THE DATASHEET OF

RT8809BZQW

Multi-Phase PWM Controller for GPU Core Power Supply

General Description

The RT8809A/B is a dual-phase synchronous buck PWM controller with integrated drivers which are optimized for high performance graphic microprocessor and computer applications. The IC integrates a G-NAVP™ PWM controller, two 12V MOSFET drivers with internal bootstrap diodes, as well as output current monitoring and protection functions into the WQFN-24L 4x4 package. The RT8809A/B adopts DCR and $R_{DS(ON)}$ current sensing. Load line voltage positioning (droop) and over current protection are accomplished through continuous inductor DCR current sensing, while $R_{DS(ON)}$ current sensing is used for accurate channel current balance. Using both methods of current sampling utilizes the best advantages of each technique. The RT8809A/B also features a one-bit VID control operation in which the feedback voltage is regulated and tracks external input reference voltage. Other features include, adjustable operating frequency, external compensation, and enable/shutdown functions.

Applications

- Middle to High End GPU Core Power
- High End Desktop PC Memory Core Power
- Low Voltage, High Current DC/DC Converter
- Voltage Regulator Modules

Ordering Information

RT8809A/B □□

- Package Type
  QW : WQFN-24L 4x4 (W-Type)
- Lead Plating System
  G : Green (Halogen Free and Pb Free)
  Z : ECO (Ecological Element with Halogen Free and Pb free)
- A : With Droop Function
  B : Without Droop Function

Note :

Richtek products are :

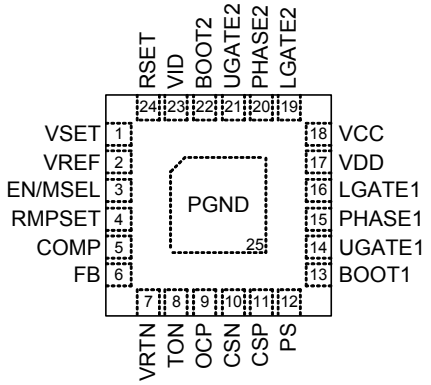
- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Features

- **Dual-Phase PWM Controller**
- **Two Embedded MOSFET Drivers and Embedded Switching Boot Diode**
- **Green-NAVP™ (Green Native Adaptive Voltage Positioning) Topology**
- **Dynamic Auto Phase Control with Programmable Threshold**
- **Cross-talk Jitter Suspend (CJS™)**
- **Remote GND Detection for High Accuracy**
- **Automatic Diode Emulation Mode/Or Ultrasonic Mode at Light Load**
- **Lossless $R_{DS(ON)}$ Current Sensing for Current Balance**
- **Lossless DCR Current Sensing for AVP & OCP**
- **Reference Voltage Output with 1% Accuracy**
- **External Reference Input with Soft-Start (RISS)**
- **Embedded One-Bit VID Control**
- **Programmable OCP Threshold**
- **Programmable Switching Frequency**
- **Reference Tracking UVP/OVP Protection**
- **Shoot Through Protection and Short Pulse Free Technology**
- **RoHS Compliant and Halogen Free**

Pin Configurations

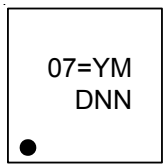
(TOP VIEW)



WQFN-24L 4x4

Marking Information

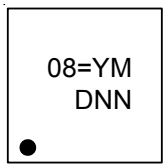
RT8809AGQW



07= : Product Code

YMDNN : Date Code

RT8809BGQW



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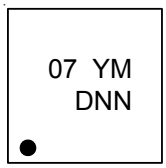
RT8809AZQW



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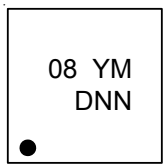

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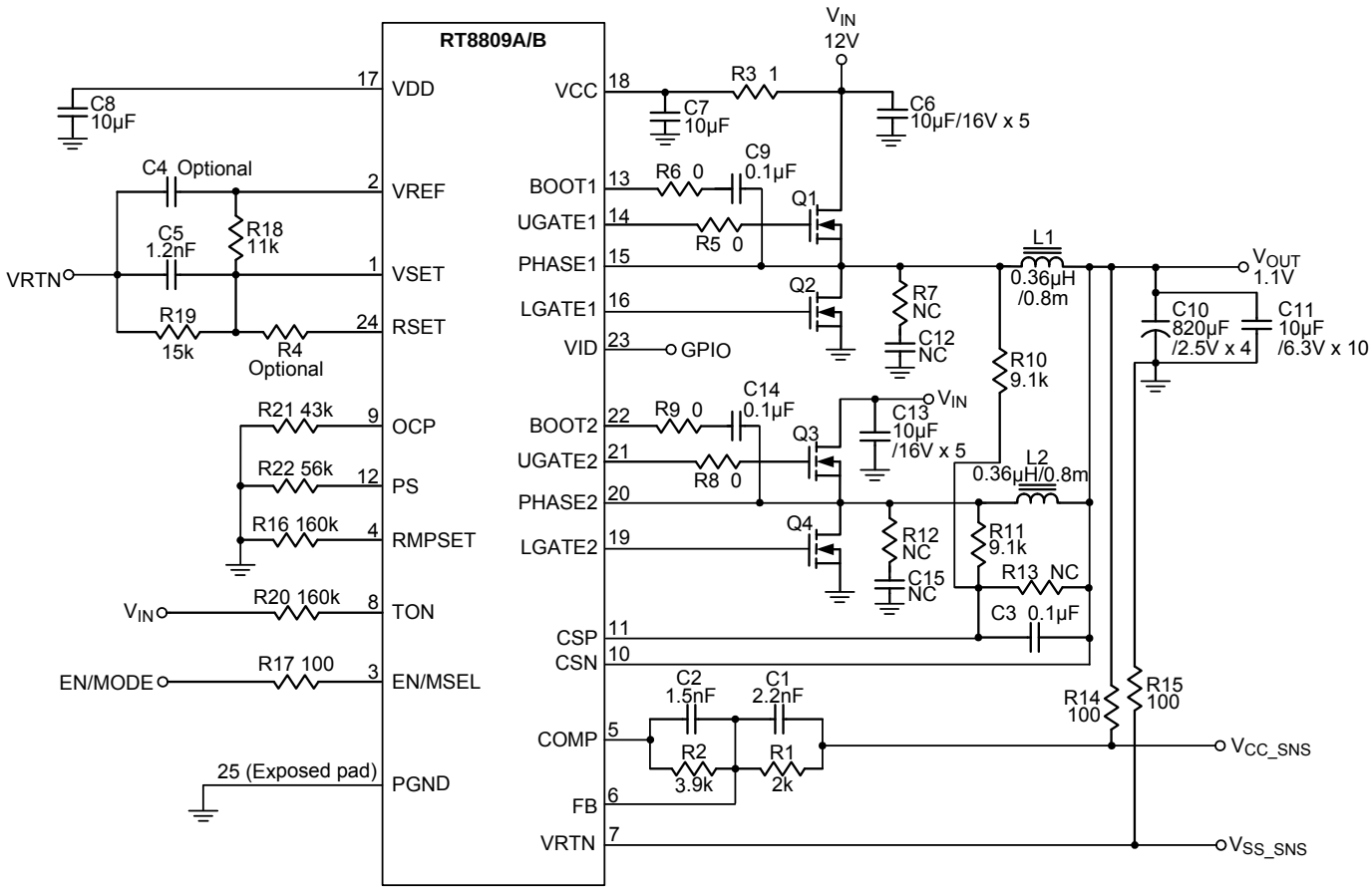
Typical Application Circuit

