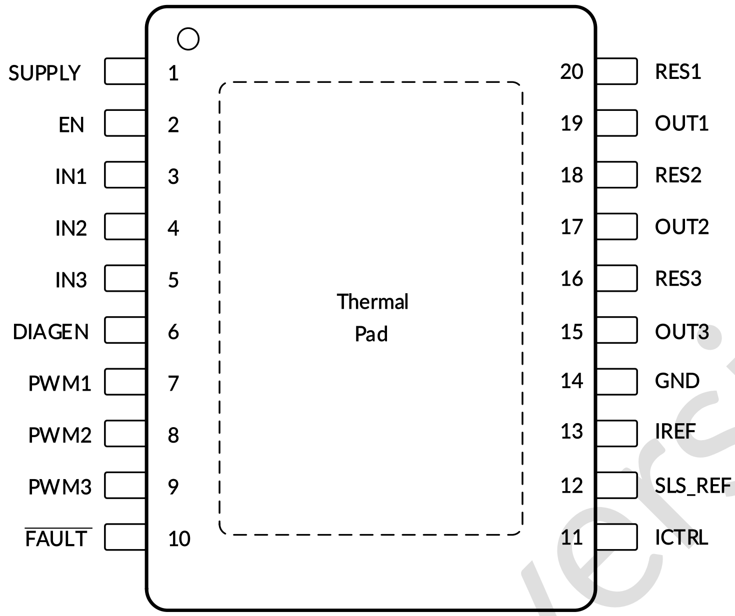
(2) Lead finish/Ball material. Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(3) RUNIC classify the MSL level with using the common preconditioning setting in our assembly factory conforming to the JEDEC industrial standard J-STD-20F. Please align with RUNIC if your end application is quite critical to the preconditioning setting or if you have special requirement.

(4) There may be additional marking, which relates to the lot trace code information (data code and vendor code), the logo or the environmental category on the device.

7 PIN CONFIGURATIONS

TOP VIEW



ETSSOP20

PIN DESCRIPTION

PIN		I/O (1)	FUNCTION
NAME	NO.		
SUPPLY	1	I	Device power supply.
EN	2	I	Device enable pin.
IN1	3	I	Current input for channel 1.
IN2	4	I	Current input for channel 2.
IN3	5	I	Current input for channel 3.
DIAGEN	6	I	Enable pin for LED open-circuit detection and single LED short detection to avoid false open and single LED short diagnostics during low-dropout operation.
PWM1	7	I	PWM input for OUT1 and RES1 current output ON/OFF control.
PWM2	8	I	PWM input for OUT2 and RES2 current output ON/OFF control.
PWM3	9	I	PWM input for OUT3 and RES3 current output ON/OFF control.
$\overline{\text{FAULT}}$	10	I/O	Fault output, support one-fails–all-fail fault bus.
ICTRL	11	O	Resistor programmable voltage reference pin for LED binning resistor or NTC resistor.
SLS_REF	12	O	Resistor programmable voltage reference pin for single LED short threshold.
IREF	13	O	Current reference pin. A 12.3-kΩ resistor is recommended to be connected between IREF pin and ground.
GND	14	-	Ground.
OUT3	15	O	Current output for channel 3. A 10-nF capacitor is recommended between the pin to GND.
RES3	16	O	Current output for channel 3 with external thermal resistor.
OUT2	17	O	Current output for channel 2. A 10-nF capacitor is recommended between the pin to GND.
RES2	18	O	Current output for channel 2 with external thermal resistor.
OUT1	19	O	Current output for channel 1. A 10-nF capacitor is recommended between the pin to GND.
RES1	20	O	Current output for channel 1 with external thermal resistor.

(1) I=input, O=output

8 SPECIFICATIONS

8.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) (1)

			MIN	MAX	UNIT
Supply	SUPPLY		-0.3	45	V
High-voltage input	DIAGEN, IN1, IN2, IN3, EN, PWM1, PWM2, PWM3		-0.3	V_{SUPPLY}+0.3	V
High-voltage output	OUT1, OUT2, OUT3, RES1, RES2, RES3, ICTRL		-0.3	V_{SUPPLY}+0.3	V
Fault bus	$\overline{FAULT}$		-0.3	V_{SUPPLY}+0.3	V
Low-voltage pin	SLS_REF, IREF		-0.3	5.5	V
$θ_{JA}$	Package thermal impedance (2)	ETSSOP20		45	°C/W
T_J	Operating junction temperature (3)		-40	150	°C
T_{stg}	Storage temperature		-40	150	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) The package thermal impedance is calculated in accordance with JESD-51.

(3) The maximum power dissipation is a function of $T_{J(MAX)}$, $R_{θJA}$, and T_A. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(MAX)} - T_A) / R_{θJA}$. All numbers apply for packages soldered directly onto a PCB.

8.2 ESD Ratings

The following ESD information is provided for handling of ESD-sensitive devices in an ESD protected area only.

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-Body Model (HBM), per AEC Q100-002 (1)	TBD	V
		Charged-Device Model (CDM), per AEC Q100-011	TBD	
		Latch-Up (LU), per AEC Q100-004	TBD	mA

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

ESD SENSITIVITY CAUTION

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

8.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
SUPPLY	Device supply voltage	4.5	40	V
IN1, IN2, IN3	Sense voltage	V_{SUPPLY}-V_{CS_REG}	V_{SUPPLY}	V
EN	Device EN pin	0	V_{SUPPLY}	V
PWM1, PWM2, PWM3	PWM inputs	0	V_{SUPPLY}	V
DIAGEN	Diagnostics enable pin	0	V_{SUPPLY}	V
OUT1, OUT2, OUT3, RES1, RES2, RES3	Driver output	0	V_{SUPPLY}	V
$\overline{FAULT}$	Fault bus	0	V_{SUPPLY}	V
ICTRL	Output current control	0	2.75	V
SLS_REF	Single LED short-circuit reference	0	3.5	V
IREF	Current reference	50	250	µA
Operating ambient temperature, T_A		-40	125	°C

8.4 Electrical Characteristics

V_{SUPPLY}=5V to 40V, V_{EN}=5V, T_J=25°C unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN[(1)]	TYP[(2)]	MAX[(1)]	UNIT
BIAS						
V_{POR_rising}	Supply voltage POR rising threshold			3.65		V
$V_{POR\_falling}$	Supply voltage POR falling threshold			3.45		V
I_{SD}	Device shutdown current	V_{EN} = 0V		14		µA
$I_{Quiescent}$	Device standby ground current	EN=HIGH		1.5		mA
I_{Fault}	Device supply current in fault mode	PWM=HIGH, $\overline{FAULT}$ externally pulled LOW		0.27		mA
LOGIC INPUTS (EN, DIAGEN, PWM)						
V_{IL_EN}	Input logic-low voltage, EN				0.7	V
V_{IH_EN}	Input logic-high voltage, EN		2			V
$I_{EN\_pulldown}$	EN pulldown current	V_{EN}=12V		3.2		µA
V_{IL_DIAGEN}	Input logic-low voltage, DIAGEN			1.1		V
V_{IH_DIAGEN}	Input logic-high voltage, DIAGEN			1.2		V
V_{IL_PWM}	Input logic-low voltage, PWM			1.1		V
V_{IH_PWM}	Input logic-high voltage, PWM			1.2		V
CONSTANT-CURRENT DRIVER						
I_{OUTx_Tot}	Device output-current for each channel	Duty of PWM=100%	5		150	mA
V_{CS_REG}	Sense-resistor regulation voltage	T_A=-40°C to +125°C, ICTRL to ground		50		mV
		T_A=-40°C to +125°C, V_{ICTRL}=0.68V		100		
		T_A=-40°C to +125°C, V_{ICTRL}=1.36V		200		
		T_A=-40°C to +125°C, V_{ICTRL}=2.75V		400		
ΔV_{CS_c2c}	Channel to channel mismatch	$\Delta V_{CS\_c2c}=1-V_{CS\_REGx}/V_{avg\_CS\_REG}$, V_{ICTRL}=0.68V		±0.25		%
		$\Delta V_{CS\_c2c}=1-V_{CS\_REGx}/V_{avg\_CS\_REG}$ V_{ICTRL}=1.36V		±0.25		
ΔV_{CS_d2d}	Device to Device mismatch	$\Delta V_{CS\_d2d}=1-V_{avg\_CS\_REG}/V_{nom\_CS\_REG}$ V_{ICTRL}=0.68V		±0.5		%
		$\Delta V_{CS\_d2d}=1-V_{avg\_CS\_REG}/V_{nom\_CS\_REG}$ V_{ICTRL}=1.36V		±0.5		
R_{CS_REG}	Sense-resistor range		0.65		20	Ω
$V_{DROPOUT}$	Voltage dropout from INx to OUTx, RESx open	Current setting of 100mA		210		mV
		Current setting of 150mA		315		
	Voltage dropout from INx to RESx, OUTx open	Current setting of 100mA		285		
		Current setting of 150mA		435		
I_{RESx}	Ratio of RESx current to total current	I_{RESx}/I_{OUTx_Tot}, $V_{INx}-V_{RESx}$>1V	95			%
V_{IREF}	IREF voltage			1.235		V
N_{ICTRL}	ICTRL current output ratio	I_{ICTRL}/I_{IREF}		10		
V_{ICTRL_SAT}	ICTRL saturated voltage	V_{CS_REG}=400mV		2.75		V
V_{CS_SAT}	$V_{SUPPLY}-V_{IN}$	V_{ICTRL}=3V		400		mV

(1) Limits are 100% production tested at 25°C. Limits over the operating temperature range are ensured through correlations using statistical quality control (SQC) method.

(2) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.

Electrical Characteristics (continued)

V_{SUPPLY}=5V to 40V, V_{EN}=5V, T_J=25°C unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN(1)	TYP(2)	MAX(1)	UNIT
DIAGNOSTICS						
$V_{OPEN\_th\_rising}$	LED open rising threshold, V_{IN} – V_{OUT}			220		mV
$V_{OPEN\_th\_falling}$	LED open falling threshold, V_{IN} – V_{OUT}			370		mV
$V_{SG\_th\_rising}$	Channel output short-to-ground rising threshold			1.2		V
$V_{SG\_th\_falling}$	Channel output short-to-ground falling threshold			0.9		V
N_{SLS_REF}	SLS_REF current output ratio	I_{SLS_REF}/I_{IREF}		1		
N_{OUT}	OUT voltage attenuation ratio	V_{OUT}=3 to 14V		4		
I_{RETRY}	Channel output V_{OUT} short-to-ground retry current			1		mA
$I_{IREF\_OPEN\_th}$	IREF pin open threshold			8		µA
$V_{IREF\_SHORT\_th}$	IREF pin short-to-ground threshold			0.6		V
$I_{IREF\_ST\_Clamp}$	Current clamp for IREF short-to-GND			460		µA
FAULT						
V_{IL_FAULT}	Logic input low threshold				0.7	V
V_{IH_FAULT}	Logic input high threshold		2			V
t_{FAULT_rising}	Fault detection rising edge deglitch time			10		µs
$t_{FAULT\_falling}$	Fault detection falling edge deglitch time			10		µs
$I_{FAULT\_pulldown}$	$\overline{FAULT}$ internal pulldown current	$V_{\overline{FAULT}}$=0.4V		3		mA
I_{FAULT_pullup}	$\overline{FAULT}$ internal pullup current			10		µA
$I_{FAULT\_leakage}$	$\overline{FAULT}$ leakage current	$V_{\overline{FAULT}}$=40V		0.4		µA
THERMAL PROTECTION						
T_{TSD}	Thermal shutdown junction temperature threshold			170		°C
T_{TSD_HYS}	Thermal shutdown junction temperature hysteresis			15		°C

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8.5 Timing Requirements

PARAMETER		TEST CONDITIONS	MIN(1)	TYP(2)	MAX(1)	UNIT
$t_{PWM\_delay\_rising}$	PWM rising edge delay(V_{IH_PWM}) to 10% output	V_{SUPPLY}=12V, V_{OUT}=6V, V_{CS_REG}=100mV, R_{SNSx}=0.667Ω, R_{RESx}=56Ω		5		µs
		V_{SUPPLY}=12V, V_{OUT}=6V, V_{CS_REG}=50mV, R_{SNSx}=0.667Ω, R_{RESx}=56Ω		5		µs
$t_{Current\_rising}$	Output current rising from 10% to 90%	V_{SUPPLY}=12V, V_{OUT}=6V, V_{CS_REG}=100mV, R_{SNSx}=0.667Ω, R_{RESx}=56Ω		0.5		µs
		V_{SUPPLY}=12V, V_{OUT}=6V, V_{CS_REG}=50mV, R_{SNSx}=0.667Ω, R_{RESx}=56Ω		0.5		µs
$t_{PWM\_delay\_falling}$	PWM falling edge delay(V_{IL_PWM}) to 90% output	V_{SUPPLY}=12V, V_{OUT}=6V, V_{CS_REG}=100mV, R_{SNSx}=0.667Ω, R_{RESx}=56Ω		3		µs
		V_{SUPPLY}=12V, V_{OUT}=6V, V_{CS_REG}=100mV, R_{SNSx}=0.667Ω, R_{RESx}=56Ω		3		µs
$t_{Current\_falling}$	Output current rising from 90% to 10%	V_{SUPPLY}=12V, V_{OUT}=6V, V_{CS_REG}=100mV, R_{SNSx}=0.667Ω, R_{RESx}=56Ω		1.8		µs
		V_{SUPPLY}=12V, V_{OUT}=6V, V_{CS_REG}=50mV, R_{SNSx}=0.667Ω, R_{RESx}=56Ω		0.5		µs
$t_{STARTUP}$	SUPPLY rising edge to 10% output current	C_{IREF}=C_{ICTRL}=10pF, V_{OUT}=6V, V_{CS_REG}=100mV, R_{SNSx}=0.667Ω, R_{RESx}=56Ω		85		µs
t_{IREF_deg}	IREF pin open and short to GND detection deglitch time			125		µs
t_{OPEN_deg}	LED-open fault-deglitch time			125		µs
t_{SG_deg}	Output short-to-ground detection deglitch time			125		µs
$t_{Recover\_deg}$	Open and Short fault recovery deglitch time			125		µs
t_{SLS_deg}	Single LED short circuit detection deglitch time			135		µs
$t_{SLS\_retry\_interval}$	Single LED short circuit failure retry interval time			10		ms
$t_{SLS\_retry\_period}$	Single LED short circuit failure retry period time			300		µs
$t_{SLS\_retry\_deg}$	Single LED short circuit failure retry deglitch time			50		µs
$t_{FAULT\_recovery}$	Fault recovery delay time			50		µs
t_{TSD_deg}	Thermal over temperature deglitch time			50		µs

(1) Limits are 100% production tested at 25°C. Limits over the operating temperature range are ensured through correlations using statistical quality control (SQC) method.

