

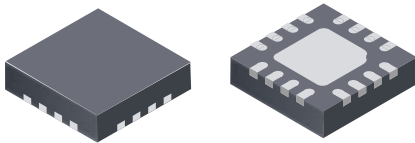
## Single LNB Supply and Control Voltage Regulator

### Features and Benefits

- Integrated boost MOSFET, current sensing, and compensation
- 704 kHz switching frequency for small low-cost components
- SLEEP pin for ultra-low power consumption mode
- Adjustable LNB output current limit (250 to 950 mA\*) limit with shutdown timer
  - Covers wide array of application requirements
  - Minimizes component sizing to fit each application
  - For startup, reconfiguration, and continuous output
- Boost peak current limit scales with LNB current limit
- Optional temporary increased current limit (+25%)
- Compatible with DiSeqC1.x control

Continued on the next page...

### Package: 16-contact QFN (suffix ES)



3 mm × 3 mm × 0.75 mm

### Description

The A8304 is a single channel low noise block regulator (LNBR). The A8304 consists of a monolithic boost converter followed by a low-drop linear regulator. It is specifically designed to provide the power and the interface signals to an LNB down converter via coaxial cable in satellite TV receiver systems.

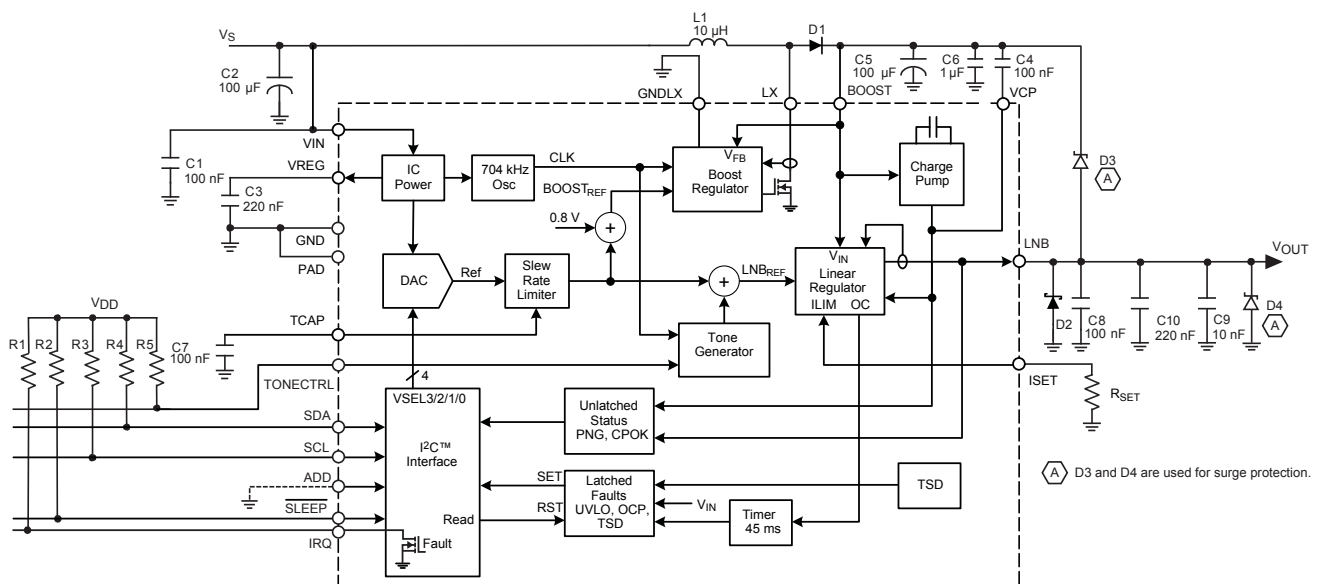
The A8304 requires few external components, with the boost switch and compensation circuitry integrated inside of the device. The 704 kHz switching frequency and user-controlled output current limit minimize the size of the passive filtering components.

The I<sup>2</sup>C™-compatible interface provides control capabilities for complex system requirements, as well as diagnostic capabilities for system fault reporting.

A sleep pin is available to maximize power savings and to quickly shut down the device if needed, without using I<sup>2</sup>C™ control.

The A8304 is provided in a small 3 × 3 mm QFN package with exposed pad for thermal dissipation. It is lead (Pb) free, with 100% matte tin leadframe plating.

