RICHTEK®

RT6158A

High Efficiency, Low Quiescent, 2A Buck-Boost Converter

1 General Description

The RT6158A converter is a high-efficiency single-inductor buck-boost converter that can operate with a wide input voltage range of 2.5V to 5V, suitable for batteries with voltages higher or lower than the output voltage. It delivers up to 2 A load current with a typical 4.5 A switch peak-current limit. The feedback loop is internally compensated for both buck and boost operation, providing seamless transitions between modes and optimal transient response. The Buck-Boost operates at a typical switching frequency of 2MHz in full synchronous operation.

The RT6158A operates in Pulse Frequency Modulation (PFM) mode to increase efficiency. The PFM mode can be disabled, forcing the RT6158A to operate at a fixed switching frequency operation of 2MHz. Additionally, the RT6158A can also be synchronized with external frequency at MODE pin ranging from 2.2MHz to 2.6MHz. The output voltage is adjustable from 2.1V to 5.2V using an external resistor divider.

The recommended junction temperature range is –40°C to 125°C and the recommended ambient temperature range is –40°C to 85°C.

2 Ordering Information

RT6158A □

Package Type(1)

WSC: WL-CSP-25B 2.07x2.33 (BSC)

Note 1.

Richtek products are Richtek Green Policy compliant and marked with (1) indicates compatible with the current requirements of IPC/JEDEC J-STD-020.

3 Features

- **Input Voltage Range: 2.5V to 5V**
- **Adjustable Output Voltage: 2.1V to 5.2V**
- **Up to 2A Load Current (V_{IN} = 3V, V_{OUT} = 3.5V)**
- **Up to 96% Efficiency (V_{IN} = 4.2V, V_{OUT} = 3.5V, I_{LOAD} = 0.5A)**
- **2MHz Switching Frequency**
- **5μA Non-Switching Quiescent Current**
- **Automatic PFM/PWM Mode with Optional Forced-PWM Mode**
- **Output Discharge Function**
- **Seamless Step-Up and Step-Down Mode Transitions**
- **Protection Features: OCP, OVP, OTP, UVLO, and SCP**
- **25-Ball WL-CSP Package**

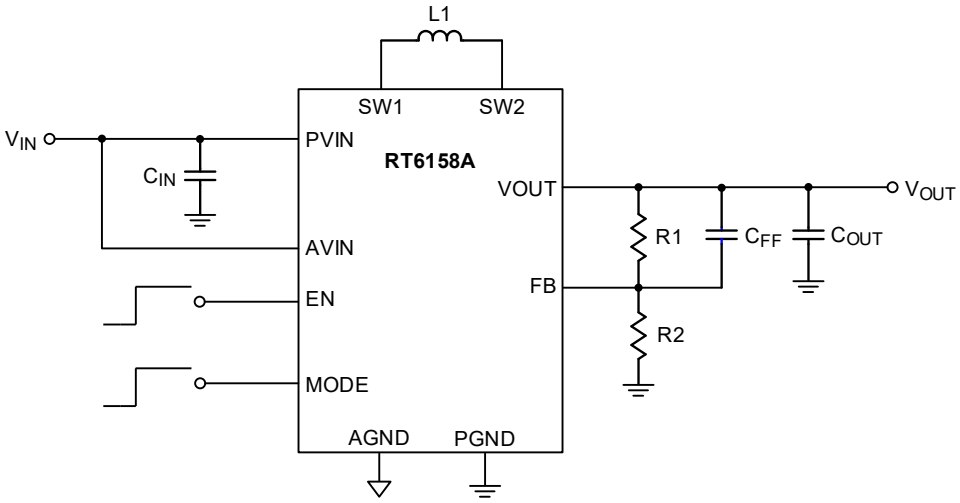
4 Applications

- Cellular Phones
- Wi-Fi Modules
- Tablet PCs
- Portable Instruments

5 Marking Information

0M: Product Code
YMDNN: Date Code

6 Simplified Application Circuit



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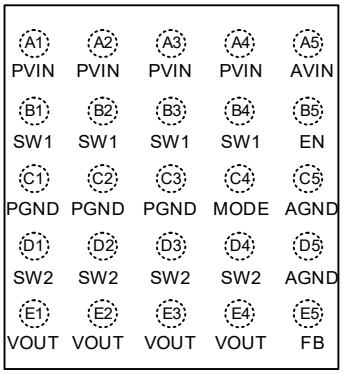
7 Pin Configuration

(TOP VIEW)

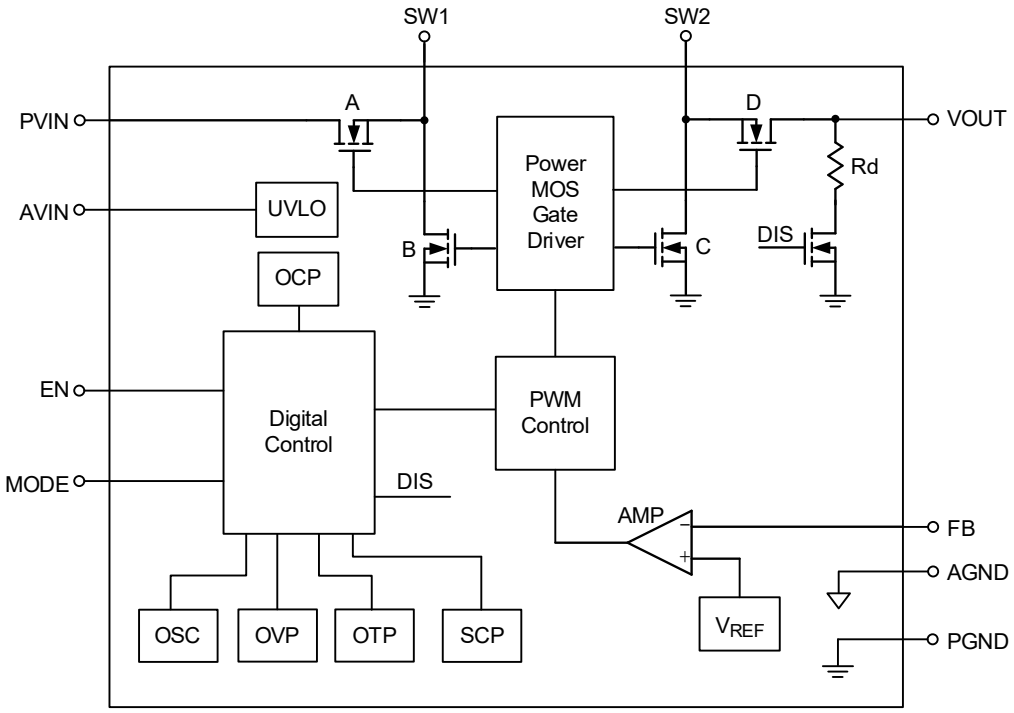


WL-CSP-25B 2.07x2.33 (BSC)