(2) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.

8.6 Typical Characteristics

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

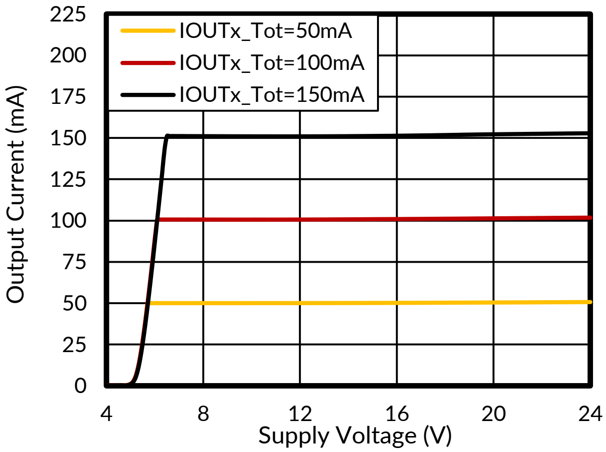


Figure 1. Output Current vs Supply Voltage

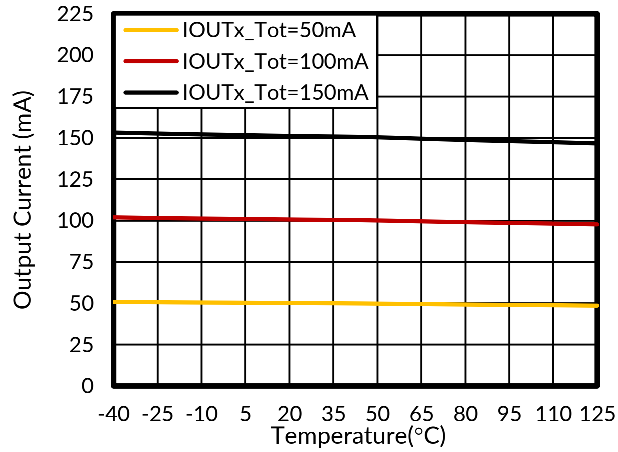


Figure 2. Output Current vs Temperature

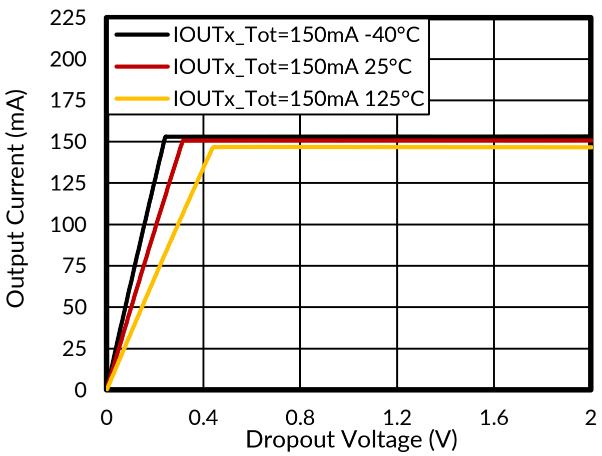


Figure 3. Output Current vs Dropout Voltage

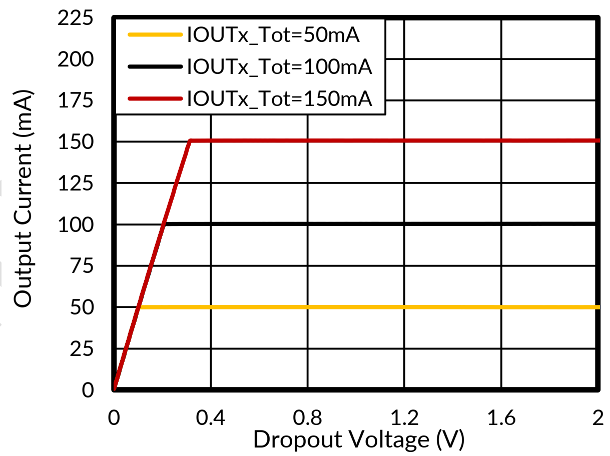


Figure 4. Output Current vs Dropout Voltage

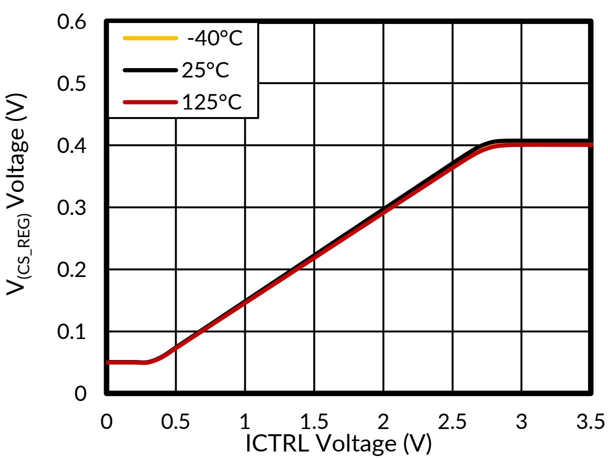


Figure 5. $V_{(CS\_REG)}$ vs ICTRL Voltage

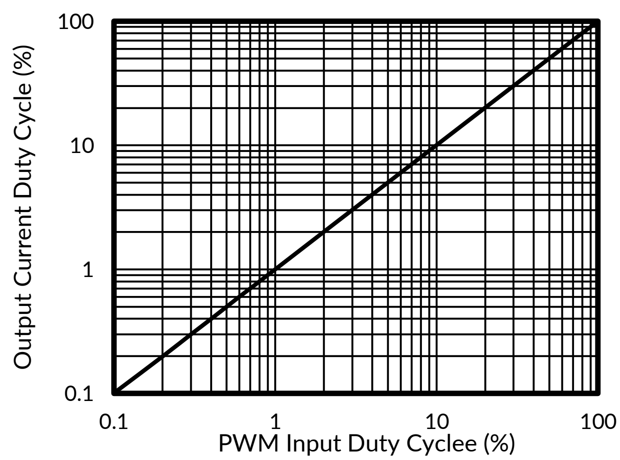


Figure 6. PWM Output Duty Cycle vs PWM Input Duty Cycle

Typical Characteristics (continued)

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

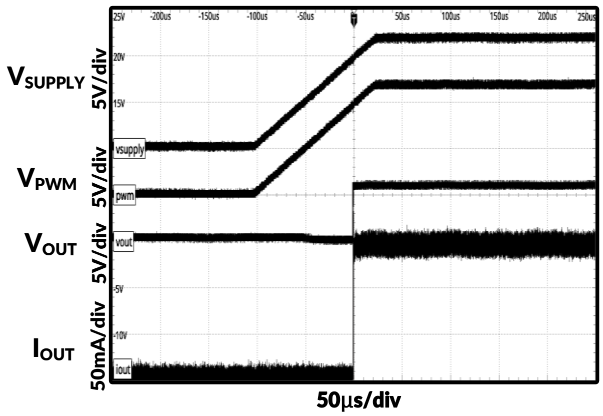


Figure 7. Power Up Sequency

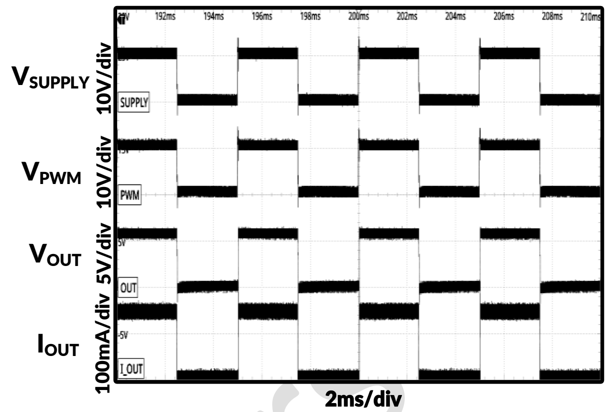


Figure 8. Supply Dimming at 200 Hz

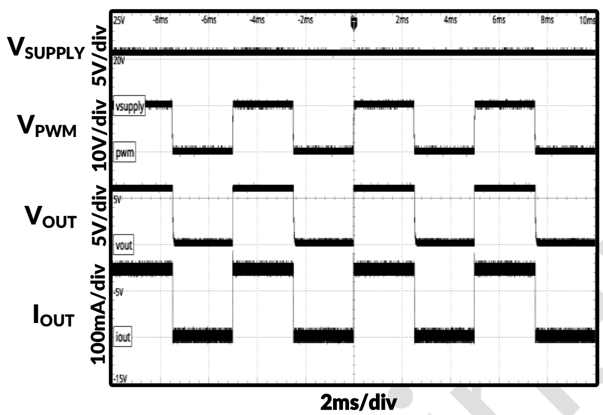


Figure 9. PWM Dimming at 200 Hz

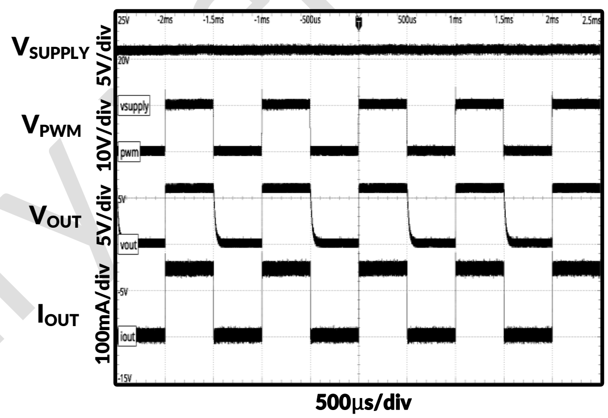


Figure 10. PWM Dimming at 1 kHz

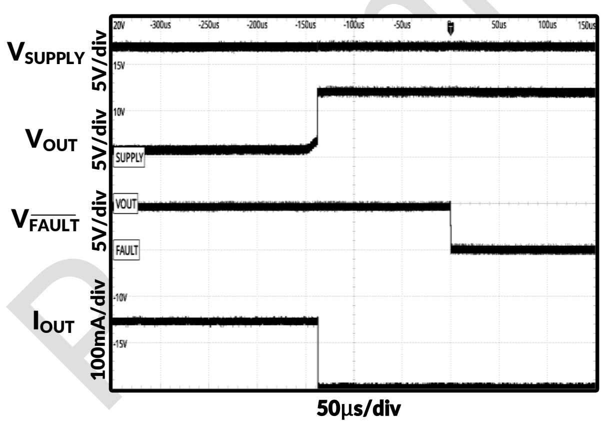


Figure 11. LED Open Protection

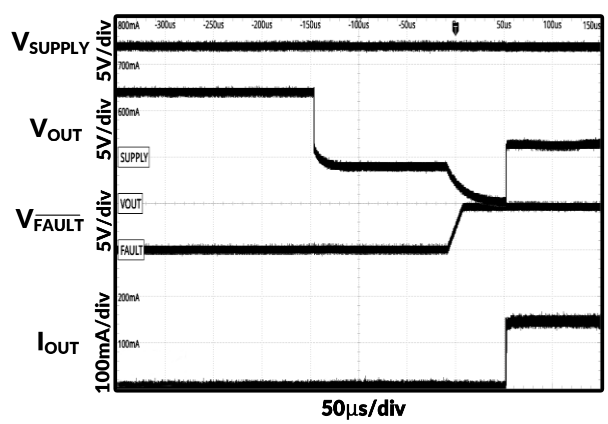


Figure 12. LED Open Protection Recovery

Typical Characteristics (continued)