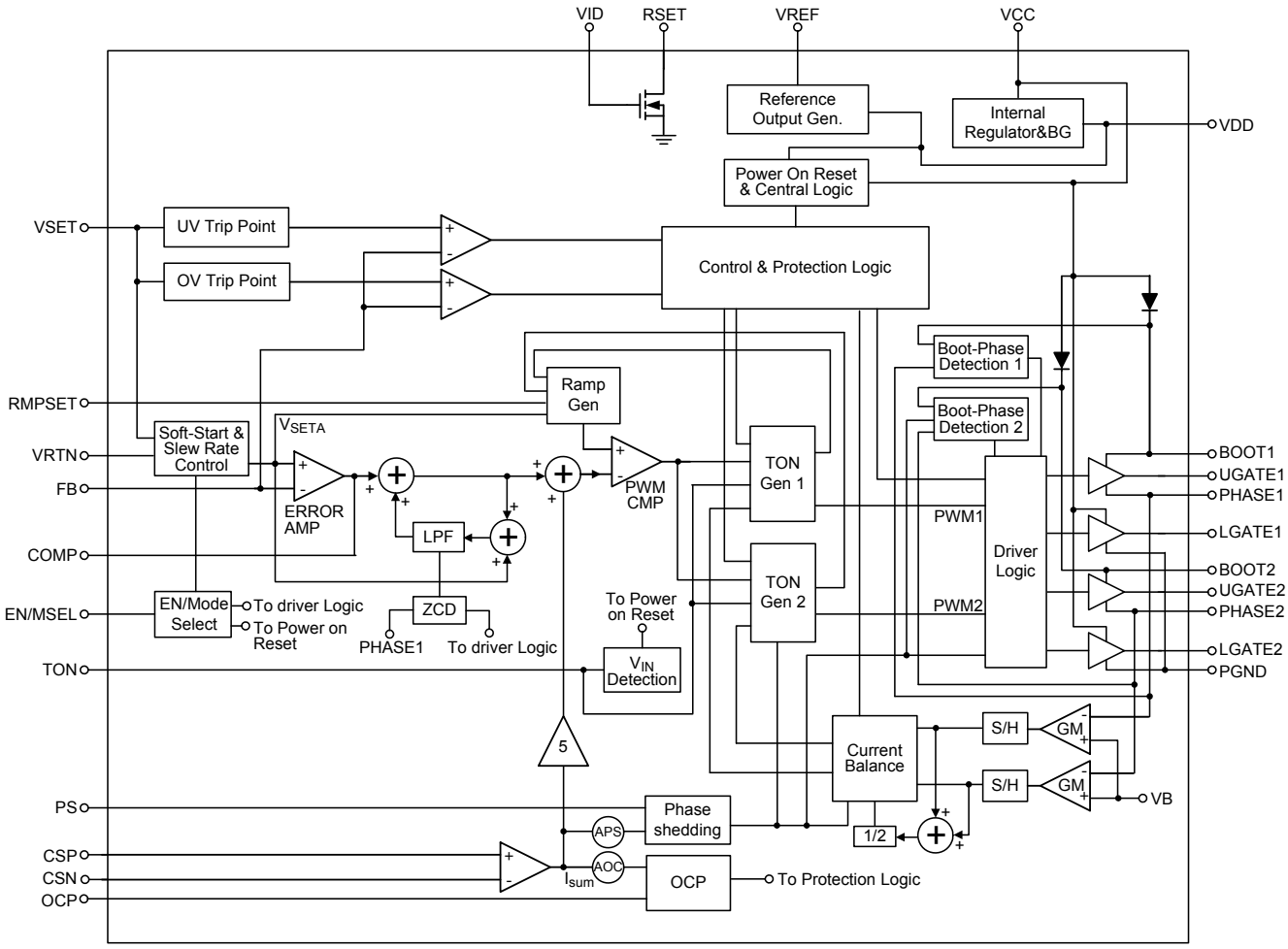


Functional Pin Description

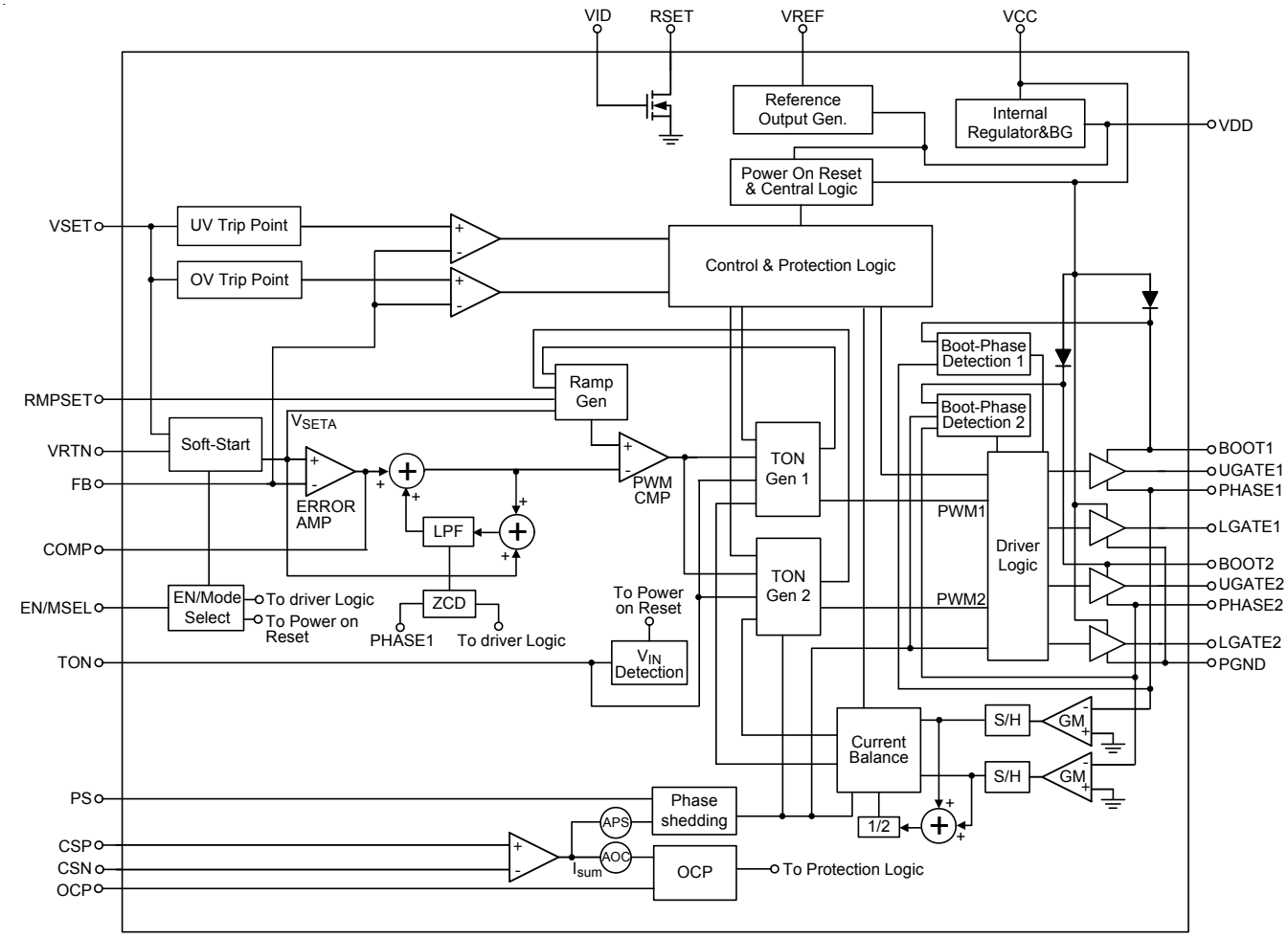
Pin No.	Pin Name	Pin Function
1	VSET	Output Voltage Setting. Connect a voltage divider from VREF to VSET to set the output voltage.
2	VREF	Reference Voltage Output (2V). RT8809A/B generates a 2V reference voltage from VREF pin to VRTN.
3	EN/MSEL	Chip Enable and Mode Selection. This pin is a tri-state input. Pull up this pin to exceed than 4.2V, controller operation into DEM mode. Pull up this pin to between 1.2V to 3V, controller operation into ASM mode. Pull down this pin to GND, controller will shutdown.
4	RMPSET	Internal Ramp Slew Rate Setting. Connect a resistor (R_{RMP}) from RMPSET to GND to the ramp slew rate. The value of R_{RMP} must be set equal to R_{TON}.
5	COMP	Compensation Pin. This pin is the output node of the error amplifier.
6	FB	Feedback Pin. This pin is the negative input node of the error amplifier.
7	VRTN	Remote Differential Feedback, Invert Input. This pin is the negative node of the differential remote voltage sensing.
8	TON	On Time (Switching Frequency) Setting. Connect a resistor (R_{TON}) from TON to VIN to set the switching frequency. The value of R_{TON} must be set equal to R_{RMP}.
9	OCP	OCP Level Setting. Connect a resistor from OCP to GND to set the current limit threshold.
10	CSN	This pin is negative input of current sensing.
11	CSP	This pin is positive input of current sensing.
12	PS	Dynamic Phase Control Input. Connect a resistor from PS to GND to set the auto down phase threshold.
13	BOOT1	Bootstrap Power Pin of PHASE1. This pin powers the high side MOSFET driver.
14	UGATE1	Upper Gate Driver of PHASE1. This pin provides the gate drive for the converter's high side MOSFET. Connect this pin to the high side MOSFET gate.
15	PHASE1	This pin is return node of the high side driver of PHASE1. Connect this pin to high side MOSFET sources together with the low side MOSFET drain and the inductor.
16	LGATE1	Lower Gate Driver of PHASE1. This pin provides the gate drive for the converter's low side MOSFET. Connect this pin to the low side MOSFET gate.
17	VDD	Internal Regulator Power. The regulated voltage provides power supply for all low voltage circuits.
18	VCC	Chip/Driver Power Pin. Connect this pin to GND by a ceramic cap larger than 1μF.
19	LGATE2	Lower Gate Driver of PHASE2. This pin provides the gate drive for the converter's low side MOSFET. Connect this pin to the low side MOSFET gate.
20	PHASE2	This pin is return node of the high side driver of PHASE2. Connect this pin to high side MOSFET sources together with the low side MOSFET drain and the inductor.
21	UGATE2	Upper Gate Driver of PHASE2. This pin provides the gate drive for the converter's high side MOSFET. Connect this pin to the high side MOSFET gate.
22	BOOT2	Bootstrap Power Pin of PHASE2. This pin powers the high side MOSFET driver.
23	VID	Programming Output Voltage Control. When VID pin is logic high, internal N-MOSFET that connected to RSET pin is turn on.
24	RSET	Output Voltage Setting. Connect a resistor from RSET pin to VSET pin, the output voltage can be switched two level by driving VID pin.
25 (Exposed Pad)	PGND	The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.

