RS3700-Q1 Automotive Single-Channel Linear LED Driver

1 FEATURES

- **RS3700-Q1 AEC-Q100 Qualification is Ongoing**
- **Functional Safety Capable**
  - **Documentation Available to Aid Functional Safety System Design**
- **Single-Channel Constant-Current LED Driver with PWM Dimming**
- **Wide Input-Voltage Range: 4.5 V–40 V**
- **Constant Output Current, Adjustable by Sense Resistor**
- **Precision Current Regulation, Tolerance ±4.6%**
- **Maximum Current: 500 mA**
- **Heat Sharing with External Resistor (Only for RS3700B-Q1)**
- **Low Dropout Voltage**
  - **Typical Dropout (V_{IN}-V_{OUT}): 180 mV at 100 mA**
  - **Typical Dropout (V_{IN}-V_{RES}): 240 mV at 100 mA (Only for RS3700B-Q1)**
- **Diagnostics and Protection**
  - **LED Open-Circuit and Short-Circuit Detection with Auto-Recovery**
  - **Diagnostic-Enable with Adjustable Threshold for Low-Dropout Operation**
  - **Fault Bus up to 15 Devices, Configurable as Either One-Fails–All-Fail or Only-Failed-Channel Off**
  - **Low Quiescent Current and Fault-Mode Current (<450 µA per Device)**
- **Operating Junction Temperature Range: –40°C to 150°C**

2 APPLICATIONS

- **Automotive Convenience Lighting: Dome Light, Door Handles, Reading Lamp, and Miscellaneous Lamps**
- **Automotive Rear Lamp, Center High-Mounted Stop Lamp, Side Markers, Blind-Spot Detection Indicator, Charging Inlet Indicator**
- **General-Purpose LED Driver Applications**

3 DESCRIPTIONS

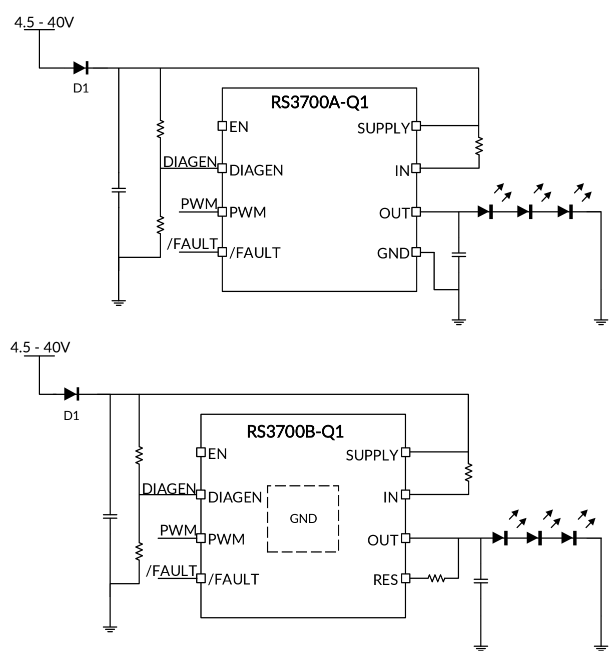
With LEDs being widely used in automotive applications, simple LED drivers are more and more popular. Compared to discrete solutions, a low-cost monolithic solution lowers system-level component counts and significantly improves current accuracy and reliability.

The RS3700-Q1 device is a simple single-channel high-side LED driver operating from an automotive car battery. It is a simple and elegant solution, with LED diagnostics, to deliver constant current for a single LED string. Its one-fails–all-fail feature is able to work together with other LED drivers to address different requirements.

Device Information (1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
RS3700-Q1	EMSOP8	3.00mm×3.00mm

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



Typical Application Diagram

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4 REVISION HISTORY

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

Version	Change Date	Change Item
A.0	2025/04/22	Preliminary version completed
A.0.1	2025/08/19	1. Modify Low Dropout Voltage in Features 2. Modify test conditions of I_{RES} parameter in Electrical Characteristics 3. Modify Typical Characteristics Figure 10, 11
A.0.2	2025/12/24	1. Add 9 APPLICATION AND IMPLEMENTATION 2. Update 8.3.7 Fault-Bus Output With One-Fails-All-Fail
A.0.3	2026/06/08	Modify test conditions of I_{RES} parameter in Electrical Characteristics

5 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
RS3700-Q1	RS3700AXEM-Q1	-40°C ~+125°C	EMSOP8	SN	TBD	RS3700A	Tape and Reel, 4000
	RS3700BXEM-Q1	-40°C ~+125°C	EMSOP8	SN	TBD	RS3700B	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.

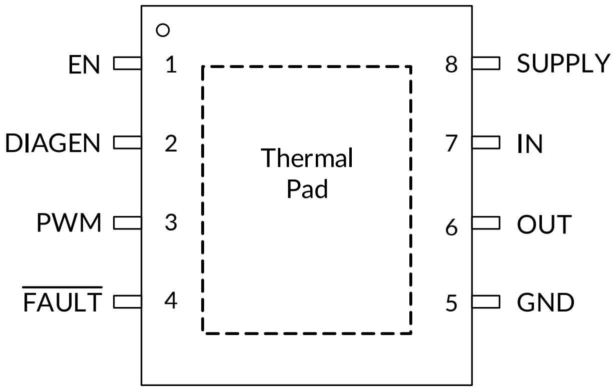
(2) Lead finish/Ball material. Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(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.

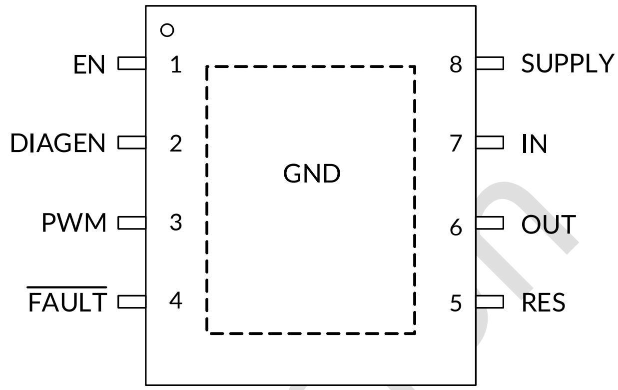
6 PIN CONFIGURATIONS

RS3700A-Q1



EMSOP8

RS3700B-Q1



EMSOP8

PIN DESCRIPTION

PIN		I/O (1)	FUNCTION
NAME	NO.		
EN	1	I	Device enable pin
DIAGEN	2	I	Enable pin for LED open-circuit detection to avoid false open diagnostics during low-dropout operation.
PWM	3	I	PWM input for OUT and RES current output ON/OFF control.
$\overline{\text{FAULT}}$	4	I/O	Fault output，support one-fails-all-fail fault bus.
GND	5	-	RS3700A-Q1: Ground.
RES		-	RS3700B-Q1: Current output with thermal balancing shunt resistor.
OUT	6	O	Current output for channel. A 10nF capacitor is recommended between the pin to GND.
IN	7	I	Current input for channel.
SUPPLY	8	I	Device power supply.
Thermal pad	Thermal Pad	-	RS3700A-Q1: Suggest to connect to GND.
GND		-	RS3700B-Q1: Ground.

(1) I=input, O=output.

7 SPECIFICATIONS

7.1 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, IN, EN, PWM		-0.3	V_{SUPPLY}+0.3	V
High-voltage output	OUT, RES		-0.3	V_{SUPPLY}+0.3	V
Fault bus	$\overline{FAULT}$		-0.3	V_{SUPPLY}+0.3	V
θ_{JA}	Package thermal impedance (2)	EMSOP8		60	°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 $T_{J(MAX)}$, $R_{\theta JA}$, and T_A. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(MAX)} - T_A) / R_{\theta JA}$. All numbers apply for packages soldered directly onto a PCB.

7.2 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)	±4000	V
		Charged-Device Model (CDM), per AEC Q100-011	±1000	V
		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.