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

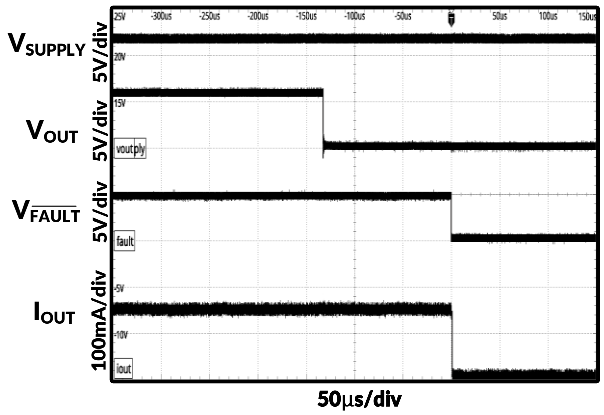


Figure 13. LED Short-Circuit Protection

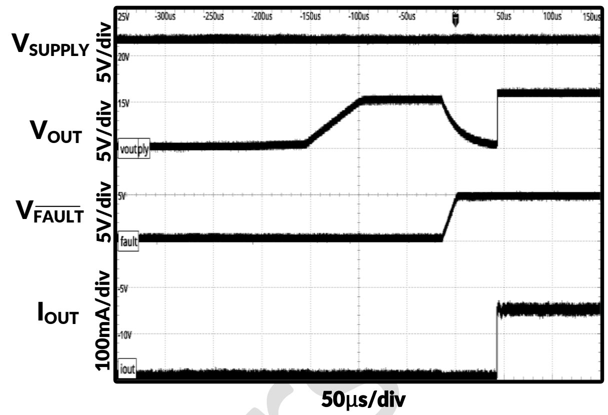


Figure 14. LED Short-Circuit Protection Recovery

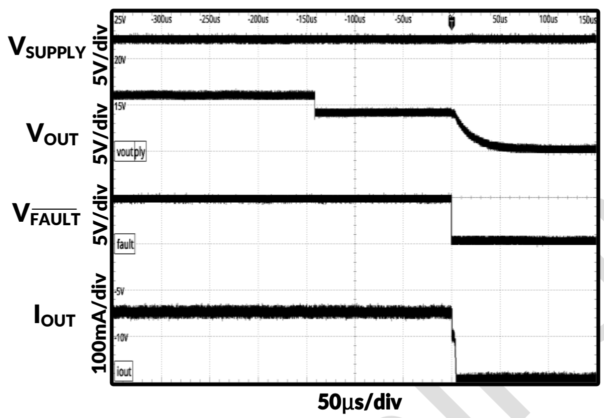


Figure 15. Single LED Short-Circuit Protection

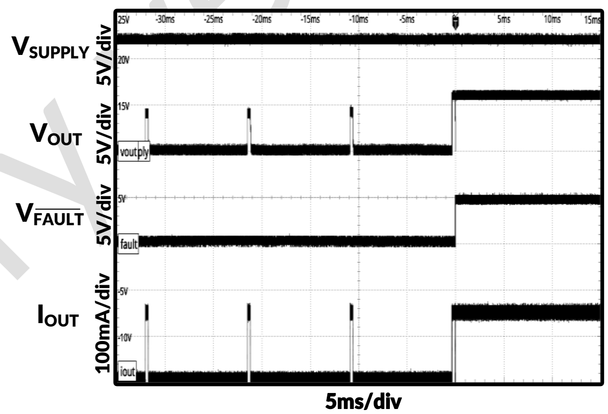


Figure 16. Single LED Short-Circuit Protection Recovery

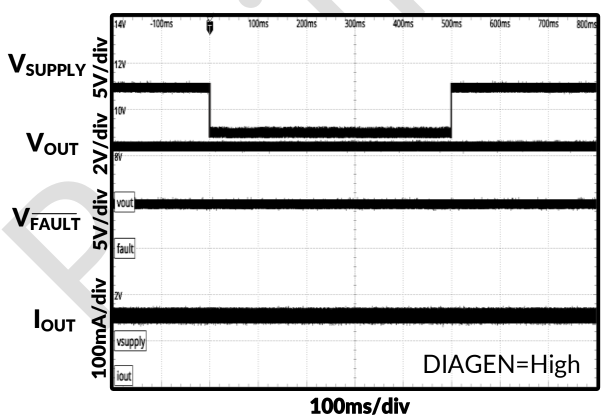


Figure 17. Transient Undervoltage

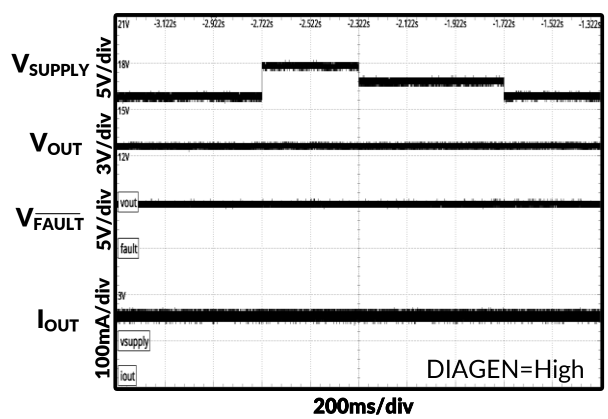


Figure 18. Transient Overvoltage

Typical Characteristics (continued)

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

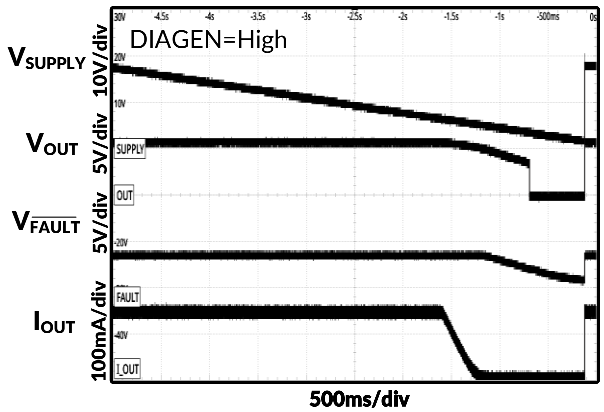


Figure 19. Slow Decrease and Quick Increase of Supply Voltage

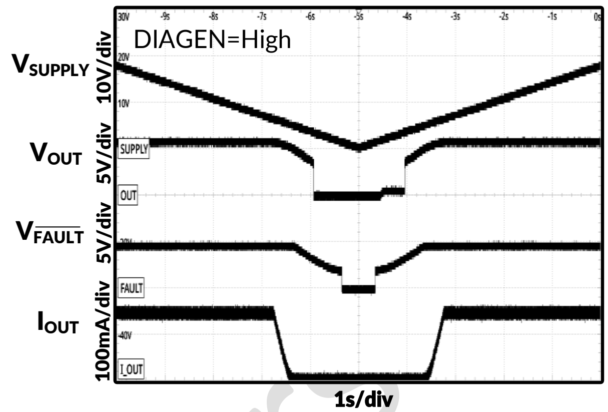


Figure 20. Slow Decrease and Slow Increase of Supply Voltage

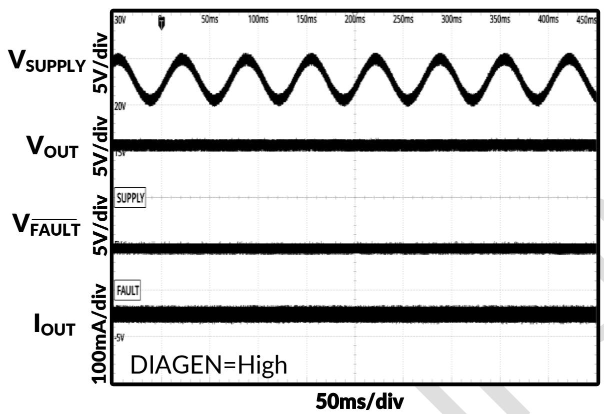


Figure 21. Superimposed Alternating Voltage 15Hz

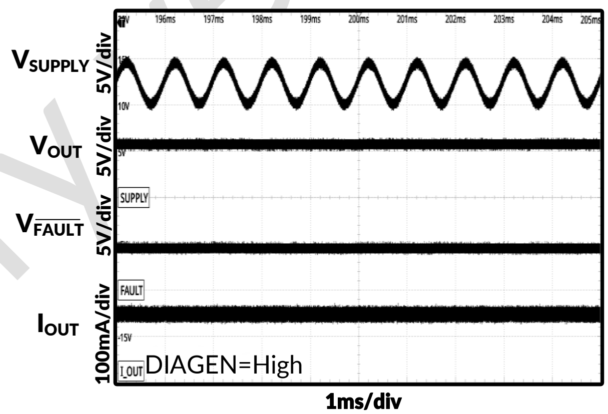


Figure 22. Superimposed Alternating Voltage 1kHz

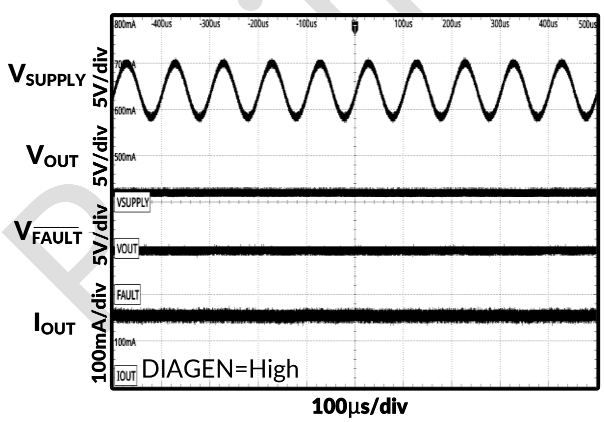


Figure 23. Superimposed Alternating Voltage 10kHz

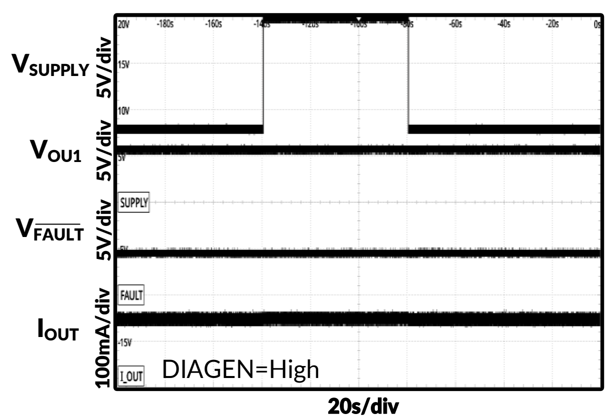


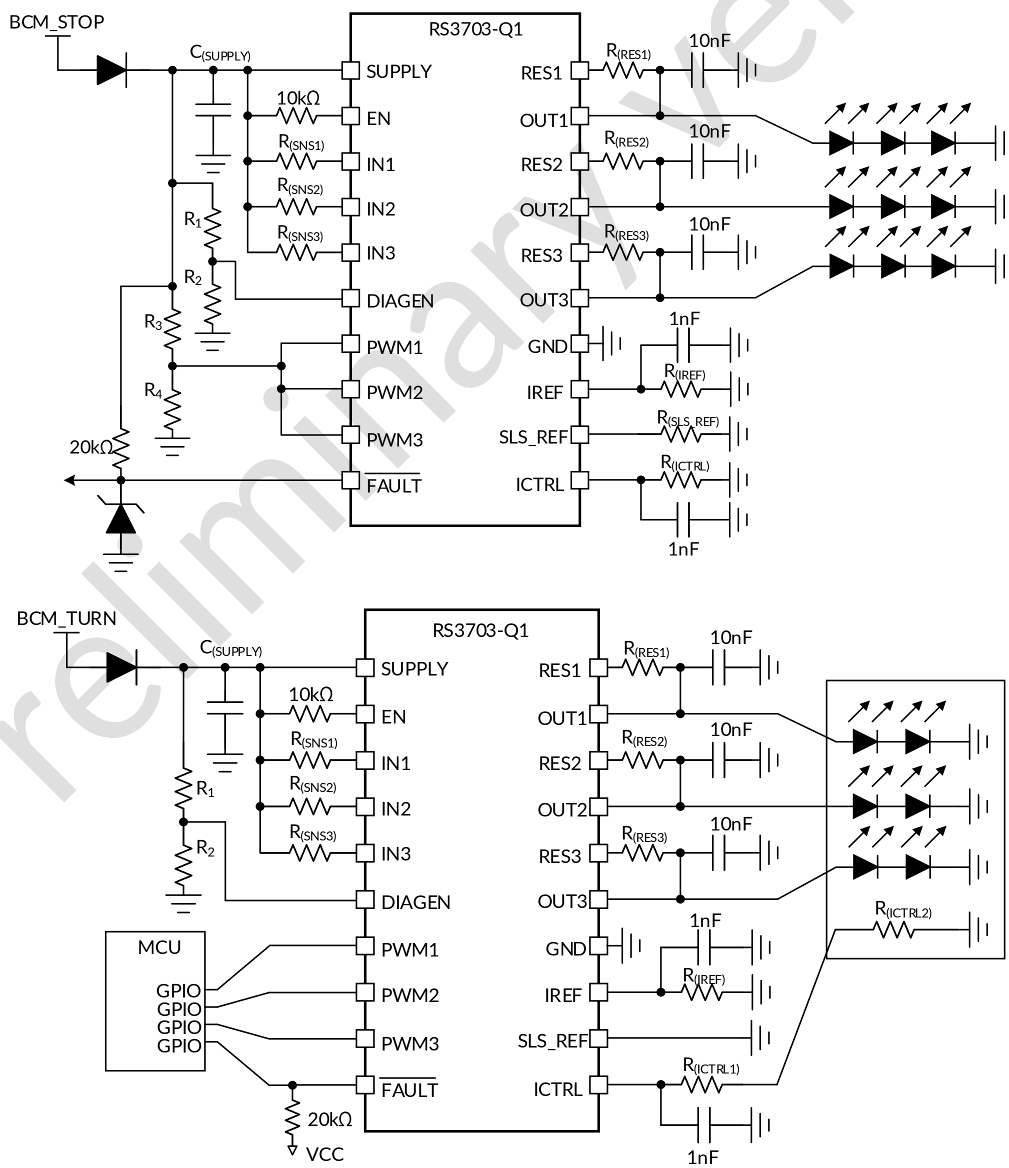
Figure 24. Jump Start

9 DETAILED DESCRIPTION

9.1 Overview

The RS3703-Q1 three-channel LED driver includes an unique thermal management design to reduce temperature rising on the device. The RS3703-Q1 is a linear driver directly powered by automotive batteries with large voltage variations to output full current loads up to 150 mA per channel. The current output at each channel can be independently set by external $R_{(SNS)}$ resistors. Current flows from the supply through the $R_{(SNSx)}$ resistor into the integrated current regulation circuit and to the LEDs through OUTx pin and RESx pin. All three-channel current is configurable by an external resistor connected to the ICTRL pin. Either a NTC resistor for LED temperature monitor or a LED brightness binning resistor can be connected to ICTRL pin in same board or off-board. The RS3703-Q1 device supports both supply control and EN/PWM control to turn LED ON/OFF. The LED brightness is also adjustable by voltage dutycycle applied on either SUPPLY or EN/PWM with frequency above 100 Hz. The RS3703-Q1 provides full diagnostics to keep the system operating reliably including LED open/short circuit detection, single LED short circuit detection, supply POR and thermal shutdown protection. The RS3703-Q1 device is in a ETSSOP package with total 20 leads. The RS3703-Q1 can be used with other family devices together to achieve one-fails-all-fail protection by tying all $\overline{\text{FAULT}}$ pins together as a fault bus.