8 Functional Pin Description

Pin No.	Pin Name	Pin Function
A1, A2, A3, A4	PVIN	Power input supply. The input voltage range is from 2.5V to 5V after soft-start is finished. Connect input capacitors between this pin and PGND with a wide PCB trace.
A5	AVIN	Analog input supply. Connect to PVIN.
B1, B2, B3, B4	SW1	Switching node 1. Connect to inductor.
B5	EN	Enable control input. This input must not be left floating and must be terminated.
C1, C2, C3	PGND	Power ground. Connect to this pin with the shortest path for power transmission to reduce parasitic component effect.
C4	MODE	High for PFM mode, low for FCCM mode. This pin also can be used to synchronize switching frequency with 2.2MHz to 2.6MHz. This input must not be left floating and must be terminated.
C5, D5	AGND	Analog ground. This is the signal reference ground for the IC.
D1, D2, D3, D4	SW2	Switching node 2. Connect to inductor.
E1, E2, E3, E4	VOUT	Output voltage pin. PCB trace length from VOUT to the output filter capacitor should be as short and wide as possible.
E5	FB	Output voltage feedback. The typical value of the voltage at the FB pin is 800mV.

9 Function Block Diagram



10 Absolute Maximum Ratings

(Note 2)

- Input Voltage, PVIN, AVIN ---------- –0.3V to 6V
- Output Voltage, V_{OUT} ---------- –0.3V to 6V
- Switch Node Voltage, SW1, SW2 ---------- –0.3V to 6V

  < 20ns ---------- –3V to 8.5V
- Other I/O Pins Voltage (EN, MODE, FB) ---------- –0.3V to 6V
- Power Dissipation, PD @ TA = 25°C

  WL-CSP-25B 2.07x2.33 (BSC) ---------- 2.8W
- Package Thermal Resistance (Note 3)

  WL-CSP-25B 2.07x2.33 (BSC), θ_{JA} ---------- 35.7°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 4)

  HBM ---------- 2kV

Note 2. 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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 3. θ_{JA} is simulated under natural convection (still air) at T_A = 25°C with the component mounted on a high effective-thermal-conductivity four-layer test board on a JEDEC 51-7 thermal measurement standard.

Note 4. Devices are ESD sensitive. Handling precautions are recommended.

11 Recommended Operating Conditions

(Note 5)

- Input Voltage, PVIN, AVIN ---------- 4.5 to 23V
- Output Voltage, V_{OUT} ---------- 4.5 to 5.5V
- Output Current, I_{OUT} ---------- 0A to 2A
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Note 5. The device is not guaranteed to function outside its operating conditions.

12 Electrical Characteristics

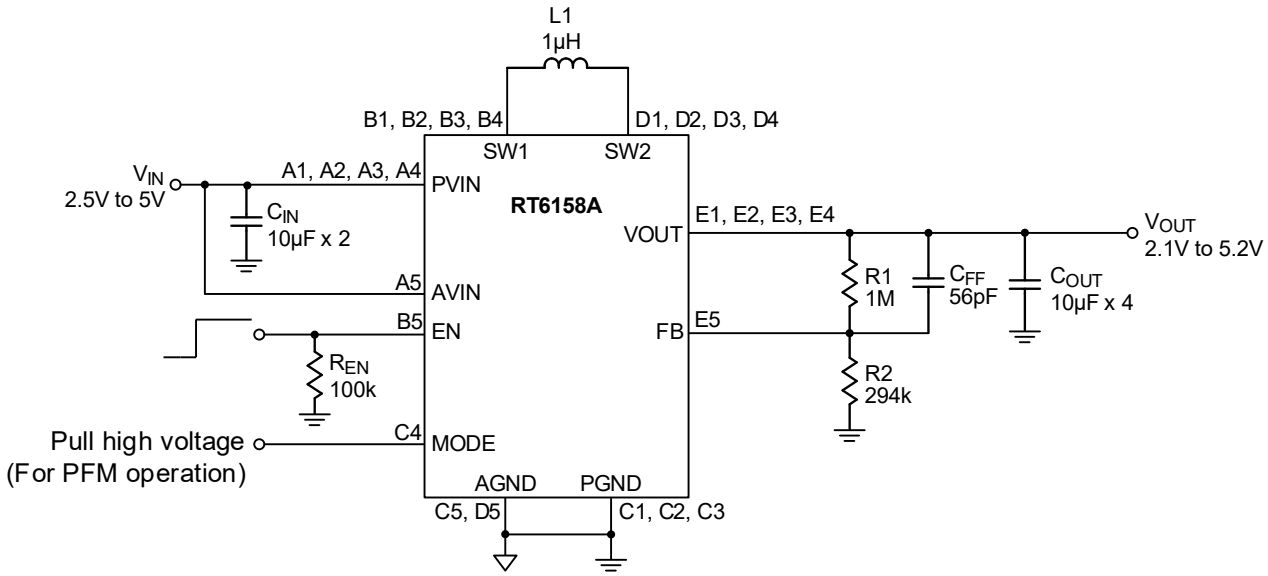
(V_{IN} = 3.6V, V_{OUT} = 3.5V, C_{IN} = 10µF x 2, C_{OUT} = 10µF x 4, L = 1µH, T_A = 25°C, unless otherwise specified.)