### Functional Block Diagram



For recommended external components, refer to table 5

# A8304

# Single LNB Supply and Control Voltage Regulator

## Features and Benefits (continued)

- 2-wire I<sup>2</sup>C™-compatible interface for control and status
    - Programmable LNB output voltage levels (2% accuracy)
    - Enable/disable output
    - Flexible 22 kHz tone generation methods
    - SINK\_DIS bit for controlling the push-pull output sink current threshold
  - Diagnostic features: PNG
  - Extensive protection features: UVLO, OCP, TSD
- \*maximum value depends on PCB thermal design

## Selection Guide

Part Number	Packing <sup>a</sup>	Description
A8304SESTR-T <sup>b</sup>	7 in. reel, 1500 pieces/reel 12 mm carrier tape	QFN surface mount 3 mm × 3 mm × 0.75 mm nominal height



<sup>a</sup>Contact Allegro for additional packing options.

<sup>b</sup>Leadframe plating 100% matte tin.

## Absolute Maximum Ratings

Characteristic	Symbol	Conditions	Rating	Unit
Load Supply Voltage, VIN pin	V <sub>IN</sub>		18	V
Output Current <sup>1</sup>	I <sub>LNB</sub>		Internally Limited	A
Output Voltage; BOOST pin			-0.3 to 32	V
Output Voltage; LNB pin		Surge <sup>2</sup>	-1.0 to 32	V
Output Voltage; LX pin			-0.3 to 30	V
Output Voltage; VCP pin			-0.3 to 37	V
TCAP, ISET, VREG Pins			-0.3 to 6	V
Logic Input Voltage			-0.3 to 5.5	V
Logic Output Voltage			-0.3 to 5.5	V
Operating Ambient Temperature	T <sub>A</sub>	Range S	-20 to 85	°C
Junction Temperature	T <sub>J</sub> (max)		150	°C
Storage Temperature	T <sub>stg</sub>		-55 to 150	°C

<sup>1</sup>Output current rating may be limited by duty cycle, ambient temperature, and heat sinking. Under any set of conditions, do not exceed the specified current ratings, or a junction temperature, T<sub>J</sub>, of 150°C.

<sup>2</sup>Use Allegro recommended application circuit.

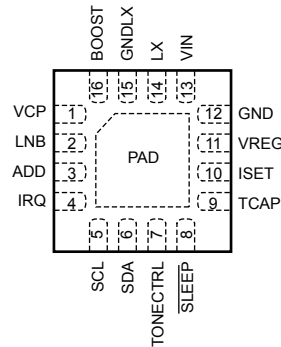
## Package Thermal Characteristics\*

Package	R <sub>θJA</sub> (°C/W)	PCB
ES	47	4-layer

\* Additional information is available on the Allegro website.



### Device Pin-out Diagram



Terminal List Table

Name	Number	Function
ADD	3	Address select
BOOST	16	Tracking supply voltage to linear regulator
GND	12	Signal ground
GNDLX	15	Boost switch ground
IRQ	4	Interrupt request
ISET	10	Output current limit set via external resistor
LNB	2	Output voltage to LNB
LX	14	Inductor drive point
PAD	Pad	Exposed pad; connect to the ground plane, for thermal dissipation
SCL	5	I <sup>2</sup> C™-compatible clock input
SDA	6	I <sup>2</sup> C™-compatible data input/output
$\overline{\text{SLEEP}}$	8	When this pin is pulled low, the A8304 enters sleep mode; LNB output, boost, I <sup>2</sup> C™ communication, and charge pump disabled to reduce input quiescent current to less than 15 $\mu$ A
TCAP	9	Capacitor for setting the rise and fall time of the LNB output
TONECTRL	7	Apply external 22 kHz tone or tone on-and-off signal to enable/disable internal tone
VCP	1	Gate supply voltage
VIN	13	Input supply voltage
VREG	11	Analog supply

**ELECTRICAL CHARACTERISTICS<sup>1</sup>** at  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 10$  to  $16\text{ V}$ ,  $\overline{\text{SLEEP}} = 1$ , • as noted<sup>2</sup>; unless noted otherwise