7.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
SUPPLY	Device supply voltage	4.5	40	V
IN	Sense voltage	V_{SUPPLY}-V_{CS_REG}	V_{SUPPLY}	V
EN	Device EN pin	0	V_{SUPPLY}	V
PWM	PWM inputs	0	V_{SUPPLY}	V
DIAGEN	Diagnostics enable pin	0	V_{SUPPLY}	V
OUT, RES	Driver output	0	V_{SUPPLY}	V
$\overline{FAULT}$	Fault bus	0	V_{SUPPLY}	V
Operating ambient temperature, T_A		-40	125	°C

7.4 Electrical Characteristics

V_{SUPPLY}=5V to 40V, V_{EN}=5V, T_J=-40°C to +150°C unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN(1)	TYP(2)	MAX(1)	UNIT
BIAS						
V_{POR_rising}	Supply voltage POR rising threshold			3.67		V
$V_{POR\_falling}$	Supply voltage POR falling threshold			3.53		V
I_{SD}	Device shutdown current	V_{EN} = 0V, V_S=12V		5		µA
$I_{Quiescent}$	Device standby ground current	PWM=HIGH		0.45		mA
I_{Fault}	Device supply current in fault mode	PWM=HIGH, $\overline{FAULT}$ externally pulled LOW		0.2		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		3.3		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_{OUT}	Device output-current	Duty of PWM=100%	4		500	mA
V_{CS_REG}	Sense-resistor regulation voltage	T_A=25°C, V_{SUPPLY}=4.5V to 18V		98		mV
		T_A=-40°C to +125°C, V_{SUPPLY}=4.5V to 18V		98		mV
R_{CS_REG}	Sense-resistor range				25	Ω
$V_{DROPOUT}$	Voltage dropout from IN to OUT, RES open	Current setting of 100mA		180		mV
	Voltage dropout from IN to RES, OUT open (Only for RS3700B-Q1)			240		
I_{RES}	Ratio of RES current to total current	I_{RES}/I_{OUT_Tot}, V_{IN}-V_{RES}>1V, I_{O_total}=100mA	95			%
DIAGNOSTICS						
$V_{OPEN\_th\_rising}$	LED open rising threshold, V_{IN} – V_{OUT}			100		mV
$V_{OPEN\_th\_falling}$	LED open falling threshold, V_{IN} – V_{OUT}			300		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
I_{RETRY}	Channel output V_{OUT} short-to-ground retry current			1		mA

(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=-40°C to +150°C unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN(1)	TYP(2)	MAX(1)	UNIT
FAULT						
V_{IL_FAULT}	Logic input low threshold				0.7	V
V_{IH_FAULT}	Logic input high threshold		2			V
V_{OL_FAULT}	Logic output low threshold	With 500μA external pullup			0.4	V
V_{OH_FAULT}	Logic output high threshold	With 1μA external pulldown, V_{SUPPLY}=12V	4			V
t_{FAULT_rising}	Fault detection rising edge deglitch time			10		µs
$t_{FAULT\_falling}$	Fault detection falling edge deglitch time			20		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
THERMAL PROTECTION						
T_{TSD}	Thermal shutdown junction temperature threshold			170		°C
T_{TSD_HYS}	Thermal shutdown junction temperature hysteresis			15		°C

(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.

7.5 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, I_{SET}=100mA		5		µs
$t_{Current\_rising}$	Output current rising from 10% to 90%	V_{SUPPLY}=12V, V_{OUT}=6V, I_{SET}=100mA		3		µs
$t_{PWM\_delay\_falling}$	PWM falling edge delay(V_{IL_PWM}) to 90% output	V_{SUPPLY}=12V, V_{OUT}=6V, I_{SET}=100mA		5		µs
$t_{Current\_falling}$	Output current rising from 90% to 10%	V_{SUPPLY}=12V, V_{OUT}=6V, I_{SET}=100mA		3		µs
$t_{STARTUP}$	EN rising edge to 10% output current	V_{SUPPLY}=12V, V_{OUT}=6V, I_{SET}=100mA		85		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
$t_{FAULT\_recovery}$	Fault recovery delay time			16		µs
t_{TSD_deg}	Thermal over temperature deglitch time			60		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.

7.6 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.

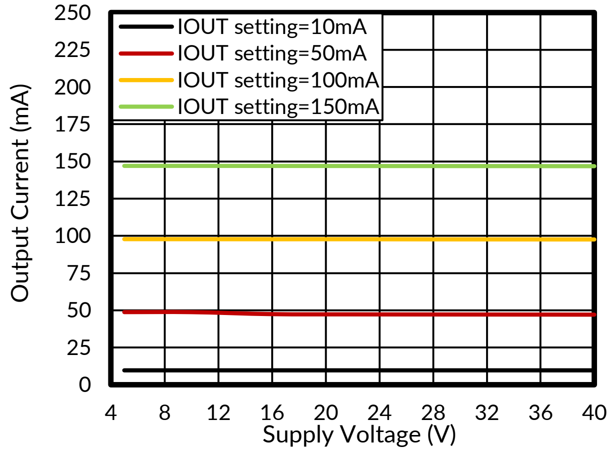


Figure 1. Output Current vs Supply Voltage

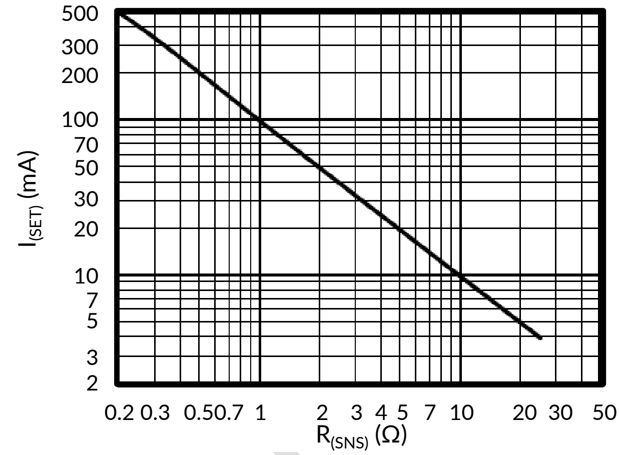


Figure 2. Output Current vs Current-Sense Resistor

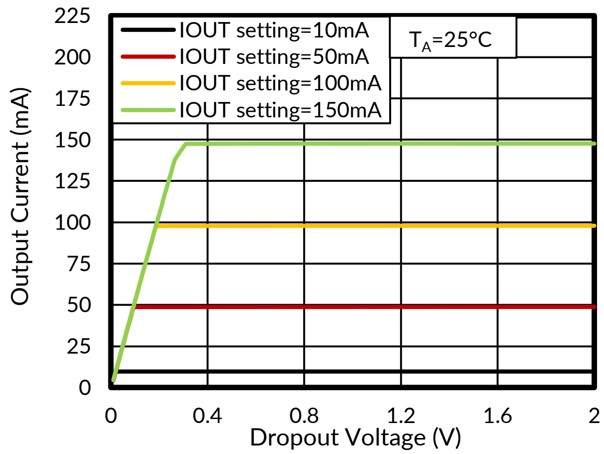


Figure 3. Output Current vs Dropout Voltage

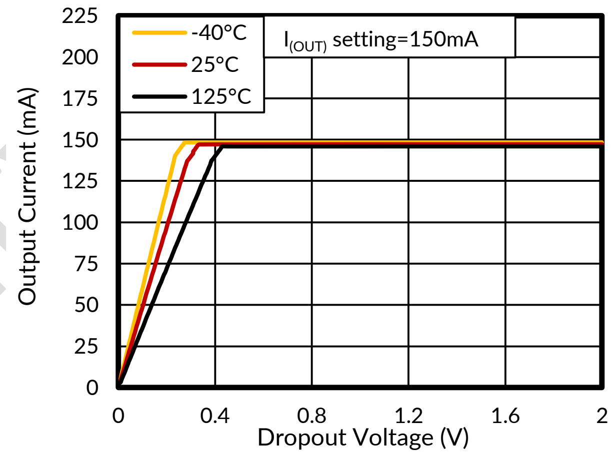


Figure 4. Output Current vs Dropout Voltage

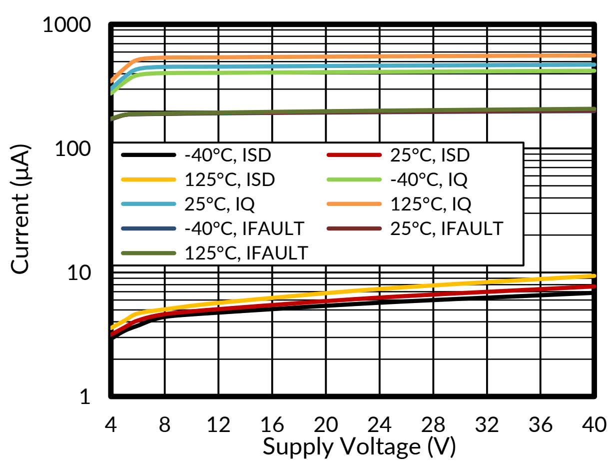


Figure 5. Shutdown, Quiescent, and Fault Current vs Supply Voltage

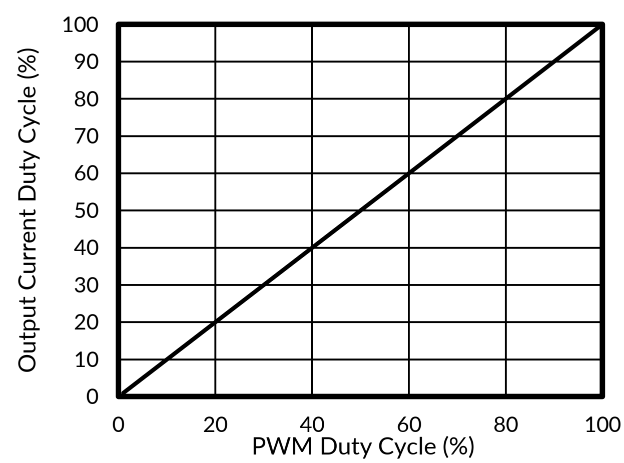


Figure 6. PWM Output Duty Cycle vs Input Duty Cycle

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.