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
VIN Supply Input Voltage	V_{IN}	PVIN and AVIN	2.5	--	5	V
Input Voltage Logic-High	V_{IH}		1.2	--	--	V
Input Voltage Logic-Low	V_{IL}		--	--	0.4	V
Output Overvoltage Rising Threshold	V_{UVLO}	Rising	2.05	2.15	2.25	V
Undervoltage Lockout Hysteresis	V_{UVLO_H}		0.02	0.1	0.25	V
Shutdown Current	I_{SHDN}	V_{IN} = 3.5V, EN = L	--	--	1	µA
Non-Switching Quiescent Current	I_{Q_NSW}	Non-switching. V_{IN} = 4.2V, V_{OUT} = 3.5V, EN = V_{IN}, Mode = V_{IN}	2	5	8	µA
Switching Quiescent Current	I_{Q_SW}	I_{LOAD} = 0A. V_{IN} = 4.2V, V_{OUT} = 3.5V, EN = V_{IN}, Mode = V_{IN}	5	8	11	µA
Switching Frequency	f_{SW}	MODE = H, $\|V_{IN} - V_{OUT}\| > 1V$	1	2	2.6	MHz
PWM Frequency	f_{PWM}	MODE = L	1.3	2	2.8	MHz
Synchronous Switching Frequency Range	f_{SWSYNC}	MODE = square wave, 10% < duty < 90%	2.2	--	2.6	MHz
Soft-Start Time	t_{SS_EN}	Time from EN goes H to 90% VOUT starts ramp up	0.3	1	2	ms
	t_{SS}	V_{IN} = 4V, V_{OUT} = 3.5V, I_{LOAD} = 200mA	0.3	1	2	
	t_{SS}	V_{IN} = 2.5V, V_{OUT} = 3.5V, I_{LOAD} = 200mA	0.6	2	4	
Minimum Off-Time	t_{OFF_MIN}		15	40	65	ns
Minimum On-Time	t_{ON_MIN}		25	40	80	ns
Feedback Voltage		CCM operation	0.792	0.8	0.808	V
On-Resistance of High-Side MOSFET	R_{DSON_H}	V_{OUT} = 5V	12	20	30	mΩ
On-Resistance of Low-Side MOSFET	R_{DSON_L}	V_{OUT} = 5V	12	20	30	mΩ
Output Overvoltage Rising Threshold	V_{OVP_R}		5.3	5.6	5.9	V
Load Current Threshold, PFM to PWM	I_{TH_PWM}	V_{IN} = 3.6V, V_{OUT} = 3.3V	--	200	--	mA
Load Current Threshold, PWM to PFM	I_{TH_PFM}	V_{IN} = 3.6V, V_{OUT} = 3.3V	--	200	--	mA
FAULT Time	t_{FAULT}		15	40	70	ms
Over-Temperature Protection Threshold	T_{OTP}	(Note 6)	--	160	--	°C

Parameters	Symbol	Test Conditions	Min	Typ	Max	Unit
Over-Temperature Protection Hysteresis	T_{OTP_HYS}	(Note 6)	--	20	--	°C
Current Limit	I_{LIM}		4.3	4.5	5	A
Line Regulation	V_{LINE_REG}	V_{IN} = 2.5V to 5V, V_{OUT} = 3.5V, CCM, I_{LOAD} = 1.5A	–2	0.6	2	%
Load Regulation	V_{LOAD_REG}	V_{IN} = 2.5V to 5V, V_{OUT} = 3.5V, CCM operation, I_{LOAD} < 2A	–2	0.6	2	%
Line Transient	V_{LINE_TR}	V_{IN} = 3V to 3.6V at 10μs, V_{OUT} = 3.5V, I_{LOAD} = 1A	--	100	200	mV
Load Transient	V_{LOAD_TR}	V_{IN} = 3.4V, V_{OUT} = 3.5V, I_{LOAD} =0.5A to 1A at 1μs	--	250	400	mV

Note 6. T_{OTP} and T_{OTP_HYS} are guaranteed by design.

13 Typical Application Circuit



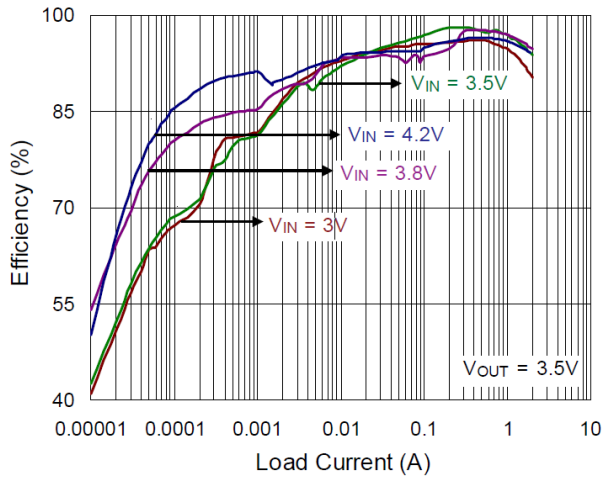
Recommended Components Information

Reference	Part Number	Description	Package	Manufacturer
C_{IN}	GRJ155R60J106ME11D	10µF/6.3V/X5R	0402	MuRata
C_{OUT}	GRJ155R60J106ME11D	10µF/6.3V/X5R	0402	MuRata
C_{FF}	GRM0335C1H560JA01D	56pF/50V/NPO	0201	MuRata
L1	DFE322520F-1R0M=P2	1µH, ±20%	3.2x2.5x2mm	MuRata

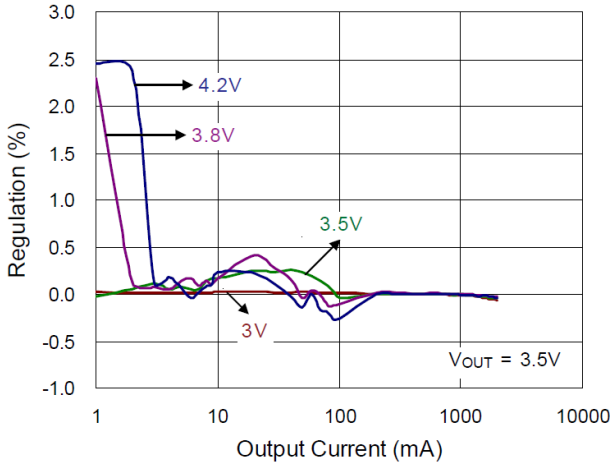
R1	C_{FF}	Application Condition
100kΩ	560pF to 680pF	Load Transient Performance for Wi-Fi application requirement (load condition 50mA to 450mA with slew rate 400mA/µs) Load = 0A to 2A, the system stability
	56pF to 680pF	Load = 0A to 2A, the system stability