Characteristics	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
<b>General</b>						
Output Voltage Accuracy	$\%V_{LNB}$	$V_{IN} = 12\text{ V}$ , $I_{LNB} = 10\text{ mA}$ , see table 2 for DAC settings	• -2	-	+2	%
Load Regulation	$\Delta V_{LNB(\text{Load})}$	$V_{IN} = 12\text{ V}$ , $V_{LNB} = 13.667\text{ V}$ , $\Delta I_{LNB} = 10$ to $450\text{ mA}$	• -	38	76	mV
		$V_{IN} = 12\text{ V}$ , $V_{LNB} = 19.000\text{ V}$ , $\Delta I_{LNB} = 10$ to $450\text{ mA}$	• -	45	90	mV
Line Regulation	$\Delta V_{LNB(\text{Line})}$	$V_{IN} = 10$ to $16\text{ V}$ , $V_{LNB} = 13.667\text{ V}$ , $I_{LNB} = 10\text{ mA}$	• -10	0	10	mV
		$V_{IN} = 10$ to $16\text{ V}$ , $V_{LNB} = 19.000\text{ V}$ , $I_{LNB} = 10\text{ mA}$	• -10	0	10	mV
Supply Current (Off)	$I_{IN(\text{OFF})}$	$\overline{\text{SLEEP}} = 0$ , $V_{IN} = 12\text{ V}$	• -	-	15	$\mu\text{A}$
		$\text{ENB} = 0$ , $V_{IN} = 12\text{ V}$	• -	4	7	mA
Supply Current (On) <sup>3</sup>	$I_{IN(\text{ON})}$	$\text{ENB} = 1$ , $V_{IN} = 12\text{ V}$ , $V_{LNB} = 19\text{ V}$ , $I_{\text{LOAD}} = 0\text{ mA}$ , $\text{TONCTRL} = 0$	-	9	-	mA
		$\text{ENB} = 1$ , $V_{IN} = 12\text{ V}$ , $V_{LNB} = 19\text{ V}$ , $I_{\text{LOAD}} = 0\text{ mA}$ , $\text{TONCTRL} = 1$	-	15	-	mA
Boost Switch On Resistance	$R_{\text{DS(on)BOOST}}$	$I_{\text{SW}} = 450\text{ mA}$	-	400	-	$\text{m}\Omega$
Switching Frequency	$f_{\text{SW}}$		633	704	774	kHz
Linear Regulator Voltage Drop	$\Delta V_{\text{LR}}$	$V_{\text{BOOST}} - V_{\text{LNB}}$ , no tone signal, $I_{\text{LOAD}} = 425\text{ mA}$	600	800	1000	mV
TCAP Pin Current	$I_{\text{TCAP}}$	TCAP capacitor (C7) charging	-13	-10	-7	$\mu\text{A}$
		TCAP capacitor (C7) discharging	7	10	13	$\mu\text{A}$
Output Voltage Rise Time <sup>3</sup>	$t_{\text{r(VLNB)}}$	For $V_{\text{LNB}} 13 \rightarrow 19\text{ V}$ ; $C_7 = 100\text{ nF}$ , $I_{\text{LOAD}} = 500\text{ mA}$	-	10	-	ms
Output Voltage Pull-Down Time <sup>3</sup>	$t_{\text{f(VLNB)}}$	For $V_{\text{LNB}} 19 \rightarrow 13\text{ V}$ ; $C_{\text{LOAD}} = 100\text{ }\mu\text{F}$ , $I_{\text{LOAD}} = 0\text{ mA}$ , $\text{SINK\_DIS} = 0$	-	20	-	ms
Output Reverse Current <sup>3</sup>	$I_{\text{RLNB}}$	$\text{ENB} = 0$	-	2	4	mA
		$\text{SINK\_DIS} = 1$ , $\text{ENB} = 1$ , $\text{TONCTRL} = 0$	-	7	10	mA
		$\text{SINK\_DIS} = 0$ , $\text{ENB} = 1$ , $\text{TONCTRL} = 0$ , Absolute(VLNB-VSEL setting) < 1.5 V	-	30	50	mA
		$\text{SINK\_DIS} = 0$ , $\text{ENB} = 1$ , $\text{TONCTRL} = 1$ , Absolute(VLNB-VSEL setting) < 1.5 V	-	60	85	mA
		$\text{SINK\_DIS} = 0$ , $\text{ENB} = 1$ , $\text{TONCTRL} = 0$ or $1$ , Absolute(VLNB-VSEL setting) > 1.5 V	-	7	10	mA
Ripple and Noise on LNB Output <sup>4</sup>	$V_{\text{rip,n(pp)}}$	20 MHz BWL; reference circuit shown in Functional Block diagram; contact Allegro for additional information on application circuit board design	-	30	-	$\text{mV}_{\text{PP}}$