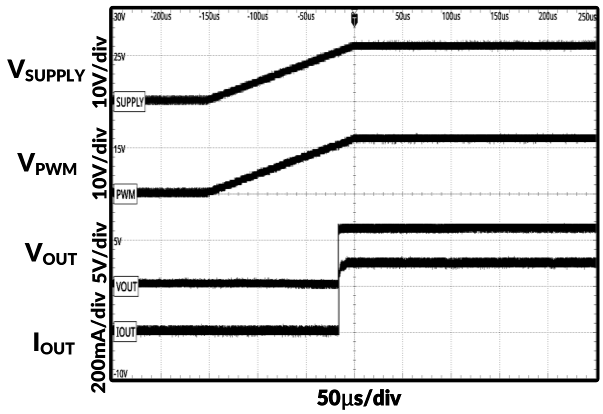


Figure 7. Power-Up Sequence

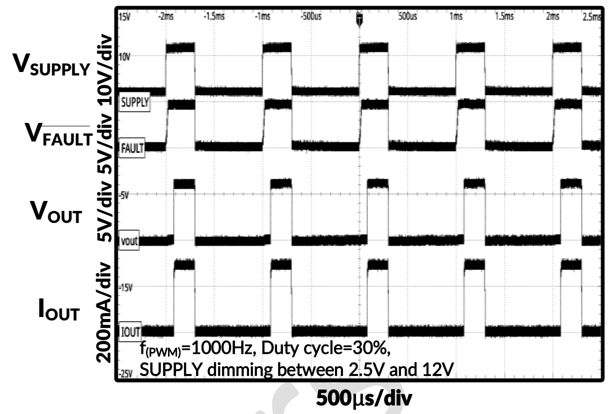


Figure 8. PWM Dimming via Power Supply

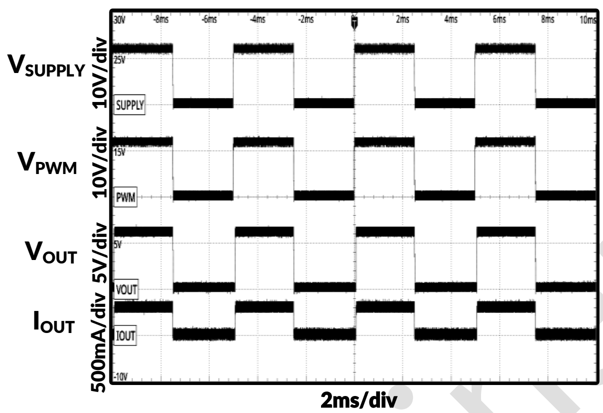


Figure 9. Supply Dimming at 200 Hz

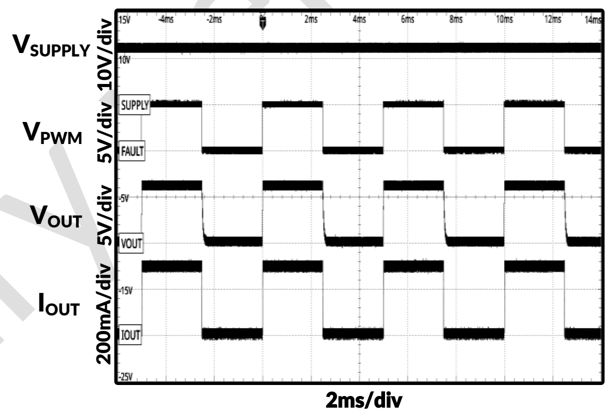


Figure 10. PWM Dimming at 200 Hz

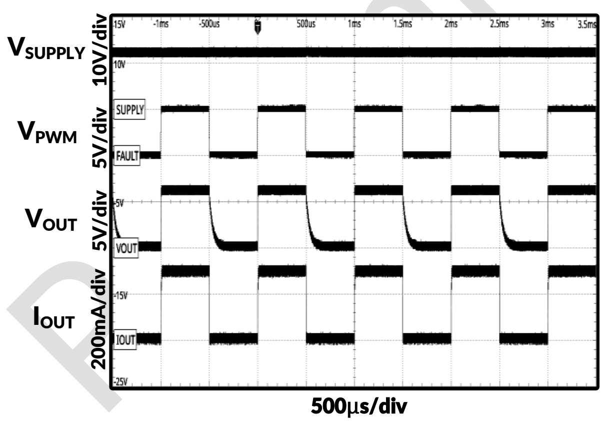


Figure 11. PWM Dimming at 1 kHz

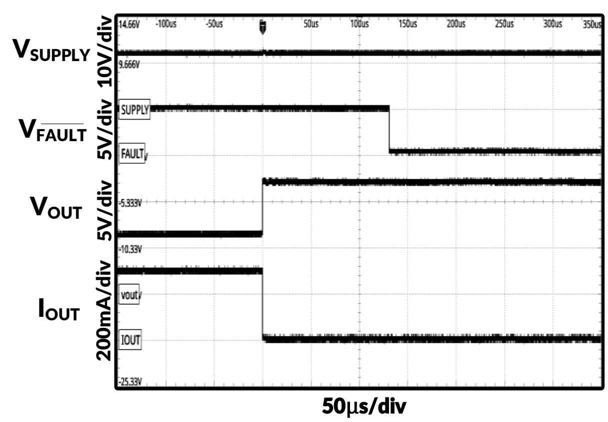


Figure 12. LED Open Protection

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.