Function Block Diagram

RT8809A (With Droop Function)



RT8809B (Without Droop Function)



Absolute Maximum Ratings (Note 1)

- VDD, VSEN, COMP, VSET, VREF, EN/MSEL, PS, OCP, CSN, CSP, RSET, VID, RMPSET to PGND ---------- –0.3V to 6V
- VCC, TON to PGND ---------- –0.3V to 15V
- VRTN to PGND ---------- –0.3V to 0.3V
- BOOTx to PHASEx ---------- –0.3V to 15V
- PHASEx to PGND
  - DC ---------- –3V to 15V
  - <20ns ---------- –5V to 30V
- UGATEx to PHASEx
  - DC ---------- –0.3V to BOOTx – PHASEx
  - <20ns ---------- –5V to (BOOTx – PHASEx + 5V)
- LGATEx to PGND
  - DC ---------- –0.3V to PVCC+ 0.3V
  - <20ns ---------- –5V to (VCC + 5V)
- Power Dissipation, P_D @ T_A = 25°C
  - WQFN-24L 4x4 ---------- 1.923W
- Package Thermal Resistance (Note 2)
  - WQFN-24L 4x4, θ_{JA} ---------- 52°C/W
  - WQFN-24L 4x4, θ_{JC} ---------- 7°C/W
- Junction Temperature ---------- 150°C
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  - HBM (Human Body Mode) ---------- 2kV
  - MM (Machine Mode) ---------- 200V

Recommended Operating Conditions (Note 4)

- Supply Voltage, V_{CC} ---------- 4.5V to 13.2V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{CC} = 12V, No Load, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Supply Input						
Supply Current	I_{VCC} + I_{PVCC}	EN = 3.3V, Not Switching	--	4	--	mA
Shutdown Current	I_{CC} + I_{PVCC}	EN = 0V	--	--	500	μA
Power On Reset						
VCC POR Threshold	V_{VCC_th}	VCC Rising	--	4.2	--	V
Power On Reset Hysteresis	V_{VCC_hys}		--	0.4	--	V
Reference						
Reference Output	V_{REF}	(No Load, Active Mode)	--	2	--	V
		Accuracy	–1%	--	1%	
Reference Input Range	V_{SET}	VSET pin (this max. voltage will affect V_{COMP} max.)	0.5	--	2	V
Start Up Delay						
Initial Soft-Start time	t_b	Initially, V_{OUT} = 0.1V to 1.2V	--	1.5	--	ms
Reference Change Delay Time	t_c		--	300	--	μs
Internal VID Change Slew Rate (RT8809A Only)	t_d	V_{OUT} = 1.2V to Set Voltage	--	10	--	mV/μs
Error Amplifier						
Input Offset Voltage	V_{OSEA}		–8	--	8	mV
DC Gain		R_L = 47kΩ	--	80	--	dB
Gain Bandwidth Product	GBW	C_{LOAD} = 5pF	--	10	--	MHz
Slew Rate	SR	C_{LOAD} = 10pF (Gain = –4, R_f = 47k, V_{OUT} = 0.5V to 3V)	--	5	--	V/μs
Output Voltage Range	V_{COMP}	R_L = 47kΩ (max. depend on VSET max.)	0.5	--	2	V
MAX Source Current	I_{OUTEA}	V_{COMP} = 2V	--	250	--	μA
Current Sense Amplifier (for Droop and OCP and Phase Shedding)						
Input Offset Voltage	V_{OSCS}		–1	--	1	mV
Impedance at Neg. Input	R_{CSN}		1	--	--	MΩ
Impedance at Pos Input	R_{CSP}		1	--	--	MΩ
DC Gain RT8809A			--	5	--	V/V
DC Gain RT8809B			--	0	--	
Input range	$V_{CSP} - V_{CSN}$		–50	--	100	mV
TON Setting						
TON Pin Output Voltage	V_{TON}	I_{RTON} = 62μA	--	VSET	--	V
ON-Time Setting	T_{ON}	I_{RTON} = 62μA	--	350	--	ns
TON Input Current Range	I_{RTON}		25	--	280	μA
Protection						
Under Voltage Lockout Threshold	V_{UVLO}	Falling edge	--	3.8	--	V

Parameter		Symbol	Test Conditions	Min	Typ	Max	Unit
Absolute Over Voltage Protection Threshold	RT8809A/BGQW	V_{OVABS}	With Respect to $V_{OUT(MAX)}$	2.1	2.2	--	V
	RT8809A/BZQW			2.6	2.9	--	
Relative Over Voltage Protection Threshold		V_{REL_OV}	With Respect to V_{OUT}	--	138	--	%
Under Voltage Protection Threshold		V_{UV}	Measured at VSENS with Respect to Unloaded Output Voltage (UOV)	--	50%	--	%
Negative Voltage Protection Threshold		V_{NV}		–50	--	--	mV
Current Source by OCP Pin		I_{OCP}		7.2	8	8.8	μA
Logic Inputs							
EN Threshold Voltage		V_{IL}	Low Level (SD) (Hysteresis)	--	--	0.5	V
EN Pin Mode Select Voltage			ASM Mode	1.2	--	3	V
			DEM Mode	4.2	--	--	
Leakage Current of EN				–1	--	5	μA
Auto Phase Control							
Current Source by PSI Pin		I_{PS}		--	8	--	μA
Maximum Duty Cycle							
UGATE Min. Off Time				--	500	--	ns
Gate Driver							
Upper Driver Source		$I_{UGATEsr}$	$V_{BOOTx} - V_{PHASEx}$ = 6V	--	1.2	--	A
Upper Driver Sink		$R_{UGATEsk}$	$V_{UGATEx} - V_{PHASEx}$ = 0.1V, I_{UGATEx} = 50Ma	--	2	--	Ω
Lower Driver Source		$I_{LGATEsr}$	$V_{CC} - V_{LGATEx}$ = 6V	--	1.2	--	A
Lower Driver Sink		$R_{LGATEsk}$	V_{LGATEx} = 0.1V, I_{LGATEx} = 50mA	--	1.4	--	Ω
Internal Boost Charging Switch On-Resistance		R_{BOOT}	PVCC to BOOTx	--	20	--	Ω

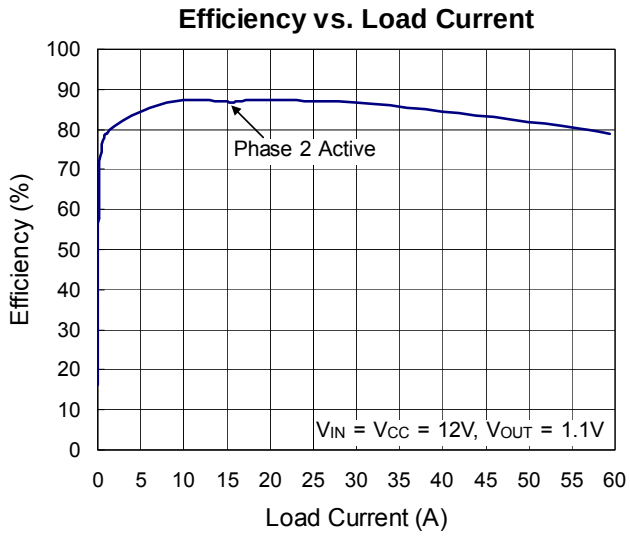
Note 1. Stresses beyond those listed "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

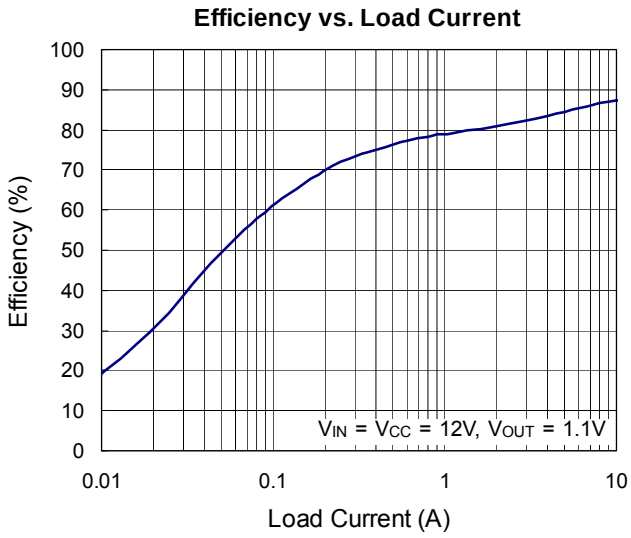
Note 2. θ_{JA} is measured at T_A = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7. θ_{JC} is measured at the exposed pad of the package.

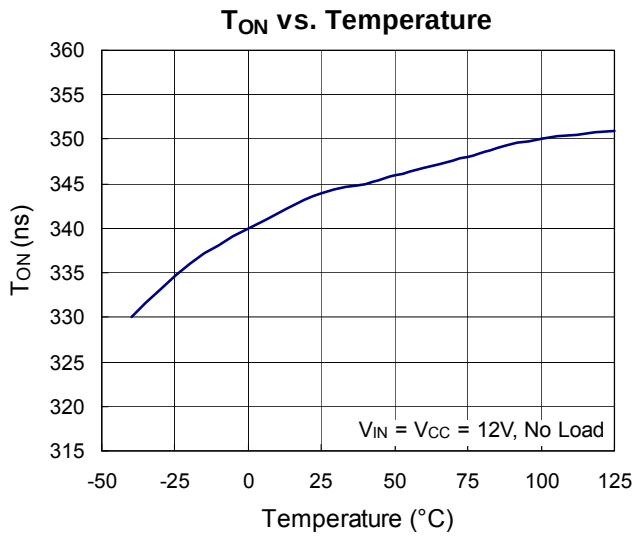
Note 3. Devices are ESD sensitive. Handling precaution is recommended.