14 Typical Operation Characteristics

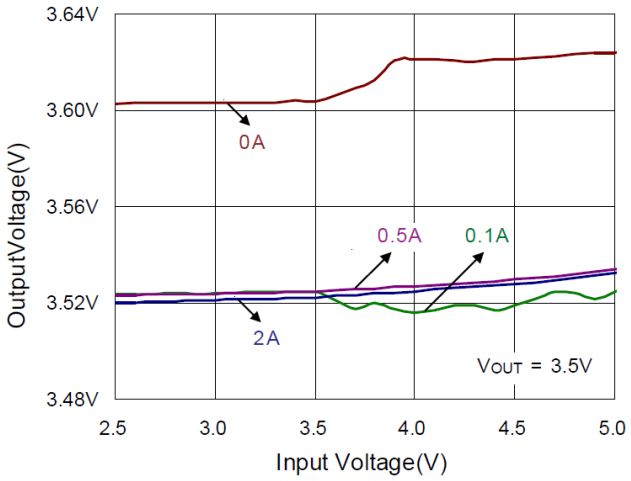
Efficiency



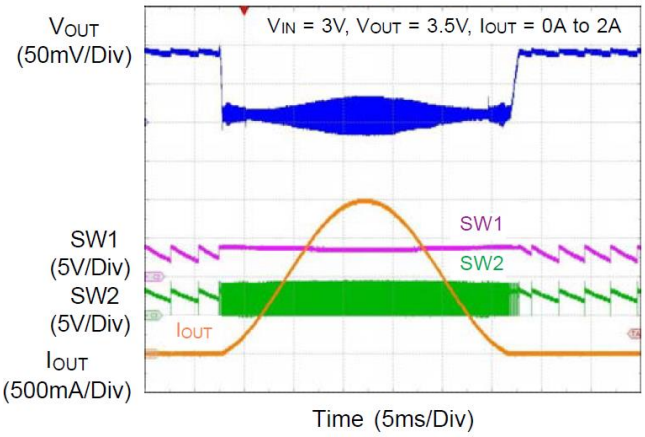
Load Regulation



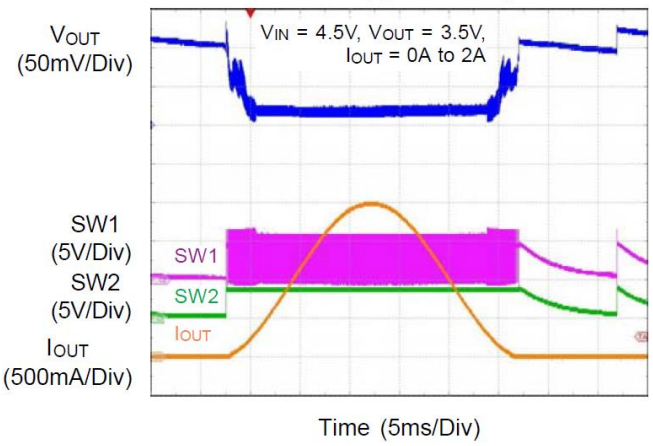
Line Regulation



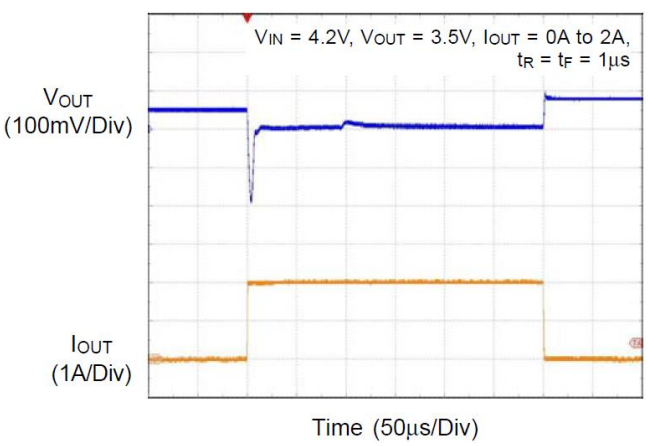
VOUT Ripple Voltage



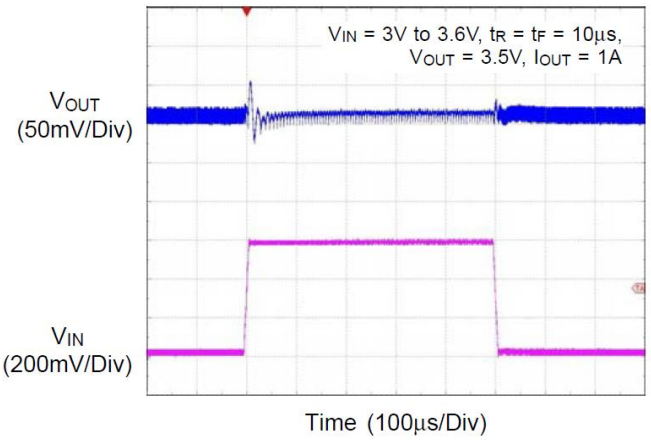
VOUT Ripple Voltage



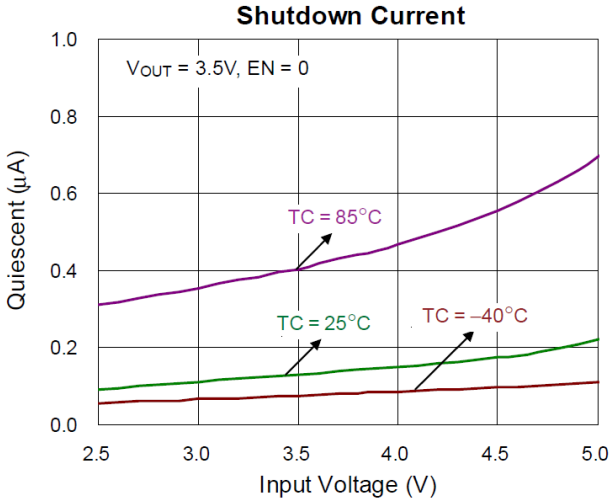
Load Transient



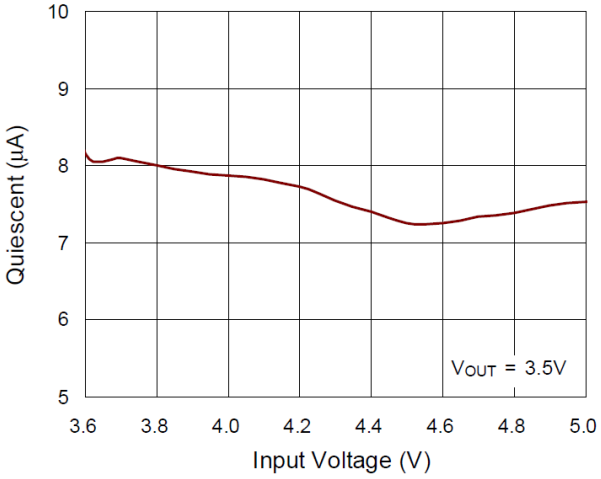
Line Transient



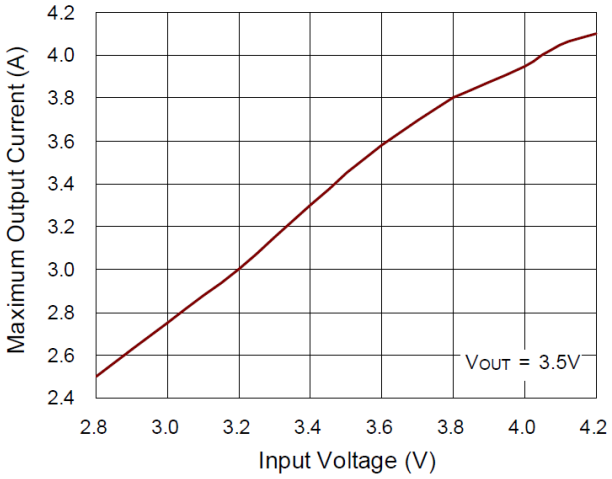
Shutdown Current



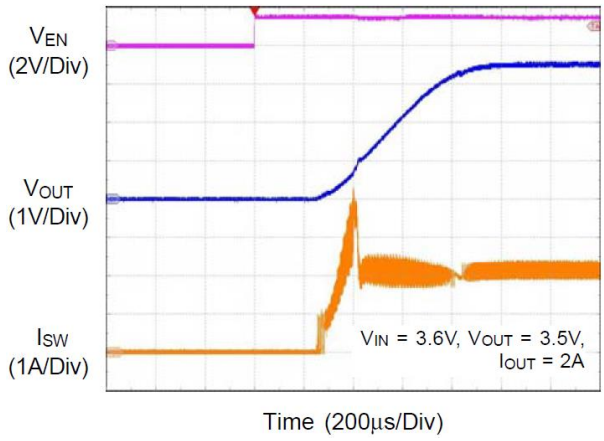
Switching Quiescent Current



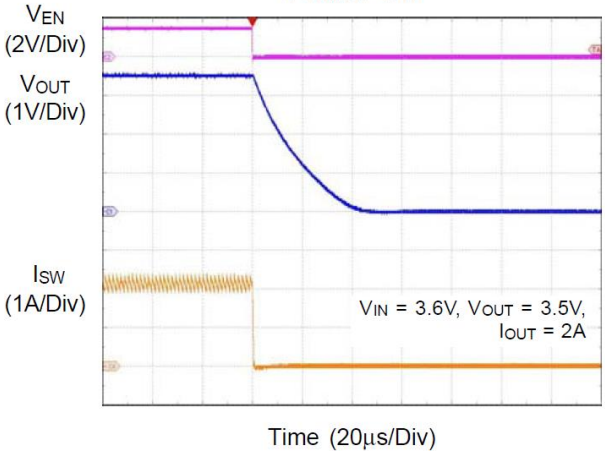
Maximum Output Current vs. Input Voltage



Power On



Power Off



15 Operation

The RT6158A is a synchronous current-mode constant on/off-time (CMCOT) switching buck-boost converter designed for an adjustable output voltage with an input supply that can be above, equal to, or below the output voltage. The inductor current is regulated by a fast current regulator controlled by a voltage control loop. The voltage error amplifier receives its feedback input from the FB pin. The output voltage of the RT6158A is adjustable and can be set by an external divided resistor. When VIN is greater than VOUT, the device operates in Buck mode. When VIN is lower than VOUT, the device operates in Boost mode. When VIN is close to VOUT, the RT6158A automatically enters Buck or Boost mode. In that case, the converter will maintain the regulation for output voltage and keep a minimum current ripple in the inductor to guarantee good performance.

16 Application Information

(Note 7)

The RT6158A buck-boost converter can operate with a wide input voltage range, suitable for batteries with voltages higher or lower than the output voltage, and it can supply the load current up to 2A. The maximum peak current in the switches is limited to a typical value of 4.5A. The typical operating input voltage range is from 2.5V and 5V. The RT6158A output voltage can be set from 2.1V to 5.2V by changing the external divided resistor on the FB pin. The converter's feedback loop is internally compensated for both buck and boost operation, providing seamless transition between Buck and Boost modes.

16.1 Enable

The device can be enabled or disabled by the EN pin. When the EN pin is set higher than the logic-high threshold, the device starts operation with a soft-start. Once the EN pin is set to low, the device will shut down. In shutdown mode, the converter stops switching, the internal control circuitry is turned off, and the chip enters a low quiescent state to minimize power consumption. The EN pin must not be left floating and must be terminated.