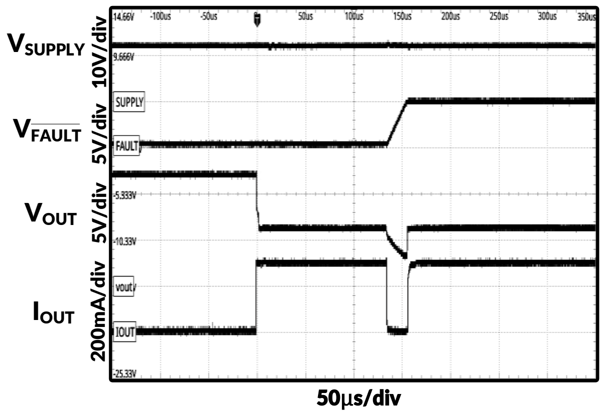


Figure 13. LED Open Protection Recovery

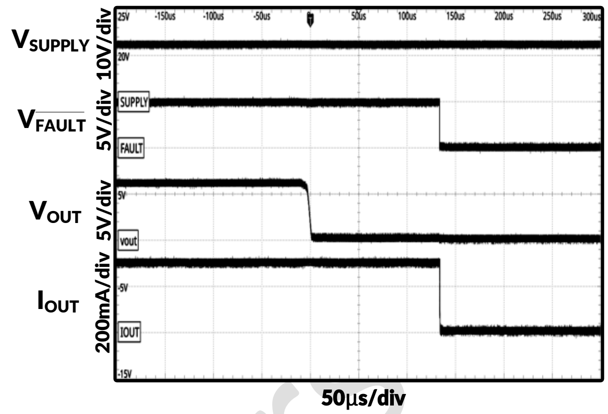


Figure 14. LED Short-Circuit Protection

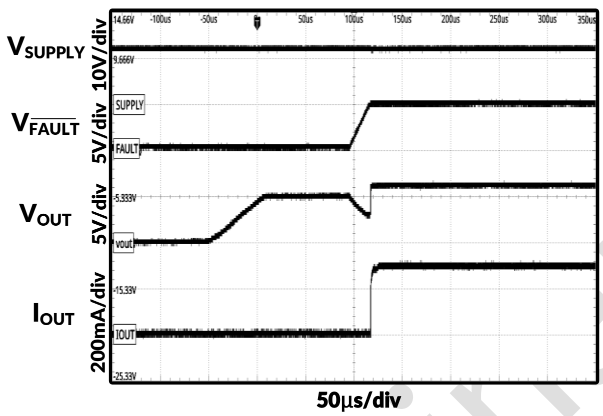


Figure 15. LED Short-Circuit Protection Recovery

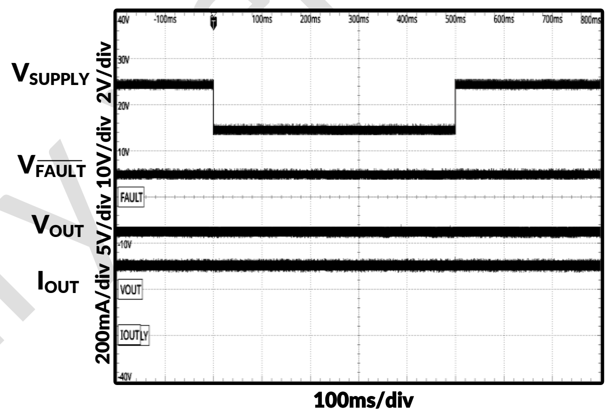


Figure 16. Transient Undervoltage

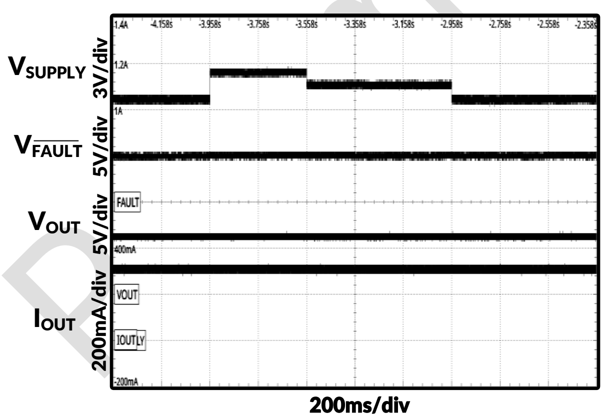


Figure 17. Transient Overvoltage

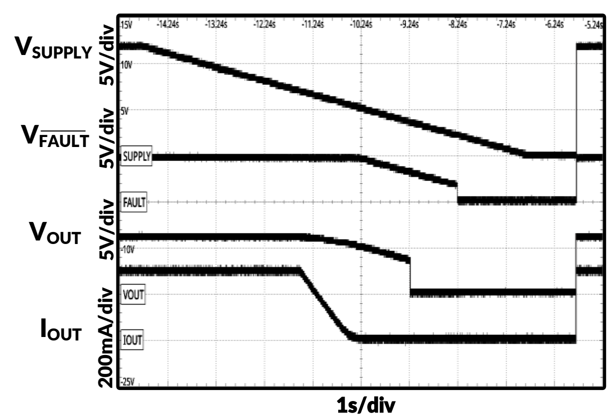


Figure 18. Slow Decrease and Quick Increase of Supply Voltage

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.