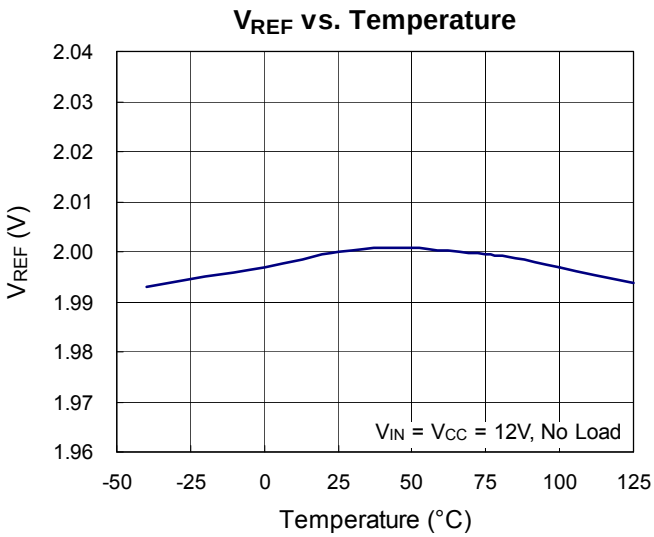
Note 4. The device is not guaranteed to function outside its operating conditions.

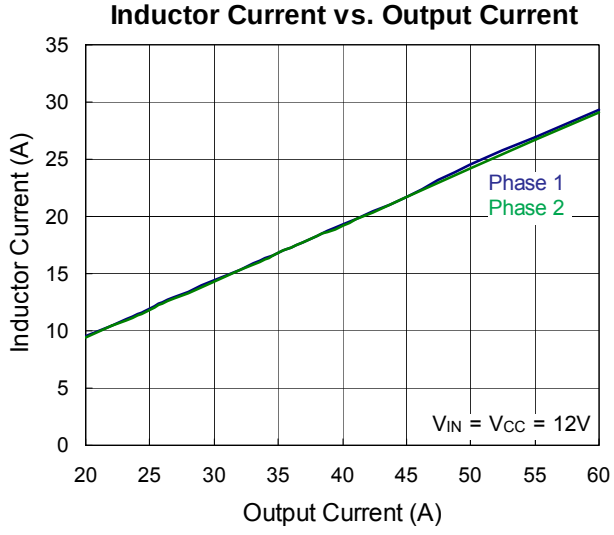
Typical Operating Characteristics

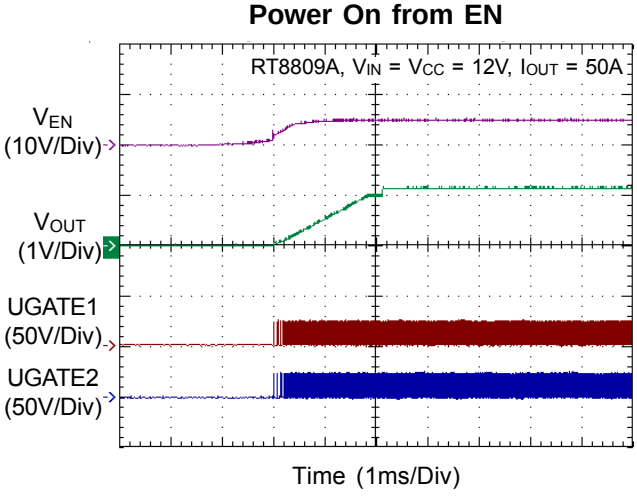




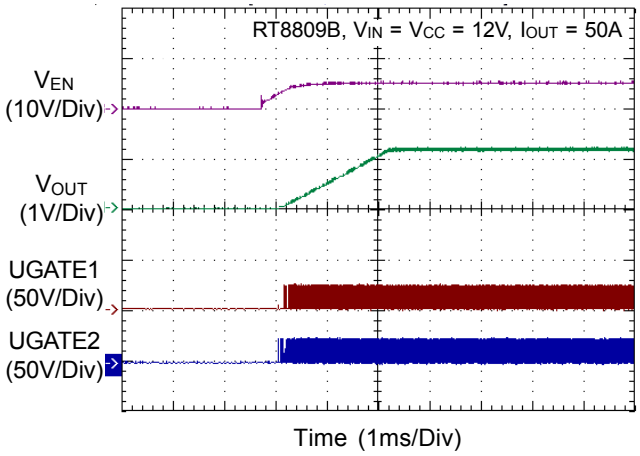




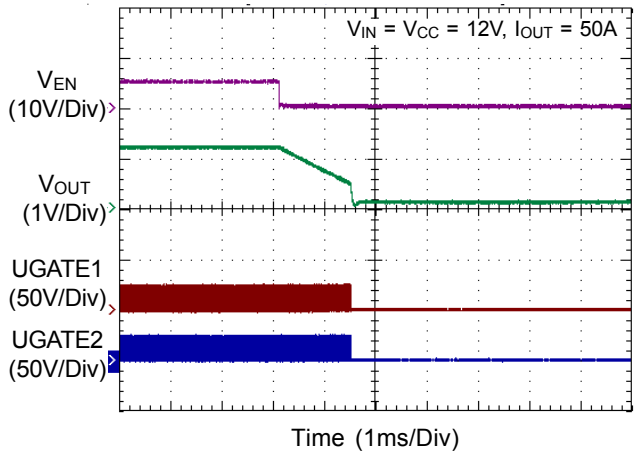




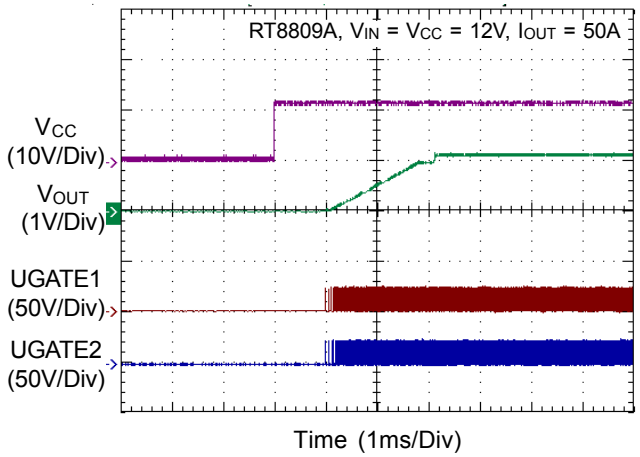
Power On from EN



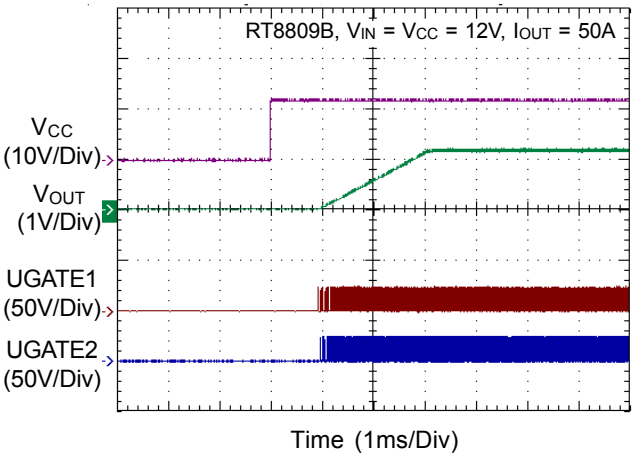
Power Off from EN



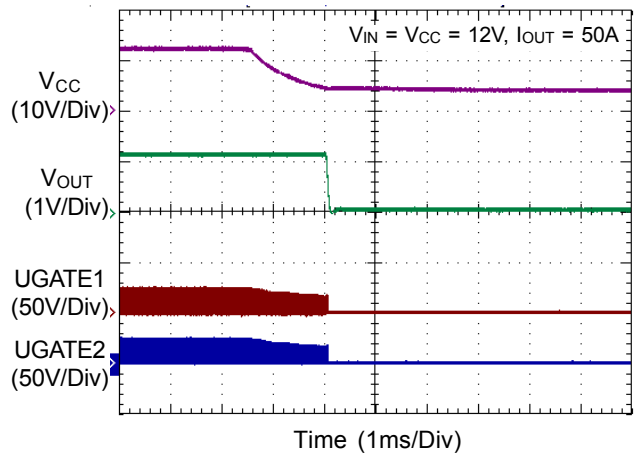
Power On from VCC



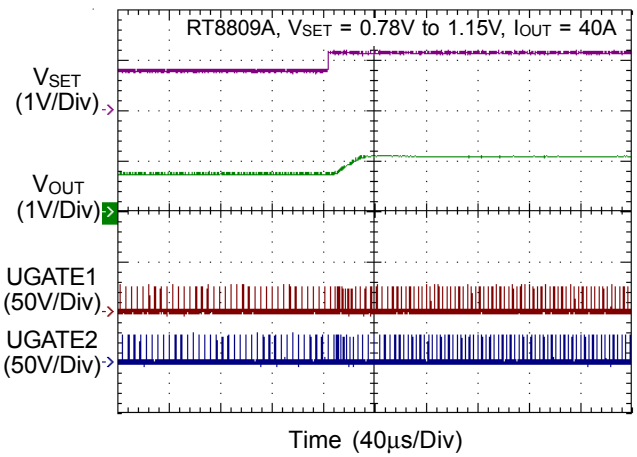
Power On from VCC