16.2 Output Voltage Setting

The RT6158A output voltage can be set from 2.1V to 5.2V by changing the external divided resistor on the FB pin. The resistor divider must be connected between VOUT, FB, and GND. The typical voltage value at the FB pin is 800mV. To decrease the leakage current on the FB pin, it is recommended to use high-value resistors. For example, R1 = 1MΩ and R2 = 294kΩ for VOUT = 3.5V application. The value of the resistors can be derived from the following equation:

$$R1 = R2 \times \left(\frac{V_{OUT}}{V_{FB}} - 1 \right)$$

16.3 Dynamic Voltage Scaling Control

The RT6158A output voltage is adjustable via an external resistor divider. If the application requires switching between multiple output voltages (dynamic voltage scaling, DVS) while the device is enabled (EN = High), the highest required output voltage must be selected as the initial setting at start-up.

For example:

V_{OUT1} = 3.3V, V_{OUT2} = 5V, V_{OUT3} = 3.8V

At start-up, select V_{OUT2} (5.0 V) as the initial setting. After regulation is established, you may switch to V_{OUT1} or V_{OUT3} as needed.

16.4 MODE States and Synchronization

The MODE pin can be used to select different operation modes. When MODE is set to high, the RT6158A will operate at PFM mode to improve efficiency. At this point, the converter reduces switching frequency and quiescent current for high efficiency. When the load increases, the device will automatically switch to PWM mode. The PFM mode can be disabled by setting the MODE pin low. Connecting a clock signal to the MODE pin can force the RT6158A switching frequency to synchronize with the connected clock frequency. The MODE pin input supports standard logic thresholds, and the frequency range is between 2.2MHz to 2.6MHz. The MODE pin must not be left floating and must be terminated.

16.5 Undervoltage-Lockout

The undervoltage-lockout circuit prevents the device from operating incorrectly at low input voltages. It ensures that the converter does not turn on the power switches under undefined conditions and protects the battery from deep discharge. The converter is enabled only when the VIN voltage exceeds 2.15V. During operation, if the VIN voltage drops below 2.05V, the converter is disabled until the supply voltage rises above the UVLO threshold. The RT6158A automatically restarts when the input voltage recovers to the UVLO high level.