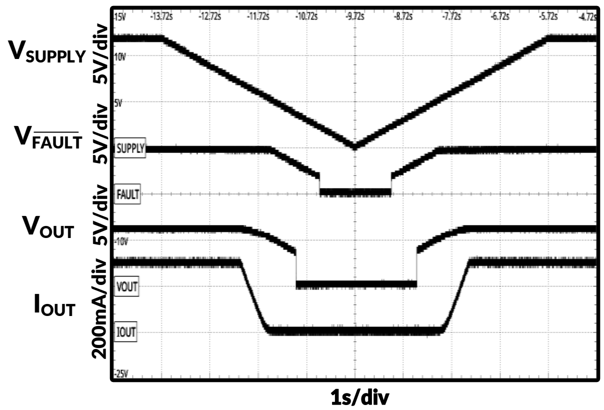


Figure 19. Slow Decrease and Slow Increase of Supply Voltage

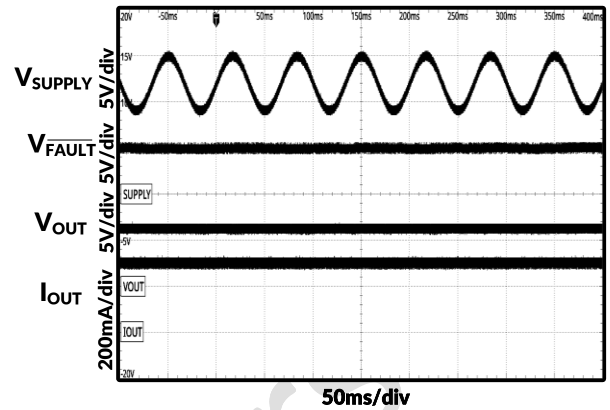


Figure 20. Superimposed Alternating Voltage 15Hz

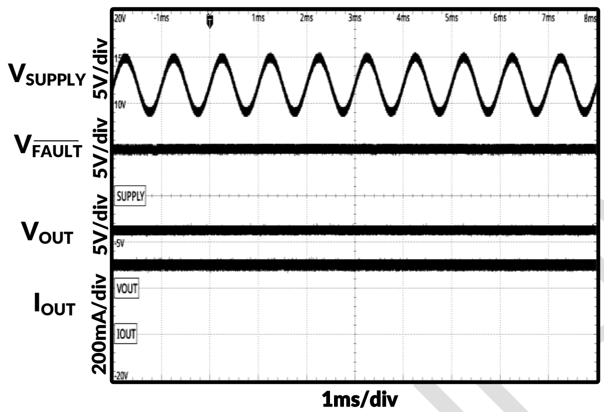


Figure 21. Superimposed Alternating Voltage 1kHz

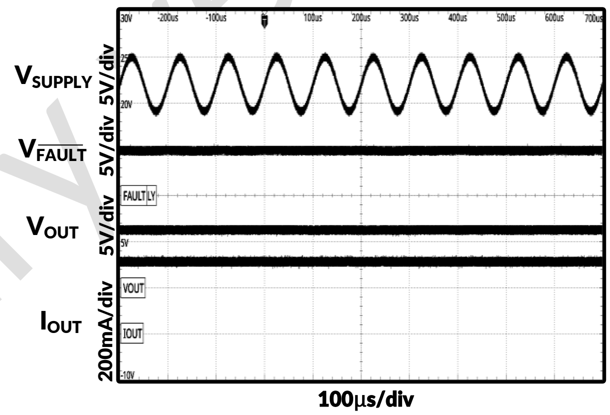


Figure 22. Superimposed Alternating Voltage 10kHz

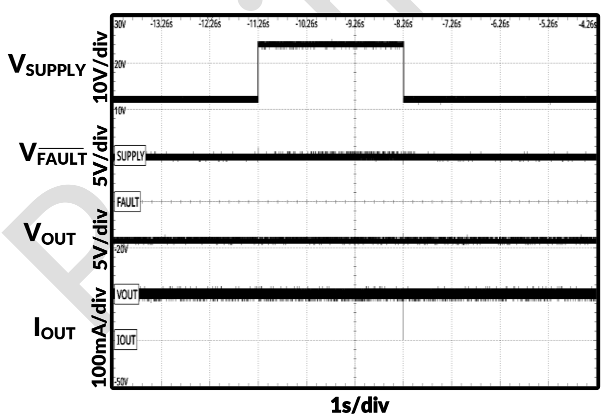


Figure 23. Jump Start

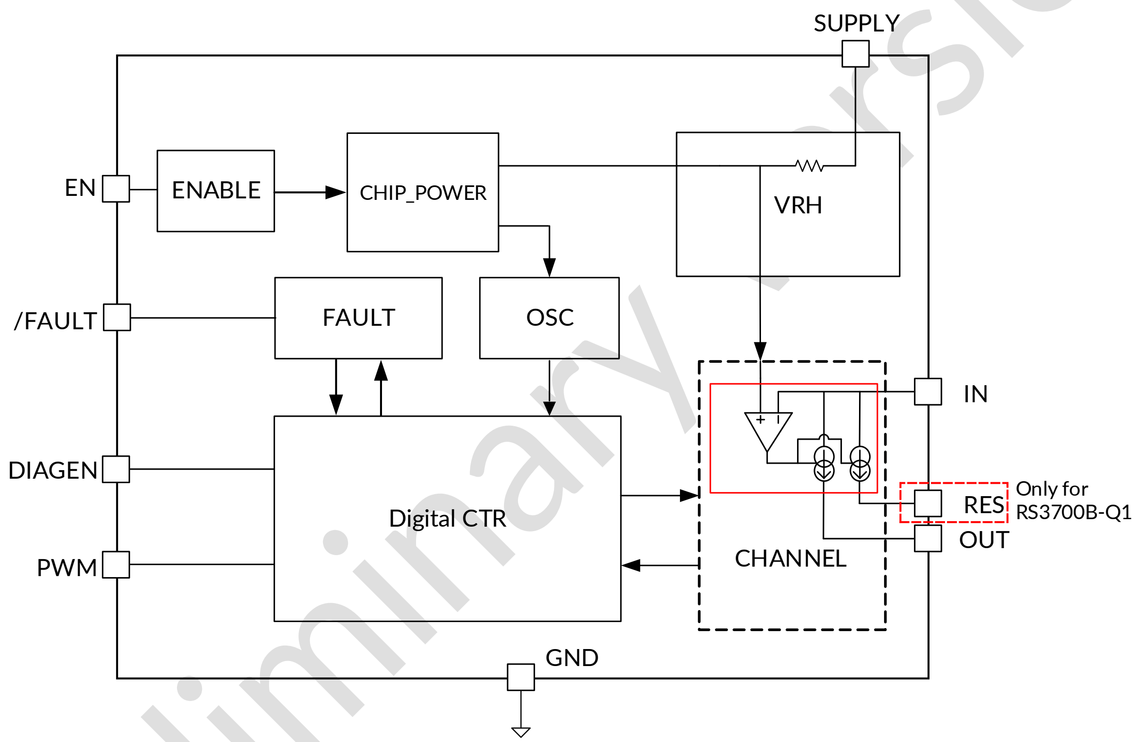
8 DETAILED DESCRIPTION

8.1 Overview

The RS3700-Q1 device is one of a family of single-channel linear LED drivers. The family provides a simple solution for automotive LED applications. Different package options in the family provide a variety of current ranges and diagnostic options. The RS3700-Q1 device in an EMSOP8 package supports LED open-circuit detection and short-to-ground detection. A one-fails–all-fail fault bus allows the RS3700-Q1 device to be used together with other LED drivers.

The output current can be set by an external $R_{(SNS)}$ resistor. Current flows from the supply through the $R_{(SNS)}$ resistor into the internal current source and to the LEDs.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Device Bias

8.3.1.1 Power-On Reset (POR)

The RS3700-Q1 device has an internal power-on-reset (POR) function. When power is applied to SUPPLY, the internal POR holds the device in the reset condition until $V_{(SUPPLY)}$ reaches $V_{(POR\_rising)}$.

8.3.1.2 Low-Quiescent-Current Fault Mode

The RS3700-Q1 device consumes minimal quiescent current when it is in fault mode. If the $\overline{\text{FAULT}}$ voltage is externally pulled LOW, the device shuts down the output driver.

If the device detects an internal fault, it pulls the $\overline{\text{FAULT}}$ output LOW to signal a fault alarm on the one-fails–all-fail fault bus.

8.3.2 Constant-Current Driver

The RS3700-Q1 device has a high-side constant-current integrated driver. The device senses channel current with an external high-side current-sense resistor, $R_{(SNS)}$. A current regulation loop drives an internal transistor and regulates the current-sense voltage at the current-sense resistor to $V_{(CS\_REG)}$. When the output driver is in regulation, the output current can be set using the following equation.

$$I_{(OUT)} = \frac{V_{(CS\_REG)}}{R_{(SNS)}} \quad (1)$$

8.3.3. Output Current Thermal Balancing (RS3700B-Q1 only)

The RS3700B-Q1 device provides two current output path. Current flows through the R_{SNS} into the integrated current regulation circuit and to the LEDs through OUT pin and RES pin. The current output on both OUT pin and RES pin is independently regulated to achieve total required current output. The summed current of OUT and RES is equal to the current through the R_{SNS}.

$$I_{Total} = \frac{V_{(CS\_REG)}}{R_{(SNS)}} = I_{OUT} + I_{RES} \quad (2)$$

The integrated independent current regulation in RS3700B-Q1 dynamically adjusts the output current on both OUT and RES output to maintain the stable summed current for LED. The RS3700B-Q1 always regulates the current output to the RES pin as much as possible until the RES current path is saturated, and the rest of required current is regulated from the OUT. As a result, the most of the current to LED outputs through the RES 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 OUT pin when the voltage headroom is relatively low between SUPPLY and LED required forward voltage.

8.3.4 Device Enable

The RS3700-Q1 device has an enable input EN. When EN is low, the device is in sleep mode with ultralow quiescent current I(Shutdown). This low current helps to save system-level current consumption in applications where battery voltage directly connects to the device without high-side switches.

8.3.5 PWM Dimming

The RS3700-Q1 device supports PWM dimming via PWM input dimming and supply dimming.

The PWM input functions as an enable for the output current. When the PWM input is low, the device also disables the diagnostic features.

Supply dimming applies PWM dimming on the power input. For an accurate PWM threshold, RUNIC recommends using a resistor divider on the PWM input stage to set the PWM threshold higher than $V_{(POR\_rising)}$.

8.3.5.1 Power Supply Control

The RS3700-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 ($V_{DROPOUT} + V_{CS\_REG}$), and the PWM pin voltage is high, the output current is turned ON and well regulated. When the voltage applied on the SUPPLY pin drops below UVLO, 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.

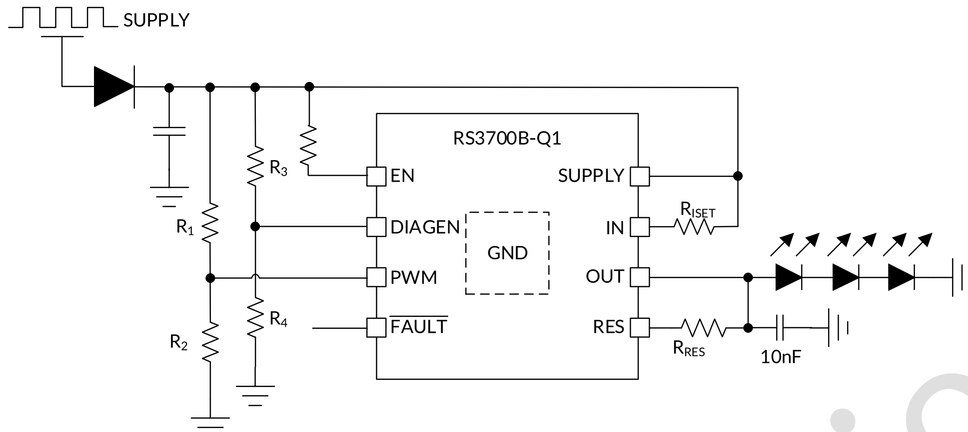


Figure 24. RS3700B-Q1 Power Supply Control LED Brightness Dimming

- To avoid the output current overshoot during turn-on phase, it is suggested to enable the PWM through resistor as below connection:

$$V_{SUPPLY\_PWM\_rising} = V_{IH\_PWM} \times \left(1+\frac{R_1}{R_2}\right) \quad (3)$$

$$V_{SUPPLY\_PWM\_rising} \geq V_{LED\_FWD\_TOT} + V_{DROPOUT} + V_{CS\_REG} \quad (4)$$

- To avoid the false open-load detection due to low-dropout region operation during turn-off phase, it is suggested to enable the DIAGEN through resistor as below connection:

$$V_{SUPPLY\_DIAGEN\_falling} = V_{IL\_DIAGEN\_} \times \left(1+\frac{R_3}{R_4}\right) \quad (5)$$

$$V_{SUPPLY\_DIAGEN\ \_falling} \geq V_{LED\_FWD\_TOT} + V_{OPEN\_th\_falling} + V_{CS\_REG} \quad (6)$$

8.3.6 Diagnostics

The RS3700-Q1 device provides advanced diagnostics and fault protection features for automotive exterior lighting systems. The device is able to detect and protect from LED string short-to-GND and LED string open-circuit faults. It also supports a one-fails–all-fail fault bus that could flexibly fit different regulatory requirements.

8.3.6.1 DIAGEN

The RS3700-Q1 device supports the DIAGEN pin with an accurate threshold to disable the open-load diagnostic function. With a resistor divider, the DIAGEN pin can be used to sense SUPPLY voltage with a resistor-programmable threshold. With the DIAGEN feature, the device is able to avoid false error reports due to low dropout voltage and to drive maximum current in low-dropout mode when the input voltage is not high enough for current regulation.

When $V_{(DIAGEN)}$ is higher than the $V_{IH(DIAGEN)}$ threshold, the device enables the LED open-circuit diagnostic. When $V_{(DIAGEN)}$ is lower than the $V_{IL(DIAGEN)}$ threshold, the device disables the LED open-circuit diagnostic.

8.3.6.2 Low-Dropout Mode

When the supply voltage drops, the RS3700-Q1 device tries to regulate current by driving internal transistors in the linear region, also known as low-dropout mode, because the voltage across the sense resistor fails to reach the regulation target.

In low-dropout mode, the open-circuit diagnostic must be disabled. Otherwise, the device treats the low-dropout mode as an open-circuit fault. The DIAGEN pin is used to avoid false diagnostics on the output channel due to low supply voltage.

When the DIAGEN voltage is low, open-circuit detection is ignored. When the DIAGEN voltage is high, open-circuit detection returns to normal operation.