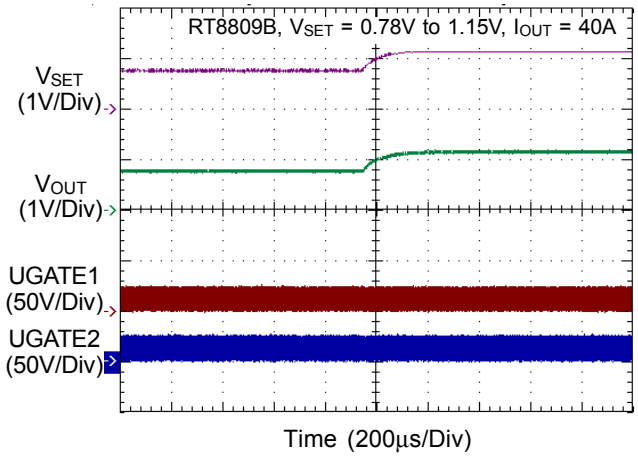
Power Off from VCC



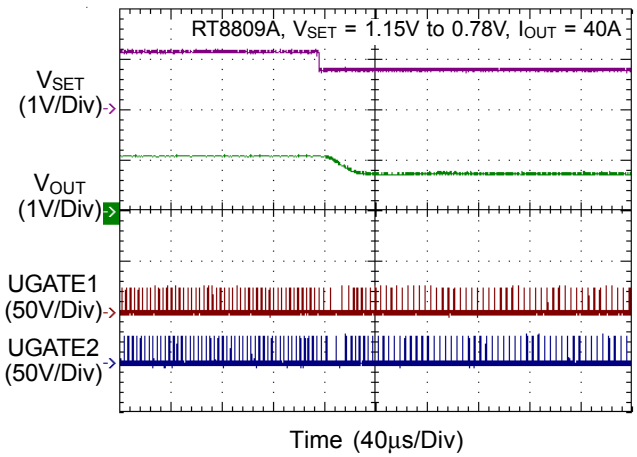
Dynamic Output Voltage Control



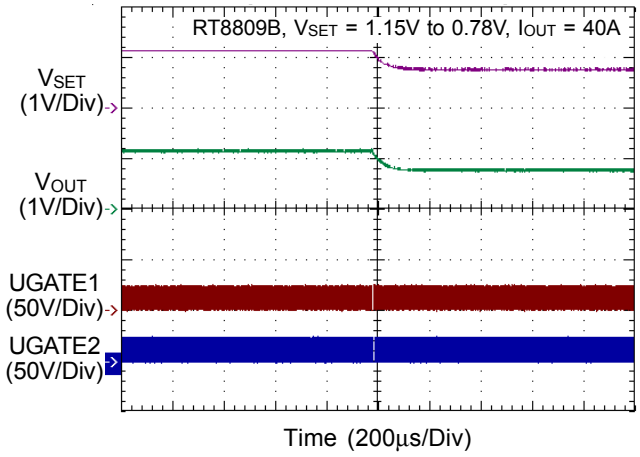
Dynamic Output Voltage Control



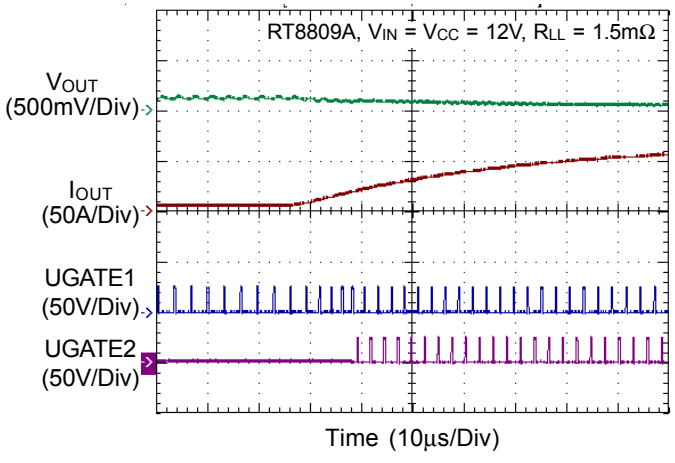
Dynamic Output Voltage Control



Dynamic Output Voltage Control



Load Transient Response



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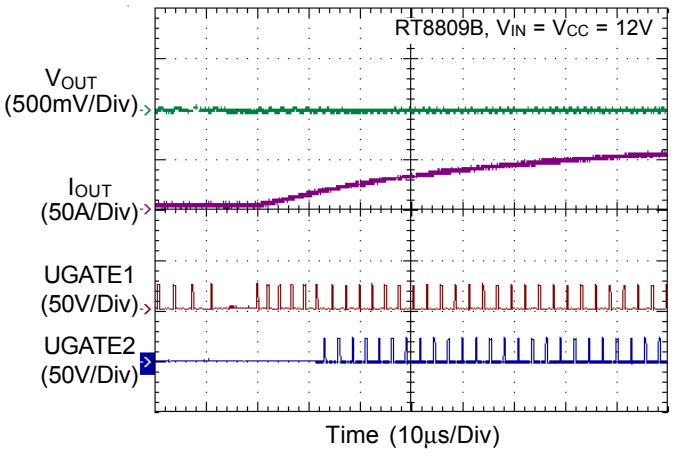

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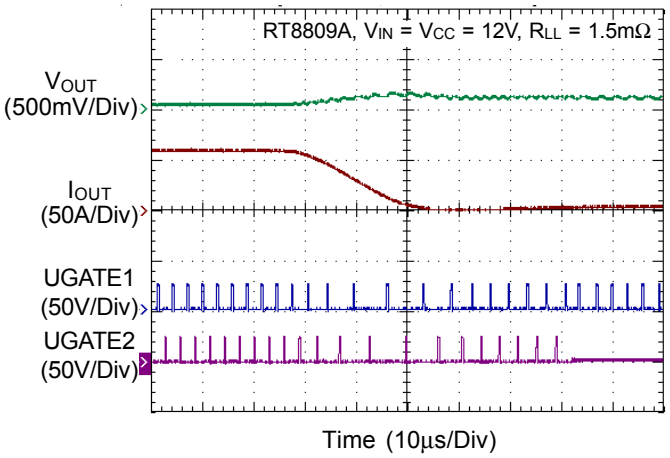
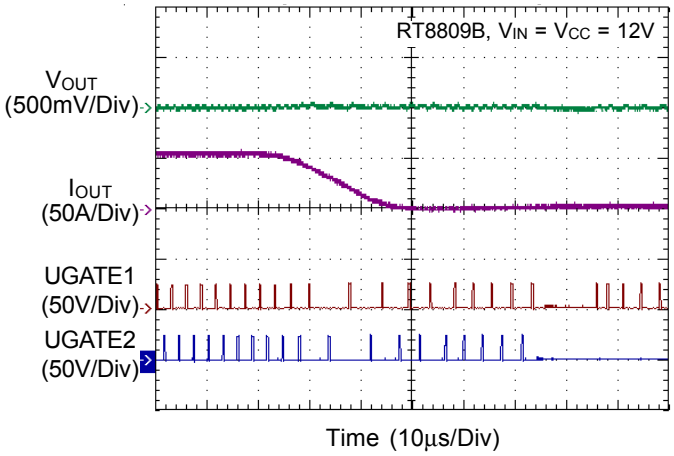
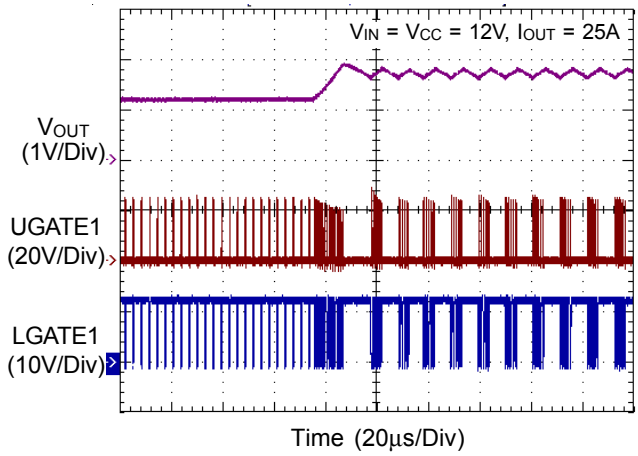