Protection Type	Threshold Refer to Electrical Spec.	Protection Method	Shut Down Delay Time	Reset Method
OCP	I_L > 4.5A	Turn on B, D MOS	CL will trigger right away.	I_L < 4.5A
UVLO	V_{IN} < 2.05V	Shutdown	100μs	V_{IN} > 2.15V
OTP	TEMP > 160°C	Shutdown	No delay	OTP Hysteresis = 20°C
Output OVP	V_{OUT} > 5.6V	Stop switching	No delay	V_{OUT} < 5.3V
SCP	V_{OUT} < 1.2V	f_{SW} become 1/4	No delay	After FAULT 40ms

16.6 Short-Circuit Protection

When the output is shorted to ground, the inductor current decays very slowly during a single switching cycle. A current runaway detector monitors the inductor current. If the current increases beyond the control of the current loop, switching cycles are skipped to prevent current runaway form occurring.

16.7 Over-Temperature Protection

The device features a built-in temperature sensor which monitors the internal junction temperature. If the temperature exceeds the OTP threshold, the device stops operating and enters shutdown mode. Once the IC temperature drops below the threshold, with hysteresis, normal operating resumes.

16.8 Overvoltage Protection

When the VOUT pin is floating, the device triggers the overvoltage protection to prevent the output voltage from exceeding critical values. If the output reaches the OVP threshold, the device regulates the output voltage to this value.

16.9 Inductor Selection

A power inductor with a nominal value of1μH and a saturation current rating of at least 4.5A is recommended. For optimal performance and efficiency, select an inductor with low DC resistance (DCR). Using a low-DCR inductor minimizes power losses and improves overall system efficiency.

16.10 Input and Output Capacitor Selection

For optimal performance, both input and output capacitors should be ceramic X5R type with low ESL and ESR. The recommended value is two 10μF capacitors for the input, and four 10μF capacitors for the output.

The selection of output capacitors determines the output voltage ripple and transient response. It is recommended to place ceramic capacitors as close as possible to the VOUT and GND pins of the IC. If large-value capacitors are required and cannot be placed near the IC, a small ceramic capacitor should be connected in parallel and positioned as close as possible to the VOUT and GND pins to ensure effective high-frequency filtering.

When the RT6158A operates in Buck mode, the worst-case voltage ripple occurs at the highest input voltage. In Boost mode, the worst-case voltage ripple occurs at the lowest input voltage. The output capacitor value should be selected to meet or exceed the calculated minimum required for control loop stability. There are no specific minimum ESR requirements; however, low ESR capacitors are preferred to minimize output voltage ripple. Larger capacitors will further reduce output voltage ripple and improve transient response by minimizing voltage drops during load changes.

16.11 Thermal Considerations

The junction temperature should never exceed the absolute maximum junction temperature $T_{J(MAX)}$, listed under Absolute Maximum Ratings, to avoid permanent damage to the device. The maximum allowable power dissipation depends on the thermal resistance of the IC package, the PCB layout, the rate of surrounding airflow, and the difference between the junction and ambient temperatures. The maximum power dissipation can be calculated using the following formula:

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

where $T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance.

For continuous operation, the maximum operating junction temperature indicated under Recommended Operating Conditions is 125°C. The junction-to-ambient thermal resistance, θ_{JA}, is highly package dependent. For a WL-CSP-25B 2.07x2.33 (BSC) package, the thermal resistance, θ_{JA}, is 35.7°C/W on a standard JEDEC 51-7 high effective-thermal-conductivity four-layer test board. The maximum power dissipation at T_A = 25°C can be calculated as below:

$P_{D(MAX)} = (125°C - 25°C) / (35.7°C/W) = 2.8W$ for a WL-CSP-25B 2.07x2.33 (BSC) package

The maximum power dissipation depends on the operating ambient temperature for the fixed $T_{J(MAX)}$ and the thermal resistance, θ_{JA}. The derating curve in Figure 1 allows the user to see the effect of rising ambient temperature on the maximum power dissipation.

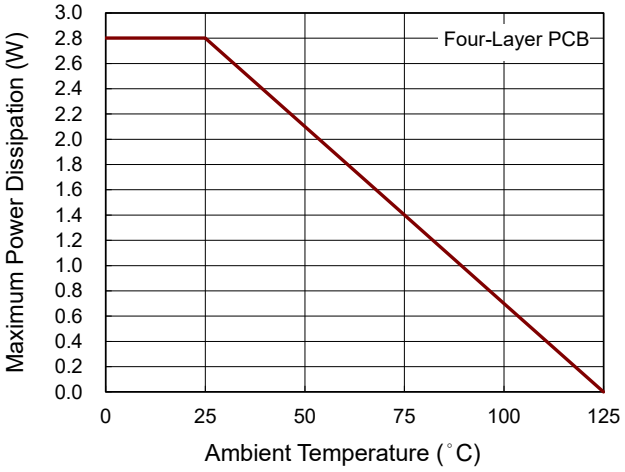


Figure 1. Derating Curve of Maximum Power Dissipation

16.12 Layout Considerations

The following are PCB layout guidelines for optimal performance of the RT6158A. The figure below illustrates real PCB layout considerations based on actual component sizes in millimeters (mm).

- The input capacitor should be placed as close as possible to the PVIN pin for effective filtering.
- The high current path should be as short and wide as possible.
- The inductor should be placed as close as possible to the SW1 and SW2 pins to reduce electromagnetic interference (EMI).
- The output capacitor should be placed as close as possible to the PGND pin to reduce noise coupling.