In low-dropout mode, a parallel diode and current-limiting resistor are recommended to clamp between SUPPLY and IN (across the sense resistor) in case of a large current pulse during recovery.

8.3.6.3 Open-Circuit Detection

The RS3700-Q1 device has LED open-circuit detection. Open-circuit detection monitors the output voltage when the channel is in the ON state. Open-circuit detection is only enabled when DIAGEN is HIGH. A short-to-battery fault is also detected as an LED open-circuit fault.

The device monitors dropout-voltage differences between the IN and OUT pins when PWM is HIGH. The voltage difference $V_{(IN)} – V_{(OUT)}$ is compared with the internal reference voltage $V_{(OPEN\_th\_rising)}$ to detect an LED open-circuit failure. If $V_{(IN)} – V_{(OUT)}$ falls below the $V_{(OPEN\_th\_rising)}$ voltage longer than the deglitch time of $t_{(OPEN\_deg)}$, the device detects an open-circuit fault. Once an LED open-circuit failure is detected, the constant-current source pulls the fault bus down. During the deglitch time period, if $V_{(IN)} – V_{(OUT)}$ rises above $V_{(OPEN\_th\_falling)}$, the deglitch timer is reset.

When the PWM input is in auto-retry, the device keeps the output ON to retry if the PWM input is HIGH; the device sources a small current $I_{(retry)}$ from IN to OUT to retry when the PWM input is LOW. In either scenario, once a faulty channel recovers, the device resumes normal operation and releases the $\overline{\text{FAULT}}$ pulldown.

8.3.6.4 Short-to-GND Detection

The RS3700-Q1 device has LED short-to-GND detection. Short-to-GND detection monitors the output voltage when the channel is in the ON state. Once a short-to-GND LED failure is detected, the device turns off the output channel and retries automatically, ignoring the PWM input. If the retry mechanism detects removal of the LED short-to-GND fault, the device resumes normal operation.

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

Once the device has detected a short-to-GND fault, the device turns off the output channel and retries automatically with a small current. When retrying, the device sources a small current $I_{(retry)}$ from IN to OUT to pull up the LED loads continuously. Once auto-retry detects output voltage rising above $V_{(SG\_th\_falling)}$, it clears the short-to-GND fault and resumes normal operation.

8.3.6.5 Overtemperature Protection

The RS3700-Q1 device monitors device junction temperature. When the junction temperature reaches thermal shutdown threshold $T_{(TSD)}$, the output shuts down. Once junction temperature falls below $T_{(TSD)} – T_{(TSD\_HYS)}$, the device resumes normal operation. During overtemperature protection, the fault bus is pulled low.

8.3.7 Fault-Bus Output With One-Fails-All-Fail

During normal operation, The $\overline{\text{FAULT}}$ pin of RS3700-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 RS3700-Q1 also monitors the $\overline{\text{FAULT}}$ pin voltage internally. If the $\overline{\text{FAULT}}$ pin of the RS3700-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 output. 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 RS3700-Q1 device is able to construct a FAULT bus by tying $\overline{\text{FAULT}}$ pins from multiple RS3700-Q1 devices to achieve one-fails-all-fail function as Figure 25 showing. The lower side RS3700-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 RS3700-Q1 (A) because the $\overline{\text{FAULT}}$ pins are connected of two devices. The upper side RS3700-Q1 (A) turns off output current for channel as a result. If the $\overline{\text{FAULT}}$ pins of each RS3700-Q1 are all connected to drive the base of an external PNP transistor as illustrated in Figure 26, the one-fails–all-fail function is disabled and only the faulty channel device is turned off.

The fault bus is able to support up to 15 pieces of LED devices.

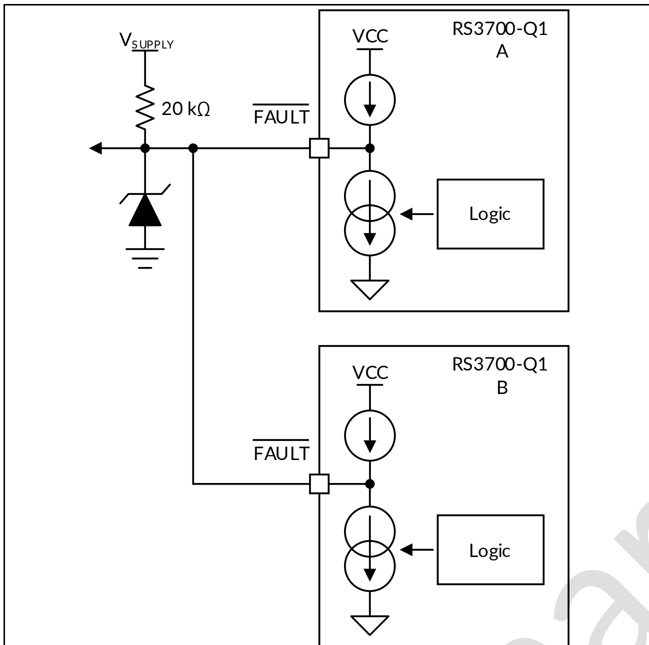


Figure 25. FAULT Bus for One-Fails-All-Fail Application

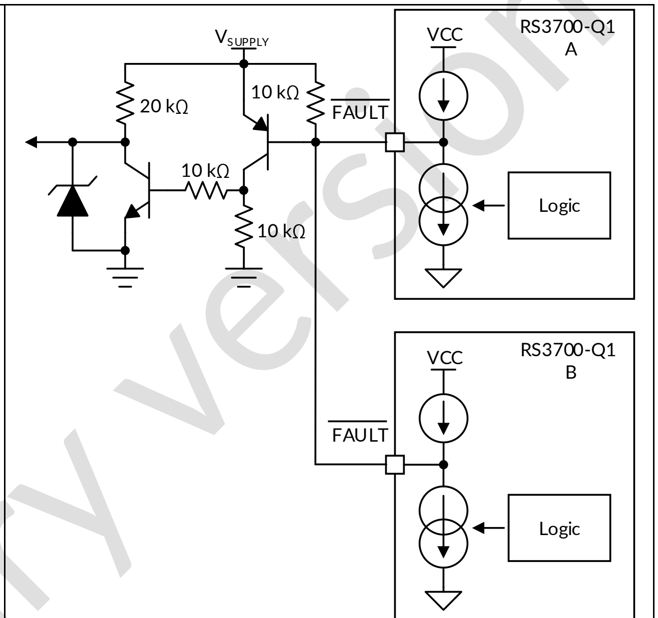


Figure 26. FAULT Bus for One-Fails-Others-On Application

Table 1. Fault Table With DIAGEN = HIGH

FAULT BUS STATUS	FAULT TYPE	DETECTION MECHANISM	CHANNEL STATE	DEGLITCH TIME	FAULT BUS	FAULT HANDLING ROUTINE	FAULT RECOVERY
$\overline{\text{FAULT}}$ floating or externally pulled up	Open-circuit or short-to-supply	$V_{(IN)} - V_{(OUT)} < V_{(OPEN\_th\_rising)}$	On	$t_{(OPEN\_deg)}$	Constant-current pulldown	Device works normally with $\overline{\text{FAULT}}$ pin pulled low. Device sources $I_{(retry)}$ current when PWM is LOW. Device keeps output normal when PWM is HIGH.	Auto recover
	Short-to-ground	$V_{(OUT)} < V_{(SG\_th\_rising)}$	On	$t_{(SG\_deg)}$	Constant-current pulldown	Device turns output off and retries with constant current $I_{(retry)}$, ignoring the PWM input.	Auto recover
	Over-temperature	$T_J > T_{(TSD)}$	On or off	$t_{(TSD\_deg)}$	Constant-current pulldown	Device turns output off.	Auto recover
Externally pulled low	Device turns output off						

Table 2. Fault Table With DIAGEN = LOW

FAULT BUS STATUS	FAULT TYPE	DETECTION MECHANISM	CHANNEL STATE	DEGLITCH TIME	FAULT BUS	FAULT HANDLING ROUTINE	FAULT RECOVERY
$\overline{\text{FAULT}}$ floating or externally pulled up	Open-circuit or short-to-supply	Ignored					
	Short-to-ground	$V_{(OUT)}$ < $V_{(SG\_th\_rising)}$	On	$t_{(SG\_deg)}$	Constant-current pulldown	Device turns output off and retries with constant current $I_{(retry)}$, ignoring the PWM input.	Auto recover
	Over-temperature	$T_J > T_{(TSD)}$	On or off	$t_{(TSD\_deg)}$	Constant-current pulldown	Device turns output off.	Auto recover
Externally pulled low	Device turns output off.						

8.4 Device Functional Modes

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

When the device is in undervoltage lockout mode, the RS3700-Q1 device disables all functions until the supply rises above the POR-rising threshold.