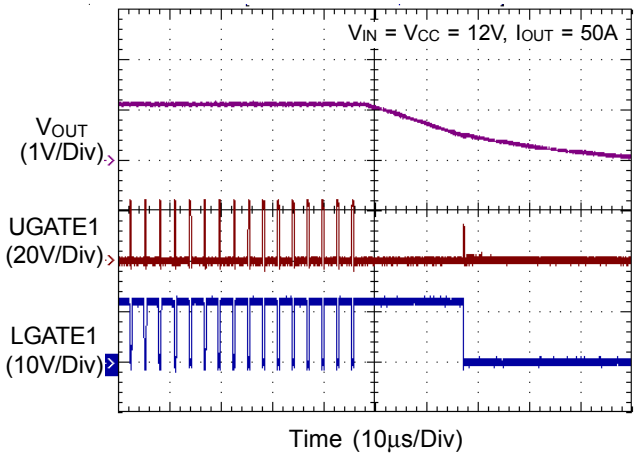
Load Transient Response



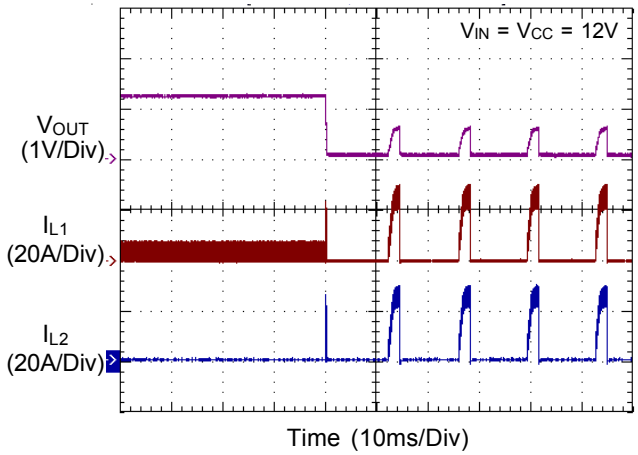
OVP



UVP



Short Circuit



Application Information

RT8809A/B is a dual-phase synchronous buck PWM controller with integrated drivers which is optimized for high-performance graphic microprocessor and computer applications. A COT (Constant-On-Time) PWM controller and two 12V MOSFET drivers with internal bootstrap diodes are integrated so that the external circuit is easily designed and the component count is reduced.

RT8809A/B adopts G-NAVP™ (Green-Native Adaptive Voltage Positioning), which is Richtek's proprietary topology derived from finite DC gain compensator with current mode control for RT8809A, the load line can be easily programmed by setting the DC gain of the error amplifier for RT8809B, the load line is fixed to zero.

RT8809A/B also adopts lossless DCR and $R_{DS(ON)}$ current sensing. Voltage positioning (only for RT8809A), dynamic phase control and current limit are accomplished through continuous inductor DCR current sensing, while $R_{DS(ON)}$ current sensing is used for accurate channel current balance.

RT8809A/B supports dynamic mode transition function with various operating states, which include dual-phase, single phase, diode emulation and audio skipping modes. These different operating states make the system efficiency as high as possible.

RT8809A/B provides a one-bit VID control operation in which the feedback voltage is regulated and tracks external input reference voltage. It also features complete fault protection functions including over voltage, under voltage and current limit.

DEM/ASM Mode Selection

DEM (Diode Emulation Mode) and ASM (Audio Skipping Mode) operation can be enabled by driving the tri-state EN/MSEL pin to a logic high level. The RT8809A/B can switch operation into DEM when EN/MSEL pin is pulled up to above 4.2V. In DEM operation, RT8809A/B automatically reduces the operation frequency at light load conditions for saving power loss. If EN/MSEL is pulled between 1.2V to 3V, the controller will switch operation into ASM. In ASM operation, the minimum switching frequency is limited to 30 kHz to avoid the acoustic noise.

Finally, if the pin is pulled to GND the RT8809A/B will shutdown.

Power On Reset

The POR (power on reset) circuit monitors the supply voltage of the controller (V_{CC}). When V_{CC} exceeds the POR rising threshold, the controller will be enable. During soft-star period, the output voltage will first boot to around 1V, and then change to the set level when using RT8809A. For RT8809B, output voltage will directly ramp to the set level. If V_{CC} falls below the POR falling threshold during normal operation, all MOSFETs stop switching and the controller resets. The POR rising and falling threshold has a hysteresis to prevent noise mis-trigger.

Soft-Start

RT8809A/B provides soft-start function. The soft-start function is used to prevent large inrush current while converter is being powered-up. An internal current source charges the internal soft-start capacitor such that the internal soft-start voltage ramps up in a monotone to a V_{BOOT} voltage RT8809A or the set level (RT8809B). The FB voltage will track the internal soft-start voltage during soft-start interval. Therefore, the duty cycle of the UGATE signal at power up as well as the input current limited. During the soft-start period, the controller will be in dual-phase operation by default to ensure enough charge during start-up.

One-Bit VID and Dynamic Output Voltage Control

The output voltage is determined by the applied voltage on the VSET pin. RT8809A/B generates a 2V reference voltage from VREF to VRTN. As shown in Figure 1, connecting a resistor divider from the VREF pin to the VSET pin can set the output voltage according to below calculation :

$$V_{OUT} = 2V \times \left(\frac{R2}{R1+R2} \right)$$

RT8809A/B also features a one-bit VID control through an internal N-MOSFET also shown in Figure 1. By connect a resistor (R3) from RSET pin to VSET pin, the output voltage can be switched between two levels by controlling the VID pin. When the VID pin is logic high, the internal N-MOSFET turns on to set the output voltage to a lower level. The output voltage can be calculated as below :

$$V_{OUT} = 2V \times \left[\frac{(R2//R3)}{R1 + (R2//R3)} \right]$$

One-Bit VID and Dynamic Output Voltage Control

In RT8809A, the dynamic VID slew rate is fixed to 10mV/μs. For RT8809B, it can be set lower than 10mV/μs by C_{VSET} as shown in Figure 1. That is, assume the ΔV_{OUT} = 300mV, R1=11kΩ, R2 = R3 = 27kΩ, the desired slew rate at falling is SR_F = 10mV/μs, and the C_{VSET} can be calculated by below formula.

$$C_{VSET} = \frac{\Delta V_{OUT}}{5 \times (R1 \,//\, R2 \,//\, R3) \times SR_F} = 1nF$$

And then, the rising slew rate SR_R will be

$$SR_R = \frac{\Delta V_{OUT}}{5 \times (R1 \,//\, R2) \times C_{VSET}} = 7.67mV/\mu S$$

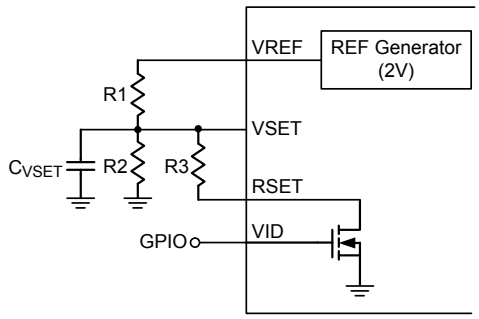


Figure 1. Output Voltage Setting with One Bit VID Control

Adjustable Switching Frequency

Switching frequency is a trade-off between efficiency and converter size. Higher operation frequency allows the use of smaller components. This is common in ultra portable devices where the load currents are lower and the controller is powered from a lower voltage supply. On the other, lower frequency operation offers higher overall efficiency at the expense of component size and board space. Figure 2 shows the On-Time Setting Circuit. Connect a resistor (R_{TON}) from TON to V_{IN} and a resistor (R_{RMP}) from RMPSET to GND to set the switching frequency according to below formula :

$$R_{TON} = \frac{V_{IN} - V_{SET}}{f_S \times C \times V_{REF}} \times \frac{V_{SET} + I_L \times (R_{DS(ON)\_L\text{-}MOS} + R_{DC} - R_{LL})}{V_{IN} + I_L \times (R_{DS(ON)\_L\text{-}MOS} - R_{DS(ON)\_H\text{-}MOS})}$$

Where

f_S : Switching frequency

R_{TON} : TON setting resistor

C : Capacitance for on time compute (13.7pF)

V_{REF} : Reference voltage for on time compute

I_L : Inductor current

$R_{DS(ON)\_L\text{-}MOS}$: $R_{DS(ON)}$ of Low Side MOSFET

$R_{DS(ON)\_H\text{-}MOS}$: $R_{DS(ON)}$ of High Side MOSFET

R_{DC} : DCR of inductor

R_{LL} : Load line resistance

The value of R_{TON} can be selected using Figure 3 and the value of R_{RMP} must be set equal to R_{TON}.