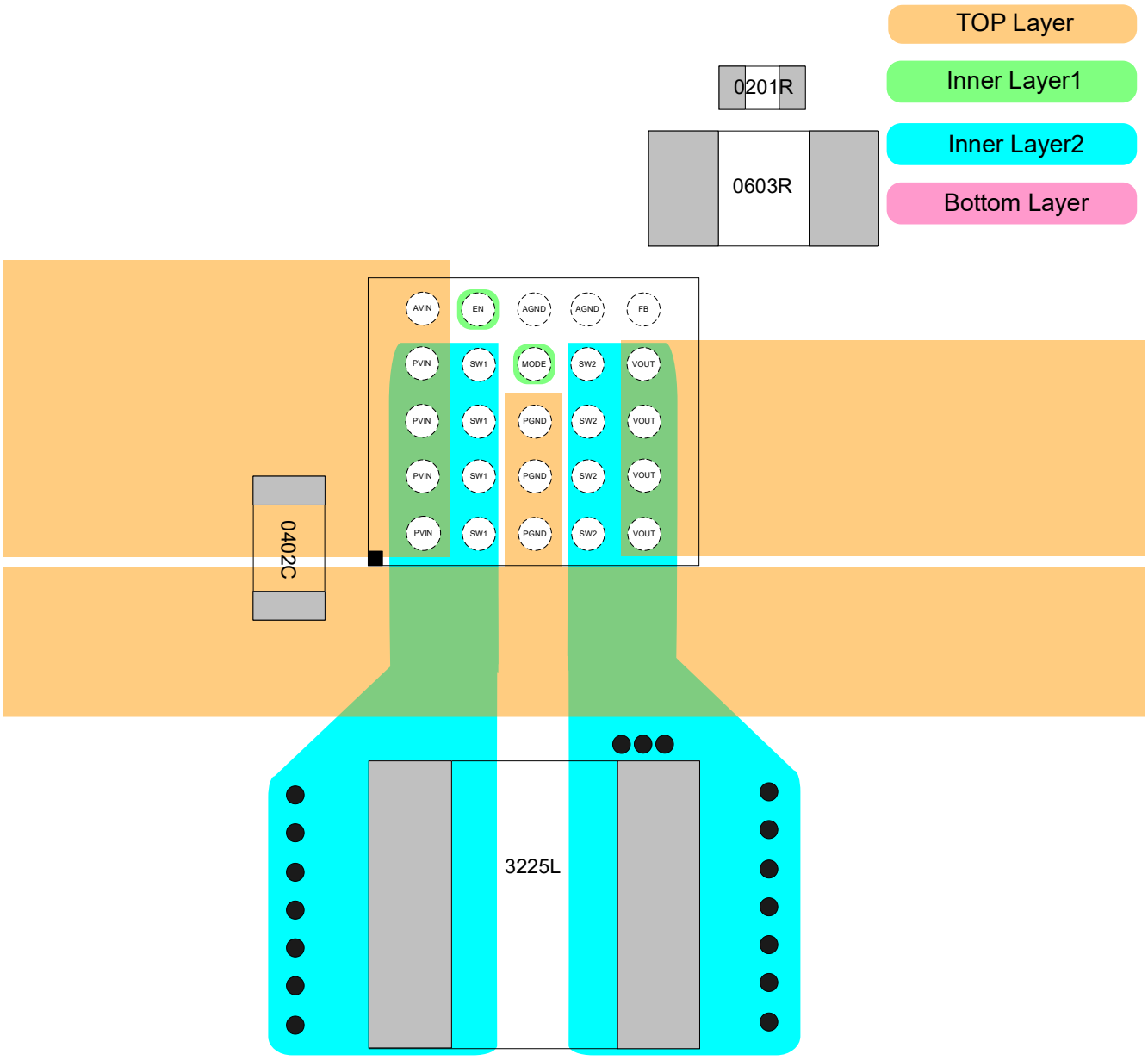
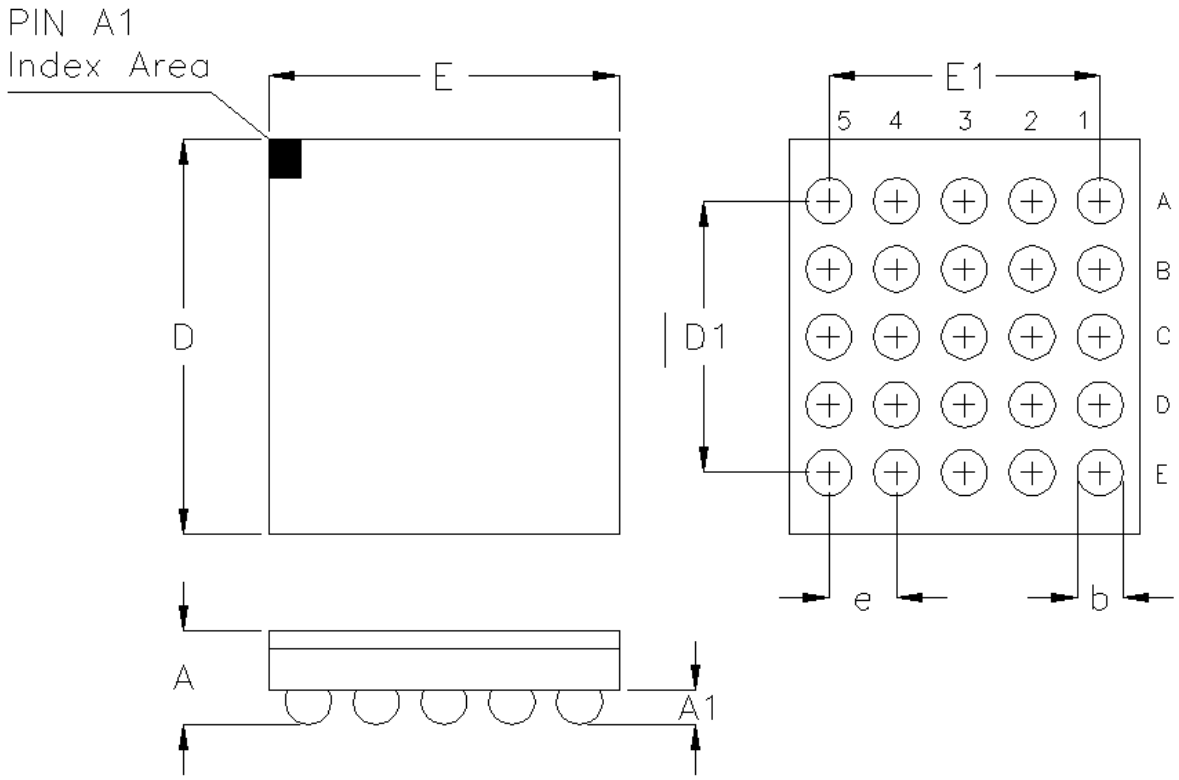


Figure 2. PCB Layout Guide

Note 7. The information provided in this section is for reference only. The customer is solely responsible for designing, validating, and testing any applications incorporating Richtek's product(s). The customer is also responsible for applicable standards and any safety, security, or other requirements.