8.4.2 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.

8.4.3 Low-Voltage Dropout

When the device drives an LED string in low-dropout mode, if the voltage drop is less than the open-circuit detection threshold, the device may report a false open. Set the DIAGEN threshold higher than the LED string voltage to avoid a false open-circuit detection.

8.4.4 Fault Mode

When the device detects an open or shorted LED, 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 $I_{(FAULT)}$.

9 APPLICATION AND IMPLEMENTATION

Information in the following applications sections is not part of the RUNIC component specification, and RUNIC does not warrant its accuracy or completeness. RUNIC's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information

In automotive lighting applications, thermal performance and LED diagnostics are always design challenges for linear LED drivers.

The RS3700-Q1 device is capable of detecting LED open-circuit and LED short-circuits. To increase current driving capability, the RS3700B-Q1 device supports using an external shunt resistor to help dissipate heat. This method provides a low-cost solution of using external resistors to minimize thermal accumulation on the device itself due to large voltage difference between input voltage and LED string forward voltage, while still keeping high accuracy of the total current output.

9.2 Typical Application Circuit

9.2.1 Simple Application without MCU

The RS3700-Q1 device can be utilized for automotive single LED string situation without MCU. The Fault pin can be used alone in the floating state or connect to external indication circuit to indicate the fault condition.

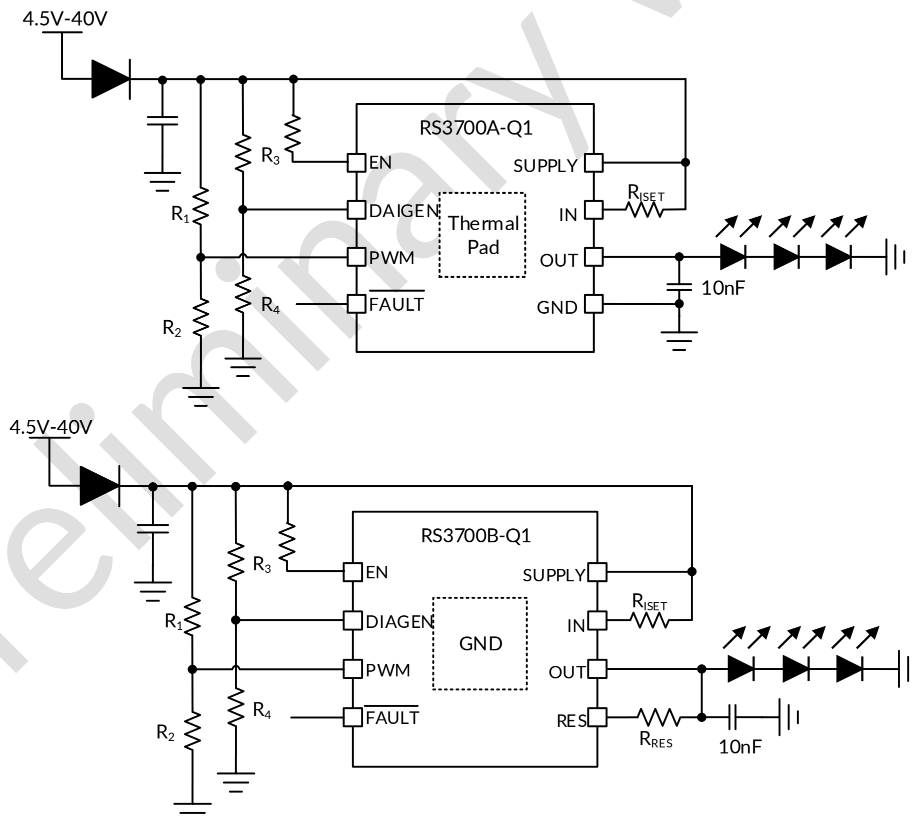


Figure 27. Simple Application Without MCU

9.2.1.1. Design Information

Input voltage range is 9 V to 16 V, LED maximum forward voltage V_{fmax} = 2.5 V, minimum forward voltage V_{fmin} = 1.9 V, current I_{LED} = 50 mA.

9.2.1.2. Design Procedure

Current setting by a sense resistor is as described in the equation:

$$R_{(SNS)} = \frac{V_{(CS\_REG)}}{I_{(LED)}} = 1.96\Omega \quad (7)$$

Where V_{CS_REG} = 98mV, I_{LED}=50mA. Due to the required output current for each LED, R_{SNS} =1.96Ω.

Calculate the current of I_{OUT} and I_{RES}, and the RES resistor R_{RES} can be obtained by using Equation 8. The RES resistor directly decides the current distribution for I_{OUT} path and I_{RES} path. In typical supply voltage application, the current RES resistor is suggested to consume 50% of the total output current.

$$R_{RES} = \frac{V_{SUPPLY} - V_{OUT}}{I_{OUT} \times 0.5} \quad (8)$$

Where V_{SUPPLY}=12V (typical), I_{LED}=50mA. The value of RES resistor is calculated as 222Ω, when the output voltage is selected as 2.15×3=6.45V.

Design the voltage divider resistor value of R_3 and R_4 on DIAGEN pin after design the threshold voltage of supply to enable the open load diagnostics.

Note that, the open-load fault cannot be detected in low dropout operation to avoid unexpected turn off, so headroom between voltage SUPPLY and OUT must be considered. It means the device must disable open-load detection when the voltage supply is below the maximum LED string forward voltage plus open load threshold $V_{OPEN\_th\_rising}$ and V_{CS_REG}. The voltage divider R_3 and R_4 can be obtained as Equation 9.

$$R_3 = \left(\frac{V_{OPEN\_th\_rising} + V_{CS\_REG} + V_{OUT}}{V_{IL\_DIAGEN}} - 1\right) \times R_4 \quad (9)$$

Where $V_{OPEN\_th\_rising}$ = 135mV (maximum), V_{CS_REG} = 102mV (maximum), V_{IL_DIAGEN} = 1.045V (minimum), R_4=10kΩ (recommended). When the maximum LED string forward voltage is 2.5V×3=7.5V, R_3=64.04 kΩ is obtained.

Calculate the divider resistor of R_1 and R_2 of PWM pin to turn on and off LED, after the threshold voltage supply is determined. In order to ensure all the LEDs is operating in normal mode, each LED should be turn off if the voltage supply is lower than LED minimum required forward voltage plus voltage dropout between OUT and V_{SUPPLY}. The minimum forward voltage of LED string is calculated as 1.9V×3=5.7V. Thus, the divider resistor R_1 and R_2 can be calculated by Equation 10.

$$R_1 = \left(\frac{V_{Dropout} + V_{CS\_REG} + V_{OUT}}{V_{IH\_PWM}} - 1\right) \times R_2 \quad (10)$$

Where $V_{DROPOUT}$ = 180mV (typical), V_{CS_REG} = 98mV, V_{IH_PWM} = 1.26V (maximum), R_2=10kΩ (recommended). According to Equation 10, R_1 is 37.44kΩ when the minimum voltage of OUT is 5.7V.

9.2.2 Application with MCU

The RS3700-Q1 devices support dimming control by PWM input single which giving by external MCU. The PWM input pin should be connected to MCU out pin to achieve more complex application.

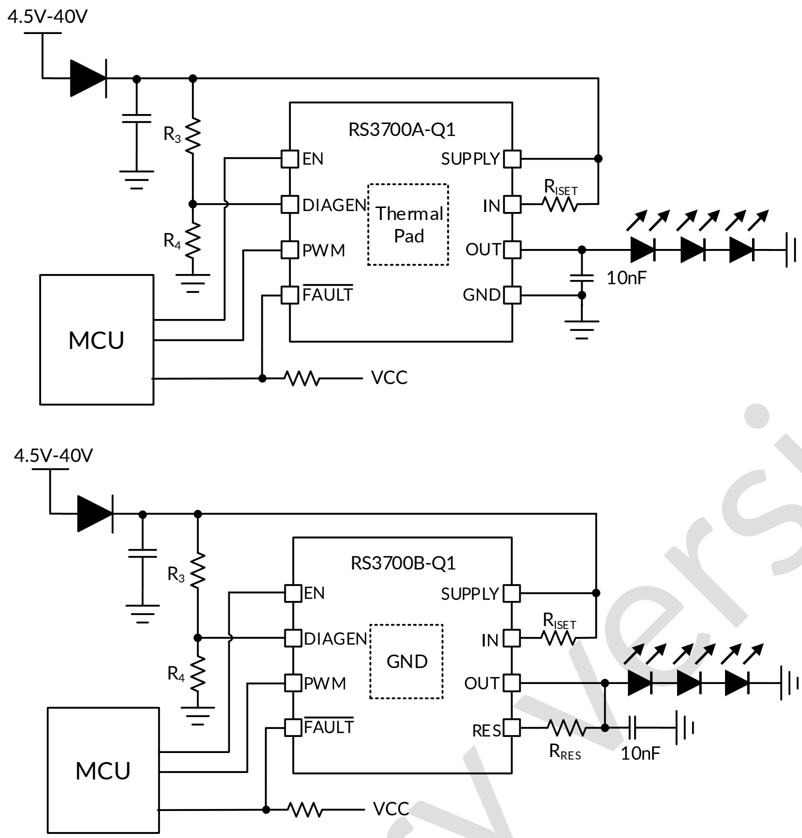


Figure 28. Application With MCU

9.2.2.1. Design Information

Input voltage range is 9 V to 16 V, LED maximum forward voltage V_{fmax} = 2.5 V, minimum forward voltage V_{fmin} = 1.9 V, current I_{LED} = 50 mA. External MCU is adopted to give PWM control signal for PWM dimming control as shown in Figure 28.