9.2 Typical Application Circuit



9.3 Feature Description
9.3.1 Power Supply (SUPPLY)
9.3.1.1 Power-On Reset
The RS3703-Q1 device has an internal power-on-reset (POR) function. When power is applied to the SUPPLY pin, the internal POR circuit holds the device in reset state until $V_{(SUPPLY)}$ is above $V_{(POR\_rising)}$.

9.3.1.2 Supply Current in Fault Mode
The RS3703-Q1 device consumes minimal quiescent current, $I_{(Fault)}$, into SUPPLY when the $\overline{FAULT}$ pin is externally pulled LOW. At the same time, the device shuts down all three output drivers, IREF and ICTRL.

If device detects a fault, it pulls down the $\overline{FAULT}$ pin by an internal constant current, $I_{(FAULT\_pulldown)}$ as a fault indication to the fault bus.

9.3.2 Enable and Shutdown (EN)
The RS3703-Q1 device has an enable input. When EN is low, the device is in sleep mode with ultralow quiescent current $I_{(SD)}$. This low current helps to save system-level current consumption in applications where battery voltage directly connects to the device without high-side switches.

9.3.3 Reference Current (IREF)
The RS3703-Q1 device has IREF pin to generate a high accuracy and low temperature shift current reference. The calculated result for $I_{(IREF)}$ is 100 µA when $R_{(IREF)}$ is 12.3 kΩ. The $I_{(IREF)}$ can be programmed by external resistor, $R_{(IREF)}$ in the range from 25 µA to 250 µA. The voltage on the IREF pin is regulated to the 1.235 V typically, and the current output on IREF pin can be calculated by using Equation 1.

$$I_{(IREF)}=\frac{V_{(IREF)}}{R_{(IREF)}} \quad (1)$$

where
- $V_{(IREF)}$ = 1.235 V (typical)
- $R_{(IREF)}$ = 12.3 kΩ recommended

The $R_{(IREF)}$ resistor needs to be placed as close as possible to the IREF pin with a 1-nF ceramic capacitor in parallel to achieve the noise immunity. The off-board $R_{(IREF)}$ setup is not allowed due to the concern of reference current instability.

9.3.4 Constant-Current Output and Setting (INx)
The RS3703-Q1 device is a high-side current driver for driving LEDs. The device controls each output current through regulating the voltage drop on an external high-side current-sense resistor, $R_{(SNSx)}$ between SUPPLY and INx independently for each channel. An integrated error amplifier drives an internal power transistor to maintain the voltage drop on the current-sense resistor $R_{(SNSx)}$ to $V_{(CS\_REG)}$, therefore regulates the current output to target value. When the output current is in regulation, the current value for each channel can be calculated by using Equation 2.

$$I_{(OUTx\_Tot)}=\frac{V_{(CS\_REG)}}{R_{(SNSx)}} \quad (2)$$

where
- $V_{(CS\_REG)}$ is variable according to Equation 3
- x = 1, 2 or 3 for output channel 1, 2 or 3

When the supply voltage drops below total LED string forward voltage plus required headroom voltage, the sum of $V_{(DROPOUT)}$ and $V_{(CS\_REG)}$, the RS3703-Q1 is not able to deliver enough current output as set by the value of $R_{(SNSx)}$, and the voltage across the current-sense resistor $R_{(SNSx)}$ is less than $V_{(CS\_REG)}$.

9.3.5 Analog Current Control (ICTRL)

The RS3703-Q1 supports analog constant current control for all three output channels together through adjusting the $V_{(CS\_REG)}$ voltage. As described in Constant-Current Output and Setting (INx), the RS3703-Q1 regulates each channel output current by maintaining the voltage drop on each $R_{(SNSx)}$ same to $V_{(CS\_REG)}$. The $V_{(CS\_REG)}$ voltage is adjustable by an external resistor on ICTRL pin. The RS3703-Q1 outputs a constant current, $I_{(ICTRL)}$, on the ICTRL pin and measures the voltage on the ICTRL pin, $V_{(ICTRL)}$, to determine the $V_{(CS\_REG)}$. The $I_{(ICTRL)}$ current is 10 times of the $I_{(IREF)}$, and the $V_{(ICTRL)}$ is multiplied result of $I_{(ICTRL)}$ and $R_{(ICTRL)}$. The RS3703-Q1 internally clamps the $V_{(ICTRL)}$ to maximum 2.75 V. The $V_{(CS\_REG)}$ voltage can be calculated by using Equation 3.

$$V_{(CS\_REG)} = \frac{I_{(IREF)} \times R_{(ICTRL)} \times 25}{17} \tag{3}$$

where
- $I_{(IREF)}$ is in A unit
- $R_{(ICTRL)}$ is in Ω unit
- $V_{(CS\_REG)}$ is in V unit

The minimum voltage of $V_{(CS\_REF)}$ is 50 mV typically to maintain the high accurate current output.

The final total output current for each channel can be calculated by using Equation 4 which is combination of Equation 1, Equation 2 and Equation 3.

$$I_{(OUTx\_Tot)} = \frac{V_{(IREF)} \times R_{(ICTRL)} \times 25}{R_{(IREF)} \times R_{(SNSx)} \times 17} \tag{4}$$

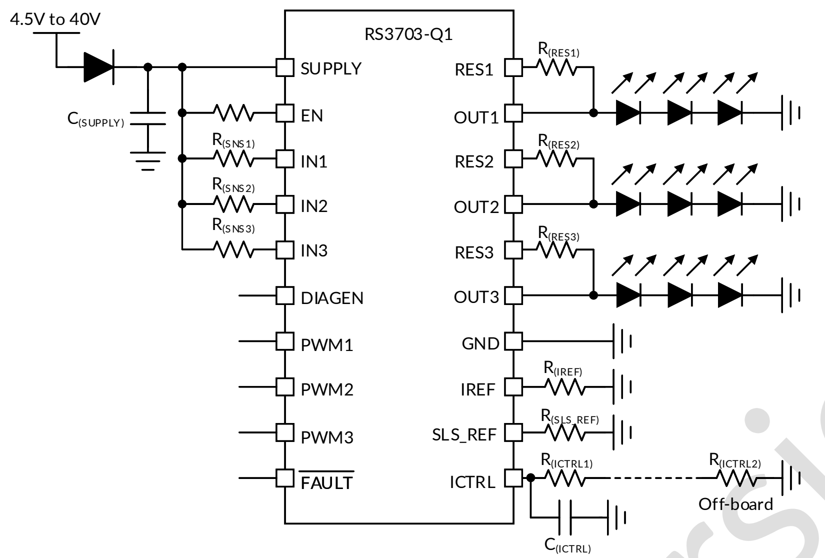
where
- $V_{(IREF)}$ = 1.235 V
- $R_{(IREF)}$ is in kΩ unit
- $R_{(ICTRL)}$ is in Ω unit
- $R_{(SNSx)}$ is in Ω unit
- $I_{(OUTx\_Tot)}$ is in mA unit

The calculated result for $I_{(OUTx\_Tot)}$ is 147.7 mA when $R_{(IREF)}$ is 12.3 kΩ, $R_{(ICTRL)}$ is 1000 Ω and $R_{(SNSx)}$ is 1Ω.

9.3.5.1 Off-Board Brightness Binning Resistor

With analog current control feature, a LED brightness binning resistor can be connected to ICTRL pin to set the output current according to LED brightness bin. The binning resistor can be placed in off-board with LED units. In order to achieve the best performance for the noise rejection, two resistors in serial can be adopted. One resistor is placed as closed as possible to the ICTRL pin in the same PCB board with device, and another one real binning resistor is placed in the other PCB board with LED units together.

As Figure 25 illustrated, the $R_{(ICTRL1)}$ resistor and $C_{(ICTRL)}$ ceramic capacitor need to be placed as close as possible to the ICTRL pin for noise decoupling. The off-board $R_{(ICTRL2)}$ resistor can be placed in LED board as real binning resistor. RUNIC recommends a 10-nF ceramic capacitor for $C_{(ICTRL)}$.



*: 10nF ceramic capacitor is recommended for each OUTx to GND

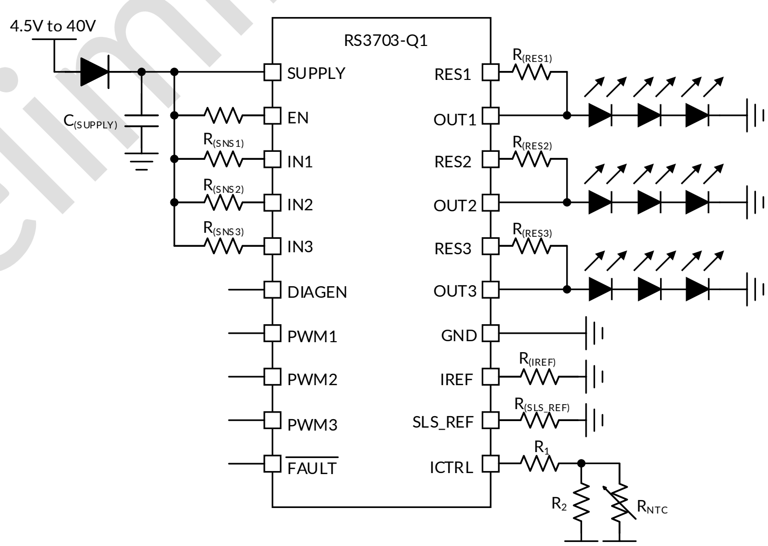
Figure 25. Application Schematic for Off-Board Brightness Binning Resistor

The $V_{(CS\_REG)}$ is 50 mV typically when the ICTRL pin is short to GND.

9.3.5.2 NTC Resistor

The analog current control feature also allows to connect a NTC thermistor on ICTRL pin to achieve the LED current derating based on measured PCB board temperature or LED unit temperature. The resistance of NTC thermistor depends on the environment temperature. The resistance of NTC thermistor is decreasing with the temperature rising. It leads to the decreasing of the equivalent resistance of R(ICTRL) on ICTRL pin and the output current reduction from the calculation based on Equation 2 and Equation 3.

RUNIC recommends to connect a resistor network including NTC thermistor (e.g. NCU18XH103F6SRB) to ICTRL pin as illustrated in below Figure 26. The resistor value of R1 and R2 work with NTC thermistor to adjust the equivalent resistance curve depending on the temperature to achieve the system required current derating.



*: 10nF ceramic capacitor is recommended for each OUTx to GND

Figure 26. Application Schematic for External NTC Thermistor

9.3.6 Thermal Sharing Resistor (OUTx and RESx)

The RS3703-Q1 device provides two current output paths for each channel. Current flows from the supply through the $R_{(SNSx)}$ resistor into the integrated current regulation circuit and to the LEDs through OUTx pin and RESx pin. The current output on both OUTx pin and RESx pin is independently regulated to achieve total required current output. The summed current of OUTx and RESx is equal to the current through the $R_{(SNSx)}$ resistor in the channel. The OUTx connects to anode of LEDs load in serial directly, however RESx connects to the LEDs through an external resistor to share part of the power dissipation and reduce the thermal accumulation in RS3703-Q1.