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**ELECTRICAL CHARACTERISTICS<sup>1</sup> (continued) at T<sub>A</sub> = 25°C, V<sub>IN</sub> = 10 to 16 V,  $\overline{\text{SLEEP}} = 1$ , • as noted<sup>2</sup>; unless noted otherwise**

Characteristics	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
<b>General (continued)</b>						
VREG Voltage	V <sub>VREG</sub>	V <sub>IN</sub> = 10 V	4.97	5.25	5.53	V
ISET Voltage	V <sub>ISET</sub>	V <sub>IN</sub> = 10 V	3.4	3.5	3.6	V
TCAP Pin Voltage	V <sub>TCAP</sub>	V <sub>IN</sub> = 10 V, V <sub>LNB</sub> = 13.667 V	–	2.28	–	V
		V <sub>IN</sub> = 10 V, V <sub>LNB</sub> = 19.000 V	–	3.17	–	V
<b>Protection Circuitry</b>						
Output Overcurrent Limit <sup>5</sup>	I <sub>LNB(MAX)</sub>	R <sub>SET</sub> = 60.4 kΩ	• 450	500	550	mA
Overcurrent Disable Time	t <sub>DIS</sub>		–	45	–	ms
Boost MOSFET Current Limit	I <sub>BOOST(MAX)</sub>	R <sub>SET</sub> = 60.4 kΩ	–	2600	–	mA
VIN Undervoltage Lockout Threshold	V <sub>UVLO</sub>	V <sub>IN</sub> falling	8.05	8.35	8.65	V
VIN Turn On Threshold	V <sub>IN(th)</sub>	V <sub>IN</sub> rising	8.40	8.70	9.00	V
Undervoltage Hysteresis	V <sub>UVLOHYS</sub>		–	350	–	mV
Thermal Shutdown Threshold <sup>3</sup>	T <sub>J</sub>		–	165	–	°C
Thermal Shutdown Hysteresis <sup>3</sup>	ΔT <sub>J</sub>		–	20	–	°C
Power Not Good (Low)	PNG <sub>LOSET</sub>	With respect to V <sub>LNB</sub> setting; V <sub>LNB</sub> low, PNG set to 1	88	91	94	%
	PNG <sub>LORESET</sub>	With respect to V <sub>LNB</sub> setting; V <sub>LNB</sub> low, PNG reset to 0	92	95	98	%
Power Not Good (Low) Hysteresis	PNG <sub>LOHYS</sub>	With respect to V <sub>LNB</sub> setting	–	4	–	%
Power Not Good (High)	PNG <sub>HISET</sub>	With respect to V <sub>LNB</sub> setting; V <sub>LNB</sub> high, PNG set to 1	106	109	112	%
	PNG <sub>HIRESET</sub>	With respect to V <sub>LNB</sub> setting; V <sub>LNB</sub> high, PNG reset to 0	102	105	108	%
Power Not Good (High) Hysteresis	PNG <sub>HIHYS</sub>	With respect to V <sub>LNB</sub> setting	–	4	–	%
<b>Tone</b>						
Amplitude	V <sub>TONE(PP)</sub>	I <sub>LNB</sub> = 425 mA, C <sub>LNB</sub> = 750 nF	• 550	700	900	mV <sub>PP</sub>
Frequency	f <sub>TONE</sub>		• 20	22	24	kHz
Duty Cycle	DC <sub>TONE</sub>		40	50	60	%
Rise Time	t <sub>R(TONE)</sub>		5	10	15	μs
Fall Time	t <sub>F(TONE)</sub>		5	10	15	μs
<b>Tone Control (TONECTRL Pin)</b>						
Logic Input	V <sub>H</sub>		2.0	–	–	V
	V <sub>L</sub>		–	–	0.8	V
Input Leakage	V <sub>(Ikg)</sub>		–1	–	1	μA
<b>Sleep Mode Control ( <math>\overline{\text{SLEEP}}</math> Pin)</b>						
Logic Input	V <sub>SLP(H)</sub>		2.0	–	–	V
	V <sub>SLP(L)</sub>		–	–	0.8	V
Input Leakage	I <sub>SLP(Ikg)</sub>		–	50	–	μA