9.2.2.2. Design Procedure

Current setting by a sense resistor is as described in the equation:

$$R_{(SNS)} = \frac{V_{(CS\_REG)}}{I_{(LED)}} = 1.96\Omega \quad (11)$$

Where V_{CS_REG} = 98mV, I_{LED}=50mA.
Due to the required output current for each LED, R_{SNS} =1.96Ω.

Calculate the current of I_{OUT} and I_{RES}, and the RES resistor R_{RES} can be obtained by using Equation 12. The RES resistor directly decides the current distribution for I_{OUT} path and I_{RES} path. In typical supply voltage application, the current RES resistor is suggested to consume 50% of the total output current.

$$R_{RES} = \frac{V_{SUPPLY} - V_{OUT}}{I_{OUT} \times 0.5} \quad (12)$$

Where V_{SUPPLY}=12V(typical), I_{LED}=50mA. The value of RES resistor is calculated as 222Ω, when the output voltage is selected as 2.15×3=6.45V.

Design the voltage divider resistor value of R_3 and R_4 on DIAGEN pin after design the threshold voltage of supply to enable the open load diagnostics.

Note that, the open-load fault cannot be detected in low dropout operation to avoid unexpected turn off, so headroom between voltage SUPPLY and OUT must be considered. It means the device must disable open-load detection when the voltage supply is below the maximum LED string forward voltage plus open load threshold $V_{OPEN\_th\_rising}$ and V_{CS_REG}. The voltage divider R_3 and R_4 can be obtained as Equation 13.

$$R_3 = \left(\frac{V_{OPEN\_th\_rising} + V_{CS\_REG} + V_{OUT}}{V_{IL\_DIAGEN}} - 1\right) \times R_4 \quad (13)$$

Where $V_{OPEN\_th\_rising}$ = 135mV (maximum), V_{CS_REG} = 102mV (maximum), V_{IL_DIAGEN} = 1.045V (minimum), R_4=10kΩ (recommended). When the maximum LED string forward voltage is 2.5V×3=7.5V, R_3=64.04 kΩ is obtained.

10 POWER SUPPLY RECOMMENDATIONS

The RS3700-Q1 device is qualified for automotive applications. The normal power supply connection is therefore to an automobile electrical system that provides a voltage within the range specified in the Recommended Operating Conditions.

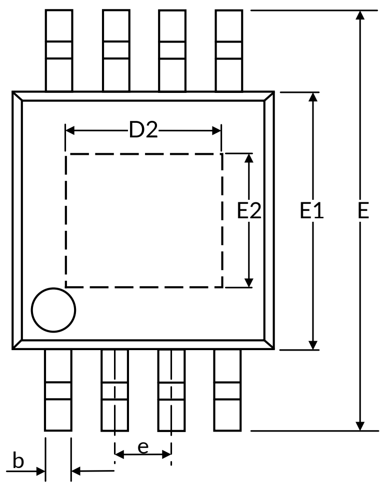
11 LAYOUT

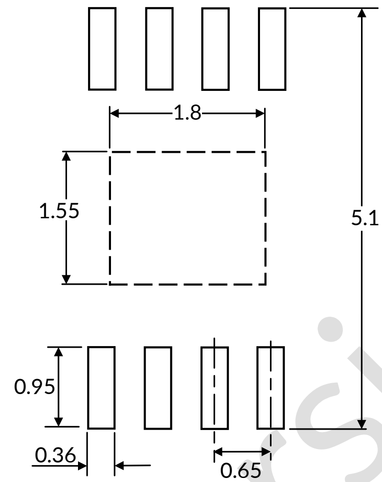
11.1 Layout Guideline

Thermal dissipation is the primary consideration for RS3700-Q1 layout. RUNIC recommends good thermal dissipation area connected to thermal pads with thermal vias.

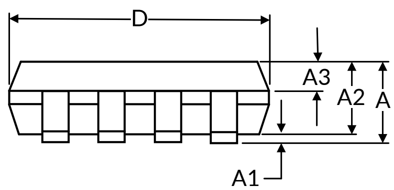
12 PACKAGE OUTLINE DIMENSIONS

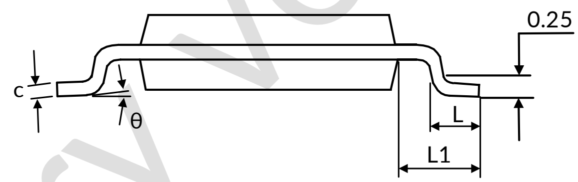
EMSOP8 (4)





RECOMMENDED LAND PATTERN (Unit: mm)





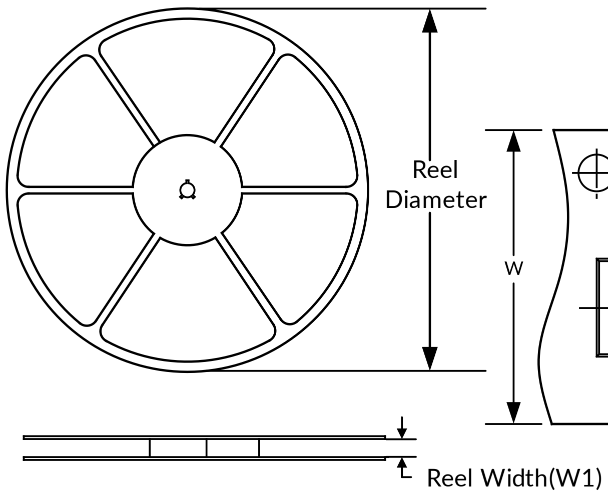
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A (1)	-	1.100	-	0.043
A1	0.050	0.150	0.002	0.006
A2	0.750	0.950	0.030	0.037
A3	0.300	0.400	0.012	0.016
b	0.280	0.360	0.011	0.014
c	0.150	0.190	0.006	0.007
D (1)	2.900	3.100	0.114	0.122
D2	1.800 REF (2)		0.071 REF (2)	
E	4.700	5.100	0.185	0.201
E1 (1)	2.900	3.100	0.114	0.122
E2	1.550 REF (2)		0.061 REF (2)	
e	0.650 BSC (3)		0.026 BSC (3)	
L	0.400	0.700	0.016	0.028
L1	0.950 REF (2)		0.037 REF (2)	
θ	0°	8°	0°	8°

NOTE:

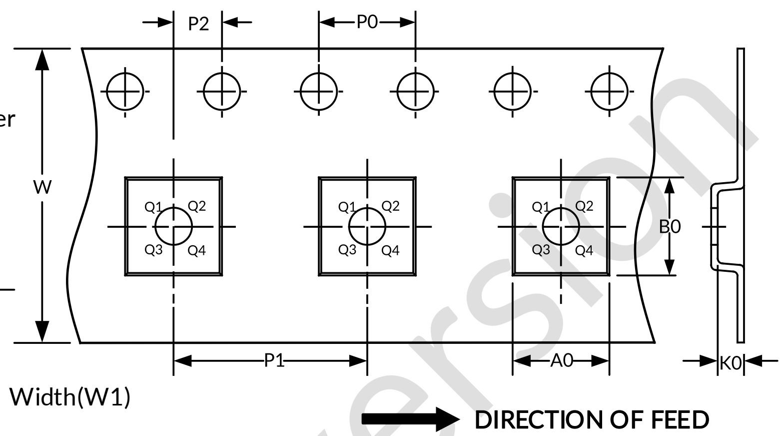
1. Plastic or metal protrusions of 0.15mm maximum per side are not included.
2. REF is the abbreviation for Reference.
3. BSC (Basic Spacing between Centers), "Basic" spacing is nominal.
4. This drawing is subject to change without notice.

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
EMSOP8	13"	12.4	5.20	3.30	1.50	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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