The integrated independent current regulation in RS3703-Q1 dynamically adjusts the output current on both OUTx and RESx output to maintain the stable summed current for LED. The RS3703-Q1 always regulates the current output to the RESx pin as much as possible until the RESx current path is saturated, and the rest of required current is regulated from the OUTx. As a result, the most of the current to LED outputs through the RESx pin when the voltage dropout is relatively high between SUPPLY and LED required total forward voltage. In the opposite case, the most of the current to LED outputs through the OUTx pin when the voltage headroom is relatively low between SUPPLY and LED required forward voltage. Figure 27 and Figure 28 shows the curve of current and power dissipation distributor depending on supply voltage when $R_{(RESx)}$ is 80 Ω

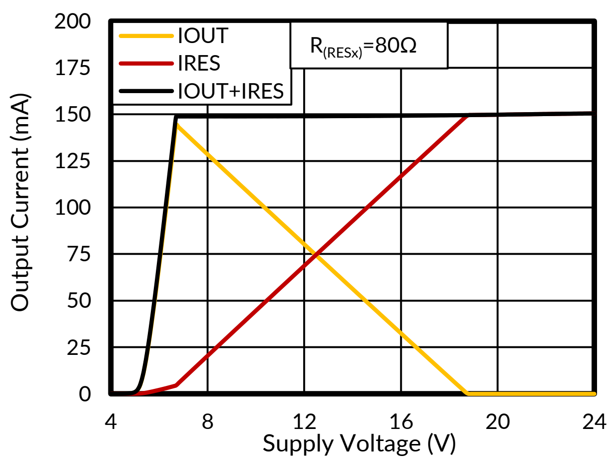


Figure 27. Output Current Distribution vs Supply Voltage

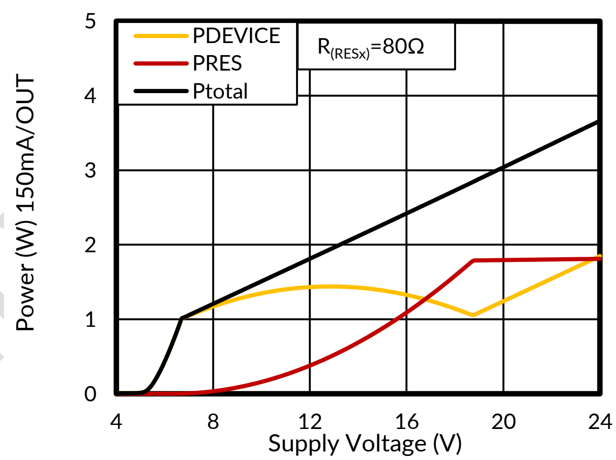


Figure 28. Power Dissipation vs Supply Voltage

9.3.7 PWM Control (PWMx)

The pulse width modulation (PWM) input of the RS3703-Q1 functions as enable for the output current. When the voltage applied on the PWM pin is higher than $V_{IH(PWM)}$, the relevant output current is enabled. When the voltage applied on PWM pin is lower than $V_{IL(PWM)}$, the output current is disabled as well as the diagnostic features. Besides output current enable and disable function, the PWM input of RS3703-Q1 also supports adjustment of the average current output for brightness control when the frequency of applied PWM signal is higher than 100 Hz, which is out of visible frequency range of human eyes. RUNIC recommends a 200-Hz PWM signal with 1% to 100% duty cycle input for brightness control. Please refer to Figure 29 for typical timming information.

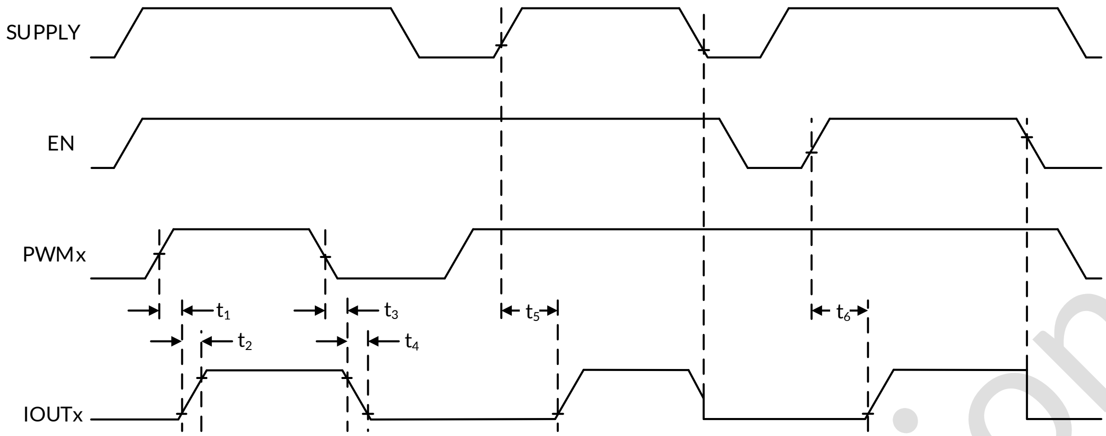


Figure 29. Power On Sequency and PWM Dimming Timing

The detailed information and value of each time period in Figure 29 is described in Timing Requirements.

The RS3703-Q1 device has three total PWM input pins, PWM1, PWM2 and PWM3, to control each of current output channel independently. PWM1 input controls the output channel1 for both OUT1 and RES1, PWM2 input controls the output channel2 for both OUT2 and RES2, and PWM3 input controls the output channel3 for both OUT3 and RES3.

9.3.8 Supply Control

The RS3703-Q1 can support supply control to turn ON and OFF output current. When the voltage applied on the SUPPLY pin is higher than the LED string forward voltage plus needed headroom voltage at required current, and the PWM pin voltage is high, the output current is turned ON and well regulated. However, when the voltage applied on the SUPPLY pin is lower than $V_{(POR\_falling)}$, the output current is turned OFF. With this feature, the power supply voltage in designed pattern can control the output current ON/OFF. The brightness is adjustable if the ON/OFF frequency is fast enough. Because of the high accuracy design of PWM threshold in RS3703-Q1, it enables a resistor divider on the PWM pin to set the SUPPLY threshold higher than LED forward voltage plus required headroom voltage as shown in Figure 30. The headroom voltage is basically the summation of $V_{(DROPOUT)}$ and $V_{(CS\_REG)}$. When the voltage on the PWM pin is higher than $V_{IH(PWM)}$, the output current is turned ON. However, when the voltage on the PWM is lower than $V_{IL(PWM)}$, the output current is turned OFF. The SUPPLY threshold voltage can be calculated by using Equation 5.

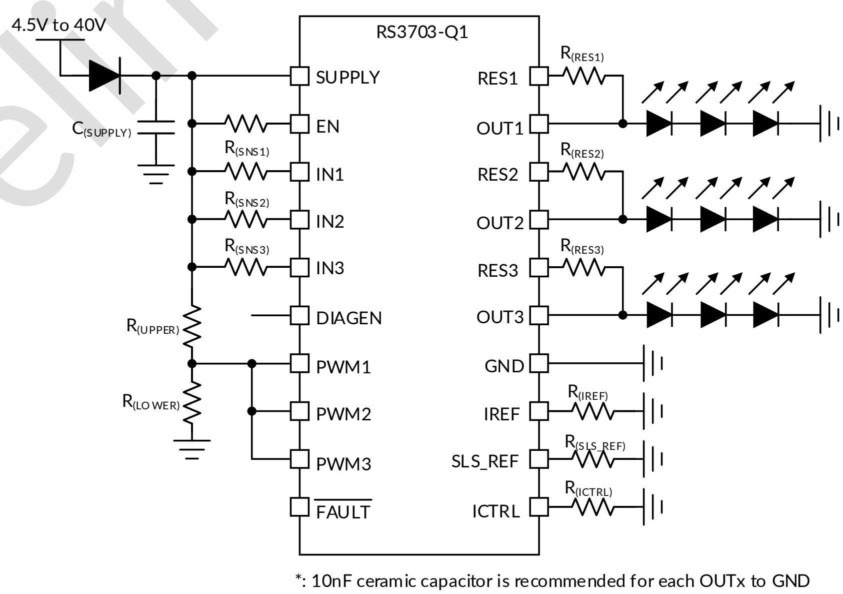


Figure 30. Application Schematic for Supply Control LED Brightness

$$V_{(SUPPLY\_PWM\_th\_rising)} = V_{IH(PWM)} \times \left(1 + \frac{R_{(UPPER)}}{R_{(LOWER)}}\right) \quad (5)$$

where

- $V_{IH(PWM)}$ = 1.2 V (typical)

9.3.9 Diagnostics

The device is able to detect and protect fault from LED-string short-to-GND, LED-string open-circuit, single LED short-circuit and junction over-temperature scenarios. It also supports one-fails–all-fail fault bus design that can flexibly fit different regulatory requirements.

9.3.9.1 IREF Short-to-GND Detection

The RS3703-Q1 device has IREF short-to-GND detection through monitoring the voltage on the IREF pin. The IREF pin short-to-GND fault is reported by constantly pulling down the $\overline{\text{FAULT}}$ pin, if the IREF pin voltage, $V_{(IREF)}$ is lower than $V_{(IREF\_SHORT\_th)}$ for longer than the deglitch time of $t_{(IREF\_deg)}$. The current for all output channels and ICTRL pin are turned off and the current out of IREF pin is clamped to $I_{(IREF\_ST\_Clamp)}$ when IREF pin short-to-GND fault is detected.

The RS3703-Q1 recovers to normal operating if the $V_{(IREF)}$ voltage rises up over $V_{(IREF\_SHORT\_th)}$.

9.3.9.2 IREF Open Detection

The RS3703-Q1 device has IREF open detection through monitoring the current through the IREF pin. The IREF pin open fault is reported by constantly pulling down the $\overline{\text{FAULT}}$ pin, when the current through IREF pin, $I_{(IREF)}$ is lower than $I_{(IREF\_OPEN\_th)}$ for longer than the deglitch time of $t_{(IREF\_deg)}$. The current for all output channels and ICTRL pin are turned off when IREF pin open fault is detected.

The RS3703-Q1 recovers to normal operating if the $I_{(IREF)}$ current rises up over $I_{(IREF\_OPEN\_th)}$.

9.3.9.3 LED Short-to-GND Detection

The RS3703-Q1 device has LED short-to-GND detection. The LED short-to-GND detection monitors the output voltage when the output current is enabled. Once a short-to-GND LED failure is detected, the device turns off the faulty channel and retries automatically, regardless of the state of the PWM input. When the retry mechanism detects the removal of the LED short-to-GND fault, the device resumes to normal operation.

The RS3703-Q1 monitors the $V_{(OUTx)}$ voltage and $V_{(RESx)}$ voltage of each channel and compares it with the internal reference voltage to detect a short-to-GND failure. When $V_{(OUTx)}$ or $V_{(RESx)}$ voltage falls below $V_{(SG\_th\_falling)}$ longer than the deglitch time of $t_{(SG\_deg)}$, the device asserts the short-to-GND fault and pulls low the $\overline{\text{FAULT}}$ pin. During the deglitch time period, if $V_{(OUTx)}$ and $V_{(RESx)}$ rises above $V_{(SG\_th\_rising)}$, the timer is reset.

Once the RS3703-Q1 has asserted a short-to-GND fault, the device turns off the faulty output channel and retries automatically with a small current. During retrying the device sources a small current $I_{(Retry)}$ from SUPPLY to OUT to pull up the LED loads continuously. Once auto-retry detects output voltage rising above $V_{(SG\_th\_rising)}$, it clears the short-to-GND fault and resumes to normal operation. Figure 31 illustrates the timing for LED short-circuit detection, protection, retry and recovery.

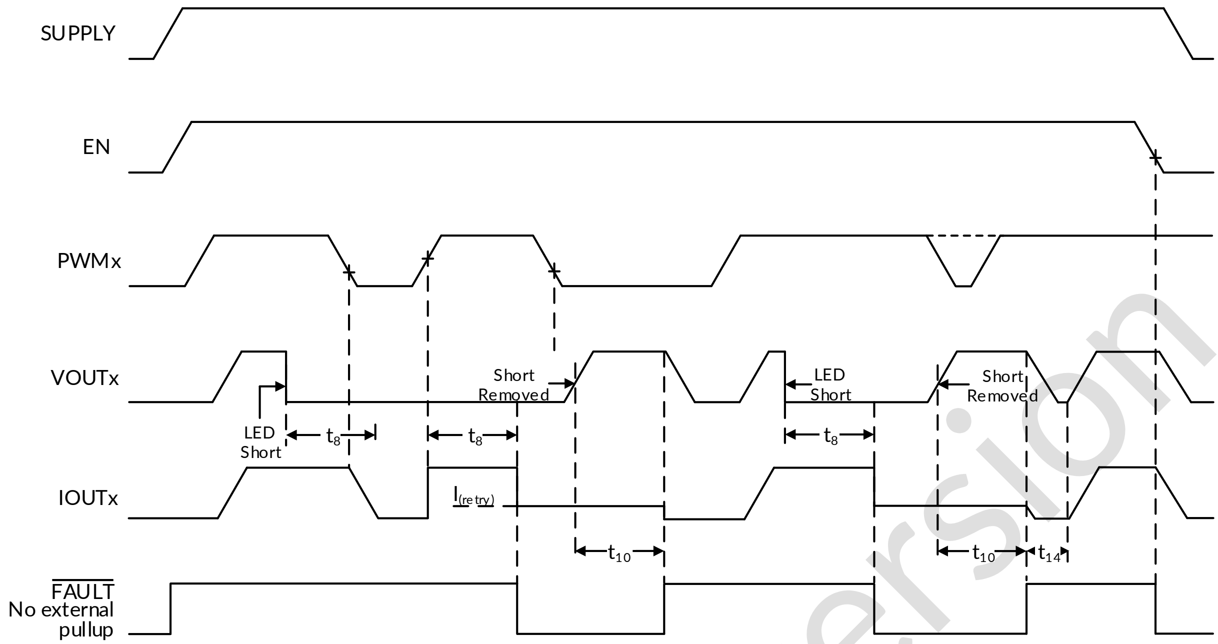


Figure 31. LED Short-to-GND Detection and Recovery Timing Diagram

The detailed information and value of each time period in Figure 31 is described in Timing Requirements.