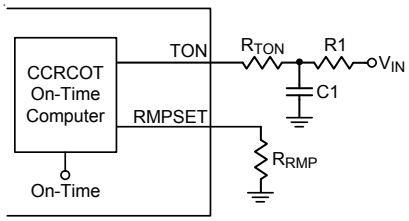


Figure 2. On-Time Setting with RC Filter

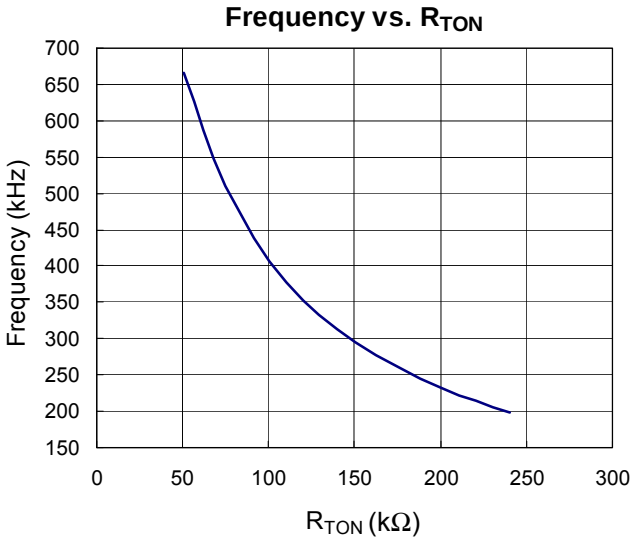


Figure 3. Frequency vs. R_{TON}

Current Sense Setting (with Temperature Compensation)

The RT8809A/B uses continuous inductor current sensing to make the controller less noise sensitive. Low offset amplifiers are used for loop control and over current detection. The CSP and CSN denote the positive and

negative input of the current sense amplifier of any phase. Since the DCR of the inductor is temperature dependent, it affects the down phase threshold, OCP threshold and output voltage accuracy, especially at heavy load. Temperature compensation is recommended for the lossless inductor DCR current sense method. Figure 4 shows a simple but effective way to compensate the unwanted temperature variations of the inductor DCR by using an NTC thermistor.

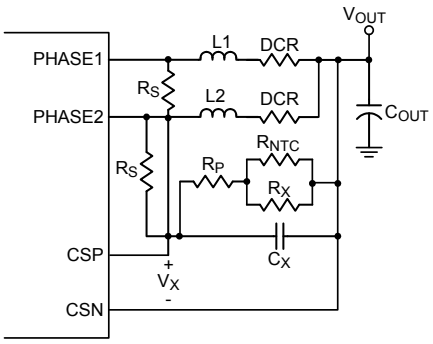


Figure 4. Inductor DCR Sensing

The RT8809A/B observes the voltage V_X, across the CSP and CSN pins for inductor current information. To design V_X without regard to the temperature coefficient, refer to below formula :

$$\frac{DCR_{TH}}{DCR_{TL}} = \frac{2+\frac{R_S}{R_{EQU\_TH}}}{2+\frac{R_S}{R_{EQU\_TL}}} \quad (1)$$

where R_{EQU_TH} is equal to R_P + R_{NTC} // R_X at high temperature and R_{EQU_TL} is equal to R_P + R_{NTC} // R_X at low temperature. Usually, R_X is set to equal R_{NTC} (25°C). R_P and R_X are selected to linearize the NTC's temperature characteristic. For a given NTC and R_P, the design is to first obtain R_S and then C_X. Usually, set R_X = R_{NTC}. To solve (1), R_S must first be obtained as below :

$$R_S = \frac{2(\alpha-1)}{\frac{1}{R_{EQU\_TH}} - \frac{\alpha}{RE_{QU\_TL}}} \quad (2)$$

Where α is equal to DCR_{TH}/DCR_{TL}

The standard formula for the resistance of the NTC thermistor as a function of temperature is given by :

$$R_{NTC,\,T°C} = R_{25°C} \times e^{\left\{\beta\left[\left(\frac{1}{T+273}\right)-\left(\frac{1}{278}\right)\right]\right\}} \quad (3)$$

where $R_{25°C}$ is the thermistor's nominal resistance at room temperature, β (beta) is the thermistor's material constant in Kelvins, and T is the thermistor's actual temperature in Celsius.

To calculate DCR value at different temperatures, can use the equation below :

$$DCR_{T°C} = DCR_{25°C} \times [1 + 0.00393 \times (T - 25)] \quad (4)$$

where the 0.00393 is the temperature coefficient of copper.

C_X can be obtained by below formula,

$$C_X = \frac{L \times \left(2+\frac{R_S}{R_{EQU\_25°C}}\right)}{R_S \times DCR_{25°C}} \quad (5)$$

Loop Control

The RT8809A/B adopts Richtek's proprietary G-NAVP™ topology. G-NAVP™ is based on the finite-gain peak current mode with CCRCOT (Constant Current Ripple Constant On Time; CCRCOT) topology. For RT8809A, the output voltage will decrease with increasing output load current. For RT8809B, the output voltage is independent with output load current. The control loop consists of PWM modulators with power stages, current sense amplifiers and an error amplifier as shown in Figure 5.

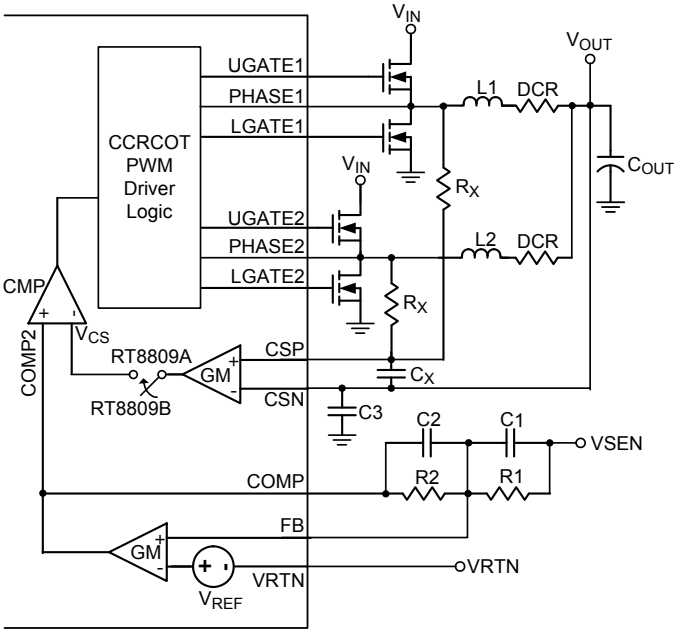


Figure 5. Simplified Schematic for Droop and Remote Sense in CCM

Similar to the peak current mode control with finite compensator gain, the HS_FET on-time is determined by the CCRCOT ON-Time generator. When the load current increases, V_{CS} increases, the steady state COMP voltage also increases and VOUT decreases, achieving Active Voltage Positioning (AVP). RT8809A/B internally cancels the inherent output offset of the finite gain peak current mode controller.

Droop Setting

Due to the native droop characteristics, the Active Voltage Positioning (AVP) can be conveniently achieved by properly setting the error amplifier gain. The target is to have

$$V_{OUT} = V_{REF} - I_{LOAD} \times R_{LL} \quad (6)$$

Then solving the switching condition $V_{COMP2} = V_{CS}$ in Figure 5 yields the desired error amplifier gain as

$$A_V = \frac{R2}{R1} = \frac{\frac{5}{2} \times DCR}{R_{LL}} \quad (7)$$

where R_{LL} is the equivalent load line resistance as well as the desired static output impedance. For a given R1, the design is to get R2 according to (7). And the R2 should be greater than 1.4kΩ.

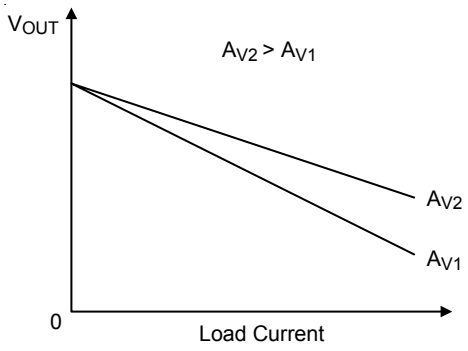


Figure 6. Error Amplifier Gain (A_V) Influence on V_{OUT} Accuracy

Note that the droop function is not available for the RT8809B

Loop Compensation

Optimized compensation of the RT8809A/B allows for best possible load step response of the regulator's output. A type-I compensator with a single pole and single zero is adequate for a proper compensation. Figure 5 shows the compensation circuit. Prior design procedure shows how to determine the resistive feedback components of the error amplifier gain, C1 and C2 must be calculated for the compensation. The target is to achieve the constant resistive output impedance over the widest possible frequency range. The pole frequency, f_P, of the compensator must be set to compensate the output capacitor ESR zero :

$$f_P = \frac{1}{2\pi \times R_C \times C} \quad (8)$$

where C is the capacitance of the output capacitor, and R_C is the ESR of output capacitor. C2 can be calculated as follows :

$$C2 = \frac{R_C \times C}{R2} \quad (9)$$

The zero of compensator has to be placed at half of the switching frequency to filter the switching related noise, such that,

$$C1 = \frac{1}{R1 \times \pi \times f_S} \quad (10)$$

Dynamic Phase Number Control

The RT8809A/B controls the operation phase number according to the total current. Figure 7 shows the dynamic phase number control circuit. By connecting a resistor (R_{PS}) from the PS pin to GND, the phase transition threshold can be set. The formula is :

$$R_{PS} = \frac{DCR \times I_{SUM} \times 5}{1\mu}$$

where I_{SUM} is the sum of the inductor valley current. For example, if DCR is 0.74mΩ, and the desired up phase threshold is 15A, the value of R_{PS} will be

$$R_{PS} = \frac{0.74 \times 10^{-3} \times 15 \times 5}{1 \times 10^{-6}} = 55.5k\Omega$$

Once the total inductor valley current is higher than the threshold, the controller will transit to dual-phase operation. when the total current becomes lower than the setting threshold minus around 5A hysteresis, the active phase number will return to single phase. If the PS pin is set floating, the controller will force to dual-phase operation.