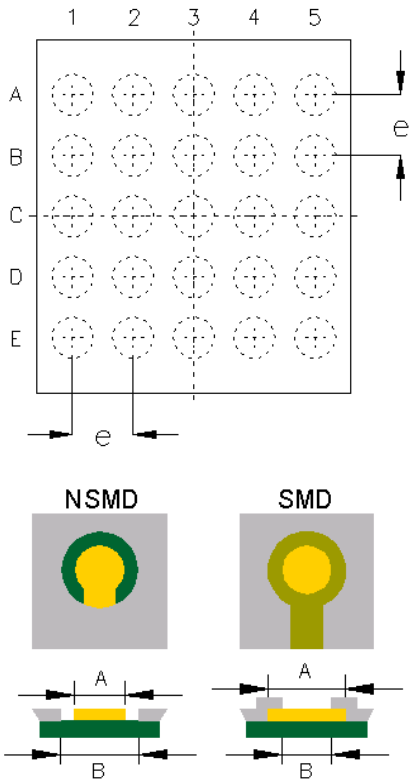
17 Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.500	0.600	0.020	0.024
A1	0.170	0.230	0.007	0.009
b	0.240	0.300	0.009	0.012
D	2.280	2.380	0.090	0.094
D1	1.600		0.063	
E	2.020	2.120	0.080	0.083
E1	1.600		0.063	
e	0.400		0.016	

25B WL-CSP 2.07x2.33 Package (BSC)

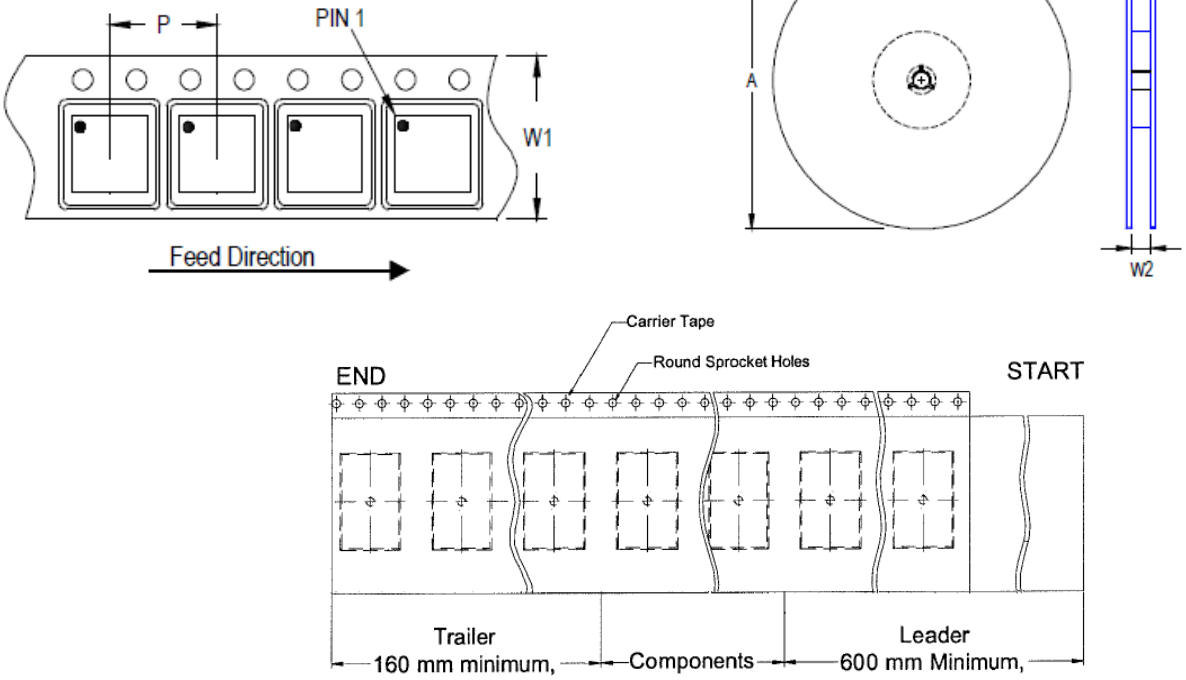
18 Footprint Information



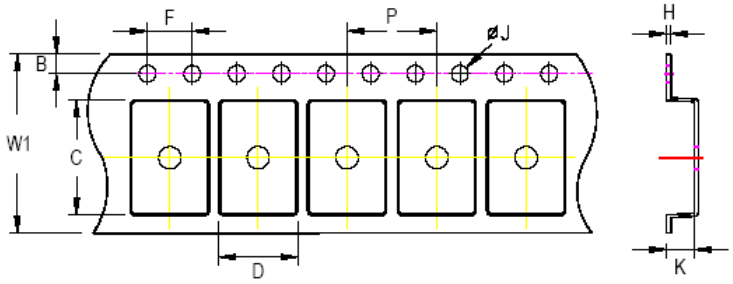
Package	Number of Pin	Type	Footprint Dimension (mm)			Tolerance
			e	A	B	
WL-CSP2.07*2.33-25(BSC)	25	NSMD	0.400	0.240	0.340	±0.025
		SMD		0.270	0.240	

19 Packing Information

19.1 Tape and Reel Data



Package Type	Tape Size (W1) (mm)	Pocket Pitch (P) (mm)	Reel Size (A)		Units per Reel	Trailer (mm)	Leader (mm)	Reel Width (W2) Min/Max (mm)
			(mm)	(in)				
WL-CSP 2.07x2.33	8	4	180	7	3,000	160	600	WL-CSP 2.07x2.33



C, D, and K are determined by component size. The clearance between the components and the cavity is as follows:

- For 8mm carrier tape: 0.5mm maximum

Tape Size	W1	P		B		F		ØJ		K		H
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Max
8mm	8.3mm	3.9mm	4.1mm	1.65mm	1.85mm	3.9mm	4.1mm	1.5mm	1.6mm	0.64mm	0.74mm	0.6mm

19.2 Tape and Reel Packing

Step	Photo/Description	Step	Photo/Description
1	 Reel 7”	4	 12 inner boxes per outer box
2	 Packing by Anti-Static Bag	5	 Outer box **Carton A**
3	 3 reels per inner box **Box A**	6	

Container / Package	Reel		Box			Carton		
	Size	Units	Item	Reels	Units	Item	Boxes	Unit
WL-CSP 2.07x2.33	7”	3,000	Box A	3	9,000	Carton A	12	108,000
			Box E	1	3,000	For Combined or Partial Reel.		

19.3 Packing Material Anti-ESD Property

Surface Resistance	Aluminum Bag	Reel	Cover tape	Carrier tape	Tube	Protection Band
Ω/cm^2	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**	**10^4 to 10^{11}**

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20 Datasheet Revision History

Version	Date	Description
07	2026/4/30	Simplified Application Circuit Pin Configuration Functional Pin Description Function Block Diagram Absolute Maximum Ratings Typical Operation Characteristics Layout Considerations - Renamed LX with SW Recommended Operating Conditions Electrical Characteristics - Modified Symbol naming Operation Application Information - Modified descriptions Figure 2. PCB Layout Guide - Updated