9.3.9.4 LED Open-Circuit Detection

The RS3703-Q1 device has LED open-circuit detection. The LED open-circuit detection monitors the output voltage when the current output is enabled. The LED open-circuit detection is only enabled when DIAGEN is HIGH. A short-to-battery fault is also detected and recognized as an LED open-circuit fault.

The RS3703-Q1 monitors dropout-voltage differences between the IN and OUT pins for each LED channel when PWM is HIGH. The voltage difference $V_{(INx)} - V_{(OUTx)}$ is compared with the internal reference voltage $V_{(OPEN\_th\_rising)}$ to detect LED open-circuit incident. When $V_{(OUTx)}$ rises causing $V_{(INx)} - V_{(OUTx)}$ less than the $V_{(OPEN\_th\_rising)}$ voltage and lasts longer the deglitch time of $t_{(OPEN\_deg)}$, the device asserts an open-circuit fault. Once a LED open-circuit failure is detected, the internal constant-current sink pulls down the $\overline{\text{FAULT}}$ pin voltage. During the deglitch time period, when $V_{(OUTx)}$ falls and makes $V_{(INx)} - V_{(OUTx)}$ larger than $V_{(OPEN\_th\_falling)}$, the deglitch timer is reset.

The RS3703-Q1 shuts down the output current regulation for the faulty channel after LED open-circuit fault is detected. The device sources a small current $I_{(Retry)}$ from SUPPLY to OUT when DIAGEN input is logic High. Once the fault condition is removed, the device resumes normal operation and releases the $\overline{\text{FAULT}}$ pin. Figure 32 illustrates the timing for LED open-circuit detection, protection, retry and recovery.

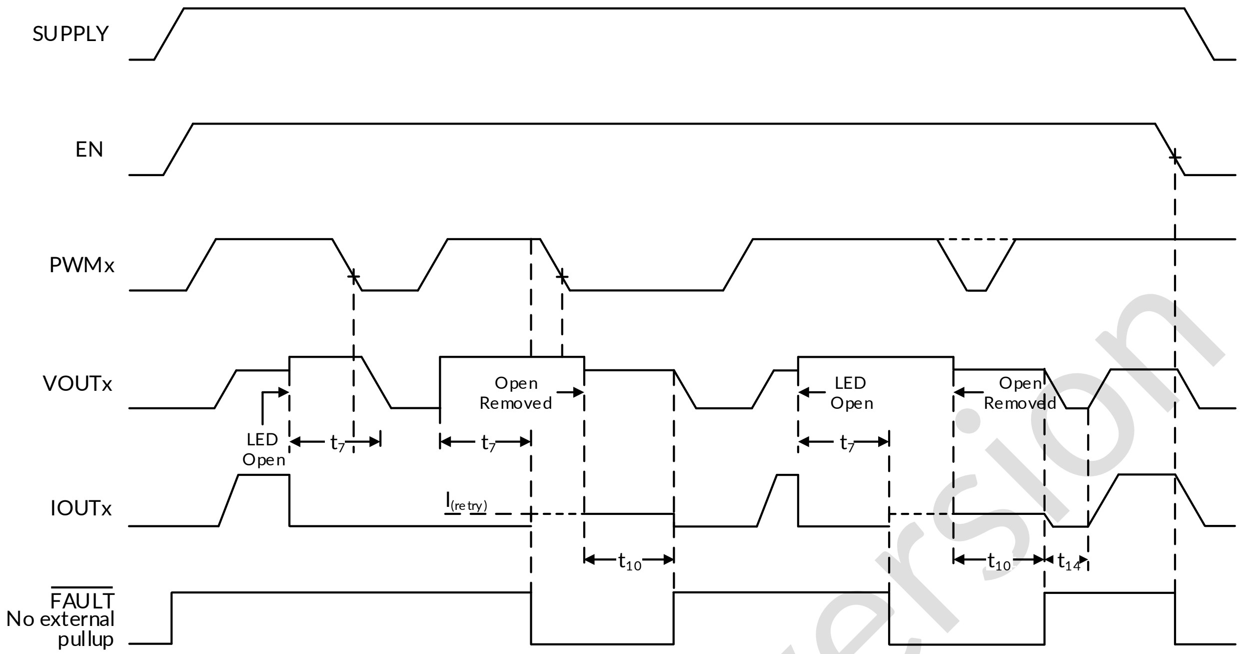


Figure 32. LED Open-Circuit Detection and Recovery Timing Diagram

The detailed information and value of each time period in Figure 32 is described in Timing Requirements.

9.3.9.5 Single LED Short-Circuit Detection (SLS_REF)

The RS3703-Q1 device has single LED short-circuit detection. The single LED short-circuit detection monitors the output voltage when the output current is enabled. Once a single LED short-circuit failure is detected, the device turns off the faulty channel and retries automatically, regardless of the state of the PWM input. If the retry mechanism detects the removal of the single LED short-circuit fault, the device resumes to normal operation.

The RS3703-Q1 monitors the $V_{(OUTx)}$ voltage of each channel and internally compares the scale down voltage of $V_{(OUTx)}$ with an external resistor programmable reference voltage on SLS_REF to detect a single LED short-circuit failure. When the voltage of $V_{(OUTx)}$ falls below $V_{(SLS\_th\_falling)}$ longer than the deglitch time of $t_{(SLS\_deg)}$, the device asserts the single LED short-circuit fault and pulls low the $\overline{\text{FAULT}}$ pin. During the deglitch time period, if the scale down voltage of $V_{(OUTx)}$ rises above $V_{(SLS\_th\_rising)}$, the timer is reset.

Once the RS3703-Q1 has asserted a single LED short-circuit fault, the device turns off the faulty output channel and retries automatically. During retrying the device sources full current from IN to OUT to pull up the LED loads every 10 ms for 300-µs period when the PWM input is logic high for the faulty channel. Once auto-retry detects the voltage of $V_{(OUTx)}$ rising above $V_{(SLS\_th\_rising)}$, it clears the single LED short-circuit fault and resumes to normal operation. The $V_{(SLS\_th\_rising)}$ is 2.5% higher the $V_{(SLS\_th\_falling)}$. The scale down ratio for $V_{(OUTx)}$ is $N_{(OUT)}$. Figure 33 describes internal diagram for single LED short-circuit detection circuit. And the $V_{(SLS\_th\_falling)}$ threshold voltage for single LED short-circuit is calculated by using Equation 6.

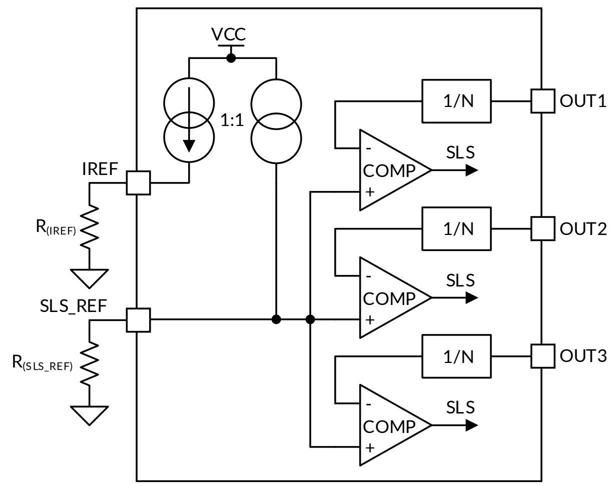


Figure 33. Single LED Short-Circuit Detection Block Diagram

$$V_{(SLS\_th\_falling)} = \frac{N_{(OUT)} \times R_{(SLS\_REF)} \times V_{(IREF)} \times N_{(SLS\_REF)}}{R_{(IREF)}} \quad (6)$$

where

- $V_{(IREF)}$ = 1.235 V (typical)
- $R_{(IREF)}$ = 12.3 kΩ recommended
- $R_{(SLS\_REF)}$ is in kΩ unit
- $N_{(OUT)}$ = 4 (typical)
- $N_{(SLS\_REF)}$ = 1 (typical)

The calculated result for $V_{(SLS\_th\_falling)}$ is 5.34 V when $R_{(IREF)}$ is 12.3 kΩ and $R_{(SLS\_REF)}$ is 13.3 kΩ.

Figure 34 illustrates the timing for single-LED short-circuit detection, protection, retry and recovery.

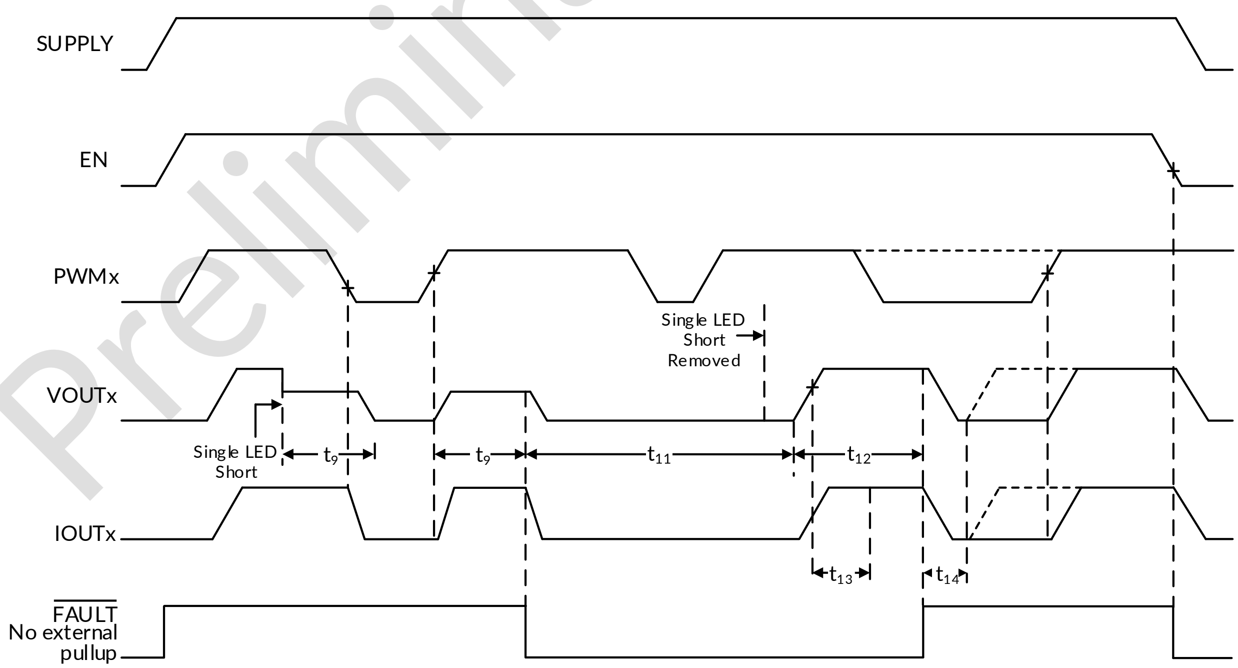


Figure 34. Single LED Short-Circuit Detection and Recovery Timing Diagram

The detailed information and value of each time period in Figure 34 is described in Timing Requirements.

9.3.9.6 LED Open-Circuit and Single LED Short-Circuit Detection Enable (DIAGEN)

The RS3703-Q1 device supports the DIAGEN pin with an accurate threshold to disable the LED open-circuit and single LED short-circuit diagnostic functions. The DIAGEN pin can be used to enable or disable LED open-circuit detection and single LED short-circuit detection based on SUPPLY pin voltage sensed by an external resistor divider as illustrated in Figure 35. When the voltage applied on DIAGEN pin is higher than the threshold $V_{IH(DIAGEN)}$, the device enables LED open-circuit and single LED short-circuit diagnosis. When $V_{(DIAGEN)}$ is lower than the threshold $V_{IL(DIAGEN)}$, the device disables LED open-circuit and single LED short-circuit detection.

Only LED open-circuit detection and single LED short-circuit detection can be disabled by pulling down the DIAGEN pin. The LED short-to-GND detection and over-temperature protection cannot be turned off by pulling down the DIAGEN pin. The SUPPLY threshold voltage can be calculated by using Equation 7.