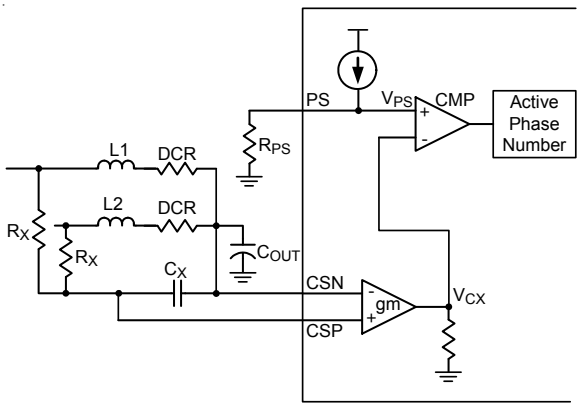


Figure 7. Dynamic Phase Number Control Circuit

Current Balance

The RT8809A/B implements internal current balance mechanism in the current loop. The RT8809A/B senses per phase current signal and compares it with the average current. If the sensed current of any particular phase is higher than average current, the on-time of this phase will be adjusted to be shorter.

Current Limit Setting

The RT8809A/B includes a built-in builds-in current limit protection function. Figure 8 shows the protection circuit. The current limit threshold is programmable by an external resistor, R_{OC}, at the OCP pin. The value of R_{OC} can be set according to the following formula :

$$R_{OC} = \frac{DCR \times I_{SUM} \times 6}{8\mu}$$

where I_{SUM} is the desired current limit threshold. Once the sensed total current exceeds the current limit threshold, the driver will be forced to turn off UGATE until the OCP situation is removed.

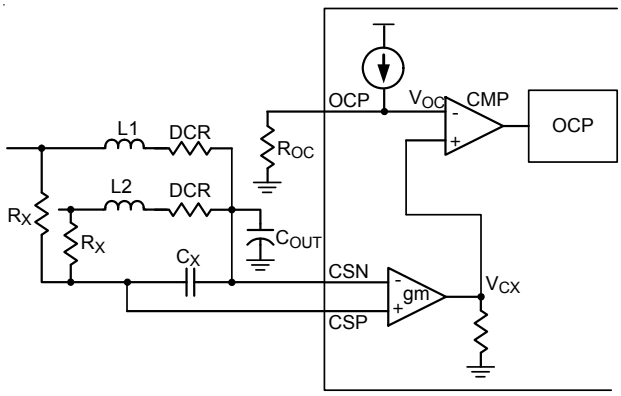


Figure 8. Over Current Protection Circuit

Over Voltage Protection

The RT8809A/B monitors the output voltage via the CSN pin for Over Voltage Protection (OVP). Once the output voltage exceeds the OVP threshold, OVP is triggered. The RT8809A/B will try to turn on low side MOSFETs and turn off high side MOSFETs to protect the load until the OVP situation is removed. A 4μs delay is used in the OVP detection circuit to prevent false trigger.

Under Voltage Protection

The voltage on CSN pin is also monitored for under voltage protection. If the output voltage is lower than the UVP threshold, UVP will be triggered. The RT8809A/B will then turn off both high side and low side MOSFETs. When UVP is triggered, The RT8809A/B will enter hiccup mode and continuously try to restart until the UVP situation is cleared.

Inductor Selection

The switching frequency and ripple current determine the inductor value as follows :

$$L_{(MIN)} = \frac{V_{IN} - V_{OUT}}{I_{RIPPLE(MAX)}} \times T_{ON}$$

where T_{ON} is the UGATE turn on period.

Higher inductance results in achieves lower ripple current and hence in higher efficiency but with a slower load transient response as a, trade off. Thus, a need for more output capacitors may be required, driving the cost up. The RT8809A/B adopts inductor DCR sensing for dynamic phase control and current limit circuit. For ensure sufficient inductor current sensing signal, the minimum DC resistance of inductor must be greater than 0.8mΩ. The core must be large enough not to be saturated at the peak inductor current.

Output Capacitor Selection

Output capacitors are used to maintain high performance for the output beyond the bandwidth of the converter itself. Two different kinds of output capacitors can be found, bulk capacitors closely located to the inductors and ceramic output capacitors in close proximity to the load. Latter ones are for mid frequency decoupling with especially small ESR and ESL values while the bulk capacitors have to provide enough stored energy to overcome the low-frequency bandwidth gap between the regulator and the GPU.

Thermal Considerations

For continuous operation, do not exceed absolute maximum junction temperature. The maximum power dissipation depends on the thermal resistance of the IC package, PCB layout, rate of surrounding airflow, and difference between junction and ambient temperature. The maximum power dissipation can be calculated by 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 recommended operating condition specifications of the RT8809A/B, the maximum junction temperature is 125°C and T_A is the ambient temperature. The junction to ambient thermal resistance, θ_{JA}, is layout dependent. For WQFN-24L 4x4 package, the thermal resistance, θ_{JA}, is 52°C/W on a standard JEDEC 51-7 four-layer thermal test board. The maximum power dissipation at T_A = 25°C can be calculated by the following formula :

$P_{D(MAX)} = (125°C - 25°C) / (52°C/W) = 1.923W$ for

WQFN-24L 4x4 package

The maximum power dissipation depends on the operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance, θ_{JA}. For the RT8809A/B package, the derating curve in Figure 9 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

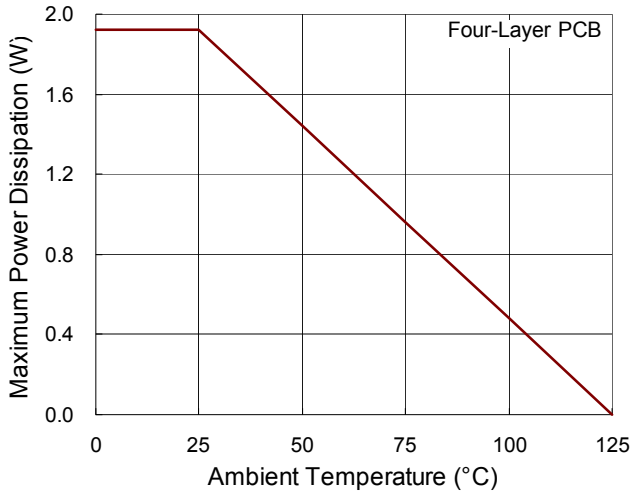


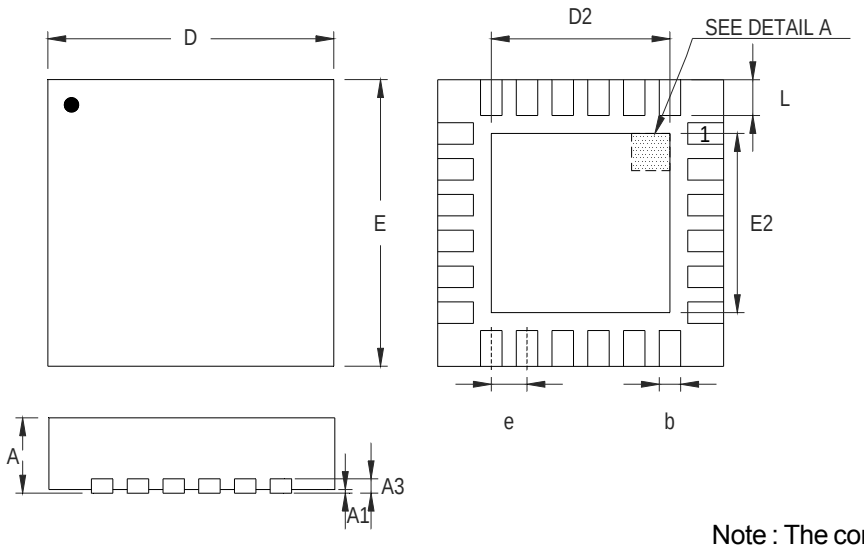
Figure 9. Derating Curves for the RT8809A/B Package

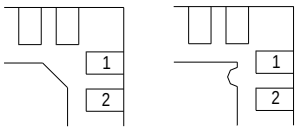
Layout Considerations

Careful PC board layout is critical to achieving low switching losses and clean, stable operation. The switching power stage requires particular attention. If possible, mount all of the power components on the top side of the board with their ground terminals flushed against one another. Follow these guidelines for optimum PC board layout :

- Keep the high current paths short, especially at the ground terminals.
- Keep the power traces and load connections short. This is essential for high efficiency.
- When trade-offs in trace lengths must be made, it's preferable to allow the inductor charging path to be made longer than the discharging path.
- Place the current sense components close to the controller. CSP and CSN connections for current limit and voltage positioning must be made using Kelvin sense connections to guarantee the current sense accuracy. The PCB trace from the sense nodes should be paralleled back to the controller.
- Route high speed switching nodes away from sensitive analog areas (COMP, FB, CSP, CSN, etc...)

Outline Dimension





DETAIL A

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.180	0.300	0.007	0.012
D	3.950	4.050	0.156	0.159
D2	2.300	2.750	0.091	0.108
E	3.950	4.050	0.156	0.159
E2	2.300	2.750	0.091	0.108
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

W-Type 24L QFN 4x4 Package

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