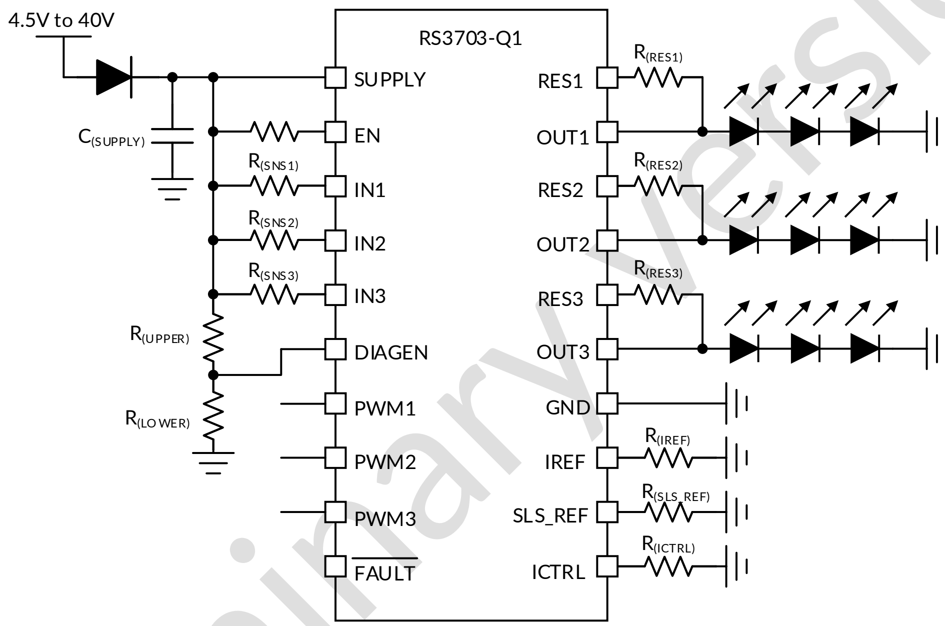


Figure 35. Application Schematic for DIAGEN

$$V_{(SUPPLY\_DIAGEN\_th\_falling)} = V_{IL(DIAGEN)} \times \left(1 + \frac{R_{(UPPER)}}{R_{(LOWER)}}\right) \quad (7)$$

where

- $V_{IL(DIAGEN)}$ = 1.1 V (typical)

9.3.9.7 Low Dropout Operation

When the supply voltage drops below LED string total forward voltage plus headroom voltage at required current, the RS3703-Q1 device operates in low-dropout conditions to deliver current output as close as possible to target value. The actual current output is less than preset value due to insufficient headroom voltage for power transistor. As a result, the voltage across the sense resistor fails to reach the regulation target. The headroom voltage is the summation of $V_{(DROPOUT)}$ and $V_{(CS\_REG)}$.

If the RS3703-Q1 is designed to operate in low-dropout condition, the open-circuit diagnostics and single LED short-circuit detection must be disabled by pulling the DIAGEN pin voltage lower than $V_{IL(DIAGEN)}$. Otherwise, the RS3703-Q1 detects an open-circuit fault or single LED short-circuit fault and reports a fault on the $\overline{\text{FAULT}}$ pin. The DIAGEN pin is used to avoid false diagnostics due to low supply voltage.

9.3.9.8 Over-Temperature Protection

The RS3703-Q1 device monitors device junction temperature. When the junction temperature reaches thermal shutdown threshold $T_{(TSD)}$, the output shuts down. Once the junction temperature falls below $T_{(TSD)} - T_{(TSD\_HYS)}$, the device recovers to normal operation. During over-temperature protection, the $\overline{\text{FAULT}}$ pin is pulled low.

9.3.10 FAULT Bus Output With One-Fails–All-Fail

During normal operation, The $\overline{\text{FAULT}}$ pin of RS3703-Q1 is weakly pulled up by an internal pullup current source, $I_{(FAULT\_pullup)}$. If any fault scenario occurs, the $\overline{\text{FAULT}}$ pin is strongly pulled low by the internal pulldown current sink, $I_{(FAULT\_pulldown)}$ to report out the fault alarm.

Meanwhile, the RS3703-Q1 also monitors the $\overline{\text{FAULT}}$ pin voltage internally. If the $\overline{\text{FAULT}}$ pin of the RS3703-Q1 is pulled low by external current sink below $V_{IL(FAULT)}$, the current output is turned off even though there is no fault detected on owned outputs. The device does not resume to normal operation until the $\overline{\text{FAULT}}$ pin voltage rises above $V_{IH(FAULT)}$.

Based on this feature, the RS3703-Q1 device is able to construct a FAULT bus by tying $\overline{\text{FAULT}}$ pins from multiple RS3703-Q1 devices to achieve one-fails-all-fail function as Figure 36 showing. The lower side RS3703-Q1 (B) detects any kind of LED fault and pulls low the $\overline{\text{FAULT}}$ pin. The low voltage on $\overline{\text{FAULT}}$ pin is detected by upper side RS3703-Q1 (A) because the $\overline{\text{FAULT}}$ pins are connected of two devices. The upper side RS3703-Q1 (A) turns off all output current for each channel as a result. If the $\overline{\text{FAULT}}$ pins of each RS3703-Q1 are all connected to drive the base of an external PNP transistor as illustrated in Figure 37, the one-fails–all-fail function is disabled and only the faulty channel is turned off.

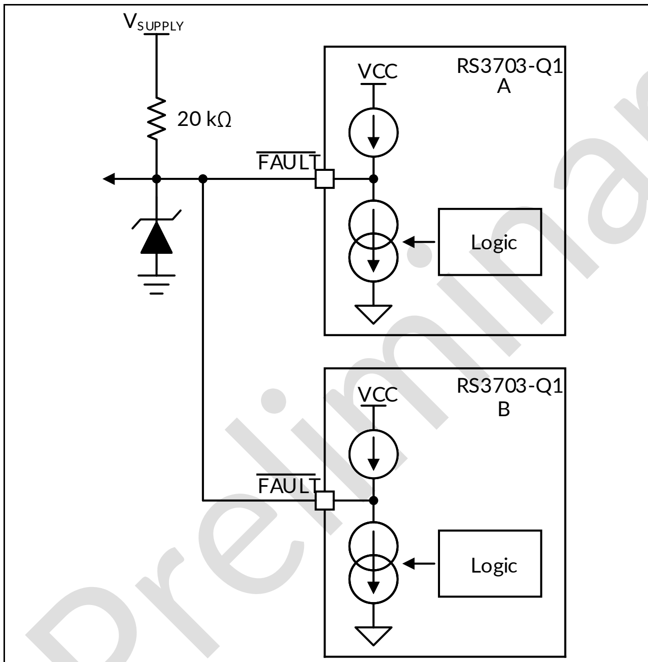


Figure 36. FAULT Bus for One-Fails-All-Fail Application

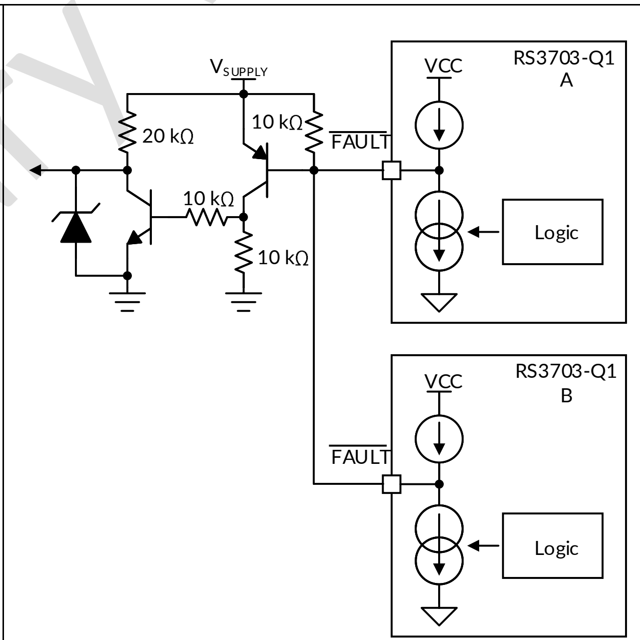


Figure 37. FAULT Bus for One-Fails-Others-On Application

9.3.11 FAULT Table

Table 1. FAULT Table With DIAGEN = HIGH (Full Function)

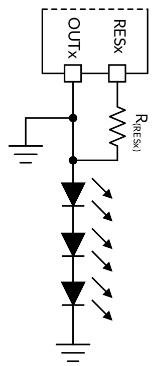
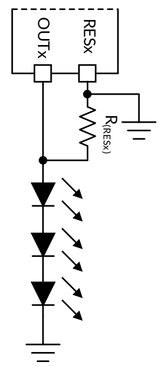
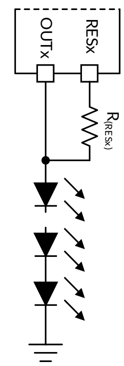
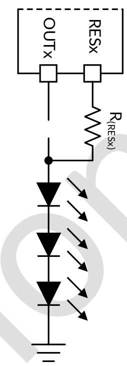
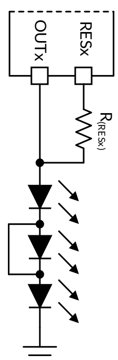
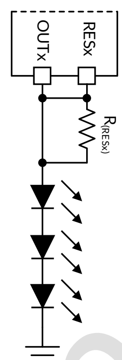
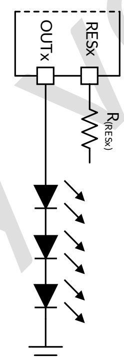
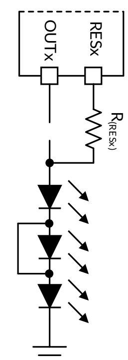
FAULT BUS STATUS	FAULT TYPE	DETECTION MECHANISM	CONTROL INPUT	DEGLITCH TIME	$\overline{FAULT}$ ACTION	FAULT HANDLING ROUTINE	FAULT RECOVERY
$\overline{FAULT}$=H	IREF short-to-GND	$V_{(IREF)} < V_{(IREF\_SHORT\_th)}$	EN=H	$t_{(IREF\_deg)}$	Constant-current pulldown	Device turns all output off. IREF current clamps to $I_{(IREF\_ST\_Clamp)}$. ICTRL current output are turned off.	Auto recovery
	IREF open	$I_{(IREF)} < I_{(IREF\_OEPN\_th)}$	EN=H	$t_{(IREF\_deg)}$	Constant-current pulldown	Device turns all output off. ICTRL current are turned off too.	Auto recovery
	SLS_REF short-to-GND	No detection	EN=H	N/A	No Action	$V_{(SLS\_th\_falling)}$=0V.	Auto recovery
	SLS_REF open	No detection	EN=H	N/A	No Action	Disable single-LED short-circuit detection.	Auto recovery
	ICTRL short-to-GND	No detection	EN=H	N/A	No Action	$V_{(CS\_REG)}$=50mV.	Auto recovery
	ICTRL open	No detection	EN=H	N/A	No Action	$V_{(CS\_REG)}$=400mV.	Auto recovery
	Open-circuit or short-to-supply	$V_{(IN)} - V_{(OUT)} < V_{(OPEN\_th\_rising)}$	EN = H and PWMx = H	$t_{(OPEN\_deg)}$	Constant-current pulldown	Device turns failed output off and retries with constant current $I_{(retry)}$, ignoring the PWM input.	Auto recovery
	Short-to-ground	$V_{(OUT)} < V_{(SG\_th\_falling)}$ OR $V_{(RES)} < V_{(SG\_th\_falling)}$	EN = H and PWMx = H	$t_{(SG\_deg)}$	Constant-current pulldown	Device turns failed output off and retries with constant current $I_{(retry)}$, ignoring the PWM input.	Auto recovery
	Single LED short-circuit	$V_{(IN)} - V_{(OUT)} > V_{(OPEN\_th\_falling)}$ & $V_{(SG\_th\_falling)} < V_{(OUT)} < V_{(SLS\_th\_falling)}$	EN = H and PWMx = H	$t_{(SLS\_deg)}$	Constant-current pulldown	Device turns failed output off and retries every 10 ms by turning output on for 300 µs when PWM input is logic high.	Auto recovery
	Over-temperature	$T_J > T_{(TSD)}$	EN=H	$t_{(TSD\_deg)}$	Constant-current pulldown	Device turns all output channels off, SLS_REF and ICTRL off.	Auto recovery
$\overline{FAULT}$=L	Fault is detected	Device turns off remained channels in operation.					
	No fault is detected	Device turns all output channels off, IREF, SLS_REF and ICTRL off.					

Table 2. FAULT Table With DIAGEN = LOW (Full Function)

FAULT BUS STATUS	FAULT TYPE	DETECTION MECHANISM	CONTROL INPUT	DEGLITCH TIME	$\overline{\text{FAULT}}$ ACTION	FAULT HANDLING ROUTINE	FAULT RECOVERY
$\overline{\text{FAULT}}$=H	IREF short-to-GND	$V_{(IREF)} < V_{(IREF\_SHORT\_th)}$	EN=H	$t_{(IREF\_deg)}$	Constant-current pulldown	Device turns all output off. IREF current clamps to $I_{(IREF\_ST\_Clamp)}$. ICTRL current output are turned off.	Auto recovery
	IREF open	$I_{(IREF)} < I_{(IREF\_OEPN\_th)}$	EN=H	$t_{(IREF\_deg)}$	Constant-current pulldown	Device turns all output off. ICTRL current are turned off too.	Auto recovery
	SLS_REF short-to-GND	No detection	EN=H	N/A	No Action	$V_{(SLS\_th\_falling)}$=0V.	Auto recovery
	SLS_REF open	No detection	EN=H	N/A	No Action	Disable single-LED short-circuit detection.	Auto recovery
	ICTRL short-to-GND	No detection	EN=H	N/A	No Action	$V_{(CS\_REG)}$=50mV.	Auto recovery
	ICTRL open	No detection	EN=H	N/A	No Action	$V_{(CS\_REG)}$=400mV.	Auto recovery
	Open-circuit or short-to-supply	Ignored					
	Single LED short-circuit						
	Short-to-ground	$V_{(OUT)} < V_{(SG\_th\_falling)}$ OR $V_{(RES)} < V_{(SG\_th\_falling)}$	EN = H and PWMx = H	$t_{(SG\_deg)}$	Constant-current pulldown	Device turns output off and retries with constant current $I_{(retry)}$, ignoring the PWM input.	Auto recovery
	Over-temperature	$T_J > T_{(TSD)}$	EN=H	$t_{(TSD\_deg)}$	Constant-current pulldown	Device turns all output channels off, SLS_REF and ICTRL off.	Auto recovery
$\overline{\text{FAULT}}$=L	Fault is detected	Device turns all output channels off and keeps retry on the failed channels.					
	No fault is detected	Device turns all output channels off, IREF, SLS_REF and ICTRL off.					

9.3.12 LED Fault Summary

Table 3. LED Connection Fault Summary

Case 1	Case 2	Case 3	Case 4
			
LED Short-to-GND Fault	LED Short-to-GND Fault	LED Open Fault	LED Open Fault
Case 5	**Case 6**	**Case 7**	**Case 8**
			
Single-LED-Short Fault	No Fault	No Fault	LED Open Fault

9.3.13 IO Pins Inner Connection

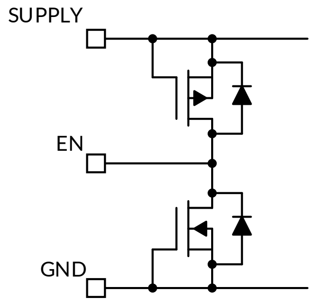


Figure 38. EN Pin

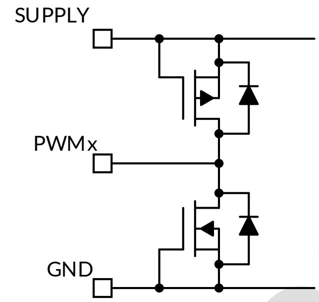


Figure 39. PWM1, PWM2 and PWM3 Pins

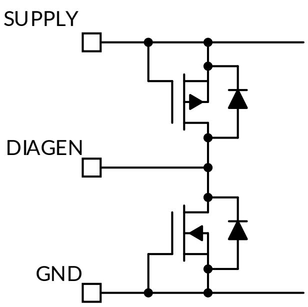


Figure 40. DIAGEN Pin

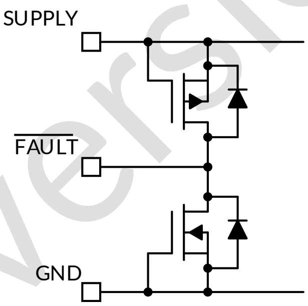


Figure 41. $\overline{FAULT}$ Pin

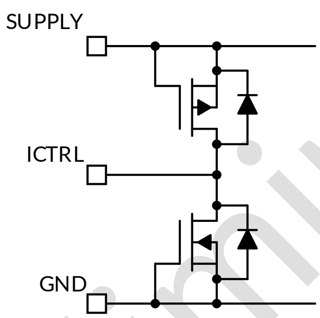


Figure 42. ICTRL pin

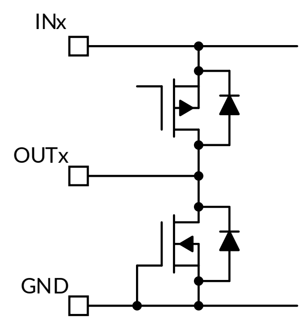


Figure 43. OUT1, OUT2 and OUT3 Pins

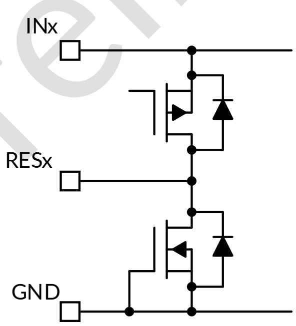


Figure 44. RES1, RES2 and RES3 Pins

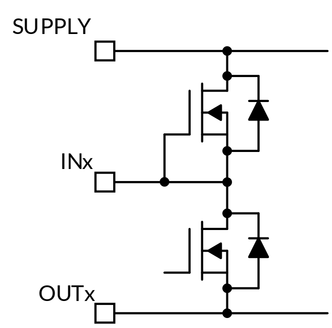


Figure 45. IN1, IN2 and IN3 Pins

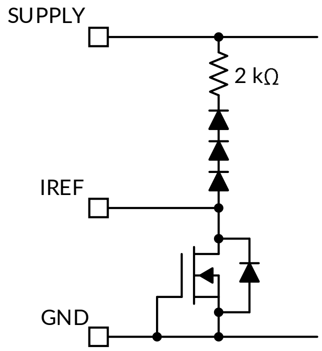


Figure 46. IREF Pin

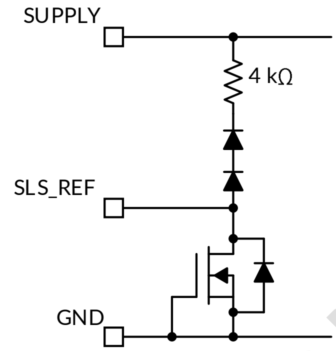


Figure 47. SLS_REF Pin

9.4 Device Functional Modes

9.4.1 Undervoltage Lockout, $V_{(SUPPLY)} < V_{(POR\_rising)}$

When the device is in undervoltage lockout status, the RS3703-Q1 device disables all functions until the supply rises above the $V_{(POR\_rising)}$ threshold.

9.4.2 Normal Operation $V_{(SUPPLY)} \geq 4.5$ V

The device drives an LED string in normal operation. With enough voltage drop across SUPPLY and OUT, the device is able to drive the output in constant-current mode.

9.4.3 Low-Voltage Dropout Operation

When the device drives an LED string in low-dropout operation, if the $V_{(DROPOUT)}$ is less than the open-circuit detection threshold, the device may report a false open-circuit fault or single LED short-circuit fault. RUNIC recommends only enabling the open-circuit detection and single LED short-circuit detection when SUPPLY voltage is enough higher than LED string voltage to avoid a false open-circuit detection.

9.4.4 Fault Mode

When the device detects any fault, the device tries to pull down the $\overline{\text{FAULT}}$ pin with a constant current. If the FAULT bus is pulled down, the device switches to fault mode and consumes a fault current of $I_{(Fault)}$.

10 POWER SUPPLY RECOMMENDATIONS

The RS3703-Q1 is designed to operate from an automobile electrical power system within the range specified in Power Supply. The $V_{(SUPPLY)}$ input must be protected from reverse voltage and load dump condition over 40 V. The impedance of the input supply rail must be low enough that the input current transient does not cause drop below LED string required forward voltage. If the input supply is connected with long wires, additional bulk capacitance may be required in addition to normal input capacitor.

11 LAYOUT

11.1 Layout Guidelines

Thermal dissipation is the primary consideration for RS3703-Q1 layout.

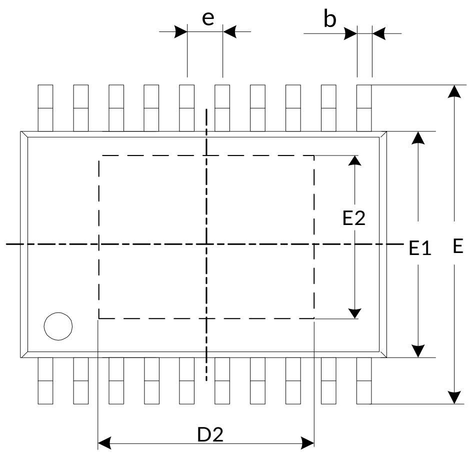
- RUNIC recommends large thermal dissipation area in both top and bottom layers of PCB. The copper pouring area in same layer with RS3703-Q1 footprint should directly cover the thermal pad land of the device with wide connection as much as possible. The copper pouring in opposite PCB layer or inner layers should be connected to thermal pad directly through multiple thermal vias.
- RUNIC recommends to place $R_{(RESx)}$ resistors away from the RS3703-Q1 device with more than 20-mm distance because $R_{(RESx)}$ resistors are dissipating some amount of the power as well as the RS3703-Q1. It is better to place two heat source components apart to reduce the thermal accumulation concentrated at small PCB area. The large copper pouring area is also required surrounding the $R_{(RESx)}$ resistors for helping thermal dissipating.

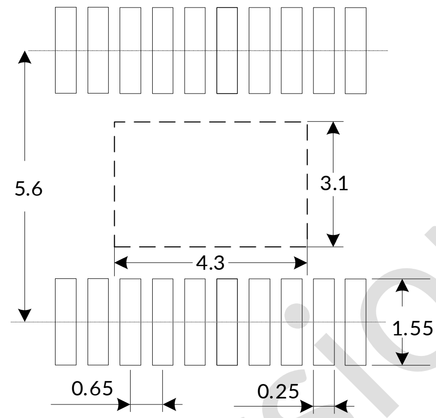
The noise immunity is the secondary consideration for RS3703-Q1 layout.

- RUNIC recommends to place the noise decoupling capacitors for SUPPLY, ICTRL and IREF pins as close as possible to the pins.
- RUNIC recommends to place the $R_{(SNSx)}$ resistor as close as possible to the INx pins with the shortest PCB track to SUPPLY pin.

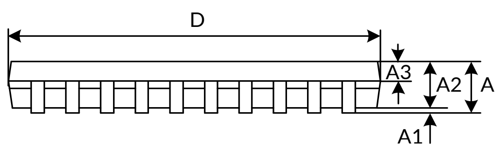
12 PACKAGE OUTLINE DIMENSIONS

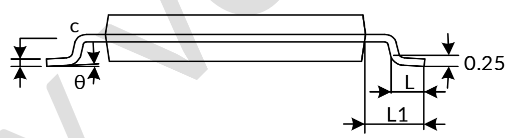
ETSSOP20 (4)





RECOMMENDED LAND PATTERN (Unit: mm)





Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A (1)		1.200		0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
A3	0.390	0.490	0.015	0.020
b	0.200	0.290	0.008	0.011
c	0.130	0.180	0.005	0.007
D (1)	6.400	6.600	0.252	0.260
D2	4.100	4.300	0.161	0.169
E2	2.900	3.100	0.114	0.122
E1 (1)	4.300	4.500	0.169	0.177
E	6.200	6.600	0.244	0.260
e	0.650 (BSC) (2)		0.026 (BSC) (2)	
L	0.450	0.750	0.018	0.030
L1	1.000 (REF) (3)		0.039 (REF) (3)	
θ	0°	8°	0°	8°

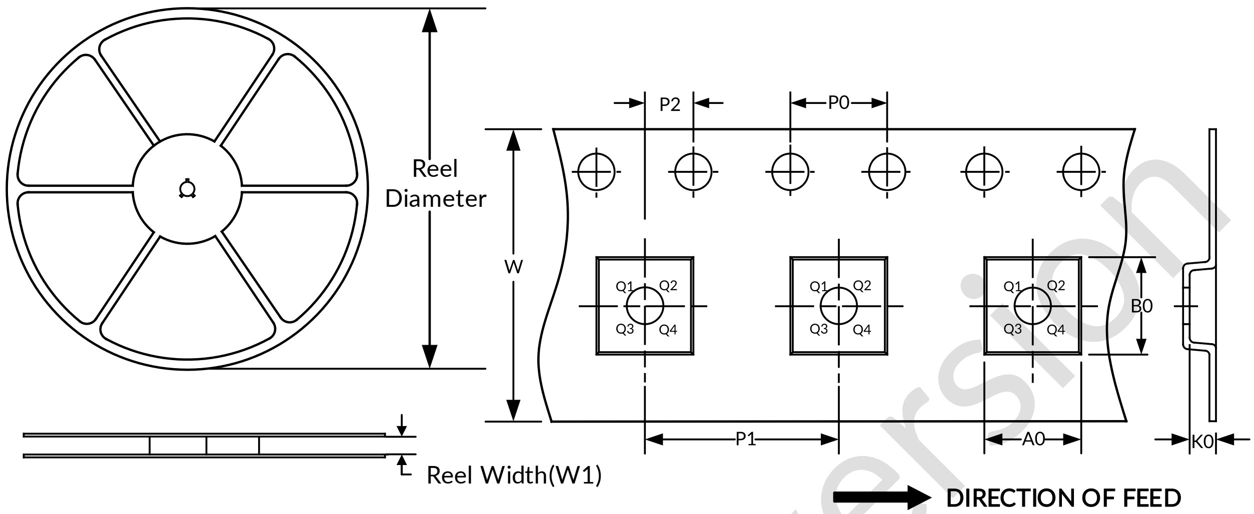
NOTE:

1. Plastic or metal protrusions of 0.15mm maximum per side are not included.
2. BSC (Basic Spacing between Centers), "Basic" spacing is nominal.
3. REF is the abbreviation for Reference.
4. This drawing is subject to change without notice.

13 TAPE AND REEL INFORMATION

REEL DIMENSIONS

TAPE DIMENSION



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width(mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
ETSSOP20	13”	12.4	6.75	6.95	1.20	4.0	8.0	2.0	12.0	Q1

NOTE:
1. All dimensions are nominal.
2. Plastic or metal protrusions of 0.15mm maximum per side are not included.

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