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**ELECTRICAL CHARACTERISTICS<sup>1</sup>** (continued) at  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 10$  to  $16$  V,  $\overline{\text{SLEEP}} = 1$ , • as noted<sup>2</sup>; unless noted otherwise

Characteristics	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
<b>I<sup>2</sup>C™-Compatible Interface</b>						
Logic Input (SDA,SCL) Low Level	$V_{SCL(L)}$		–	–	0.8	V
Logic Input (SDA,SCL) High Level	$V_{SCL(H)}$		2.0	–	–	V
Logic Input Hysteresis	$V_{I2CIHYS}$		–	150	–	mV
Logic Input Current	$I_{I2CI}$	$V_{I2CI} = 0$ to $5$ V	–1	$\leq \pm 1.0$	1	$\mu\text{A}$
Logic Output Voltage SDA and IRQ	$V_{SDA}, V_{IRQ}$	$I_{LOAD} = 3$ mA	–	–	0.4	V
Logic Output Leakage SDA and IRQ	$I_{LEAK}$	$V_{LNB} = 0$ to $5$ V	–	–	10	$\mu\text{A}$
SCL Clock Frequency	$f_{CLK}$		–	–	400	kHz
<b>I<sup>2</sup>C™ Address Setting</b>						
ADD Voltage for Address 0001,000	$V_{ADD1}$		0	–	0.7	V
ADD Voltage for Address 0001,001	$V_{ADD2}$		1.3	–	1.7	V
ADD Voltage for Address 0001,010	$V_{ADD3}$		2.3	–	2.7	V
ADD Voltage for Address 0001,011	$V_{ADD4}$		3.0	–	5.0	V

<sup>1</sup>Operation at 16 V may be limited by power loss in the linear regulator.

<sup>2</sup>Indicates specifications guaranteed from  $0 \leq T_J \leq 125^\circ\text{C}_{MIN}$ .

<sup>3</sup>Ensured by worst case process simulations and system characterization. Not production tested.

<sup>4</sup>LNB output ripple and noise are dependent on component selection and PCB layout. Refer to the Application Schematic and PCB layout recommendations. Not production tested.

<sup>5</sup>Current from the LNB output may be limited by the choice of Boost components.

## Functional Description

**Boost Converter/Linear Regulator**

The A8304 solution contains a tracking current-mode boost converter and linear regulator. The boost converter tracks the requested LNB voltage to within 800 mV, to minimize power dissipation. Under conditions where the input voltage,  $V_{\text{BOOST}}$ , is greater than the output voltage,  $V_{\text{LNB}}$ , the linear regulator must drop the differential voltage. When operating in these conditions, care must be taken to ensure that the safe operating temperature range of the A8304 is not exceeded.

The boost converter operates at 704 kHz typical. All the loop compensation, current sensing, and slope compensation functions are provided internally.

The A8304 has internal pulse-by-pulse current limiting on the boost converter and DC current limiting on the LNB output to protect the IC against short circuits. When the LNB output is shorted, the LNB output current is limited, and if the overcurrent condition lasts for more than 45 ms, the LNB output will be disabled. If this occurs, the A8304 output must be re-enabled for normal operation. The system should provide sufficient time between successive restarts to limit internal power dissipation; 1 s to 2 s is recommended.

At extremely light loads, the boost converter operates in a pulse-skipping mode. Pulse skipping occurs when the BOOST voltage rises to approximately 450 mV above the BOOST target output voltage. Pulse skipping stops when the BOOST voltage drops 200 mV below the pulse skipping level.

Two or more satellite set top boxes LNBR outputs may be connected together (for example in the case when a splitter is used). In this case the A8304 that has the highest programmed voltage will supply the LNB and all other A8304s will effectively be off. If the output of the A8304 IC supplying the LNB drops below the programmed value of the next highest voltage A8304, that unit will automatically recover from providing no-output voltage, monotonically start up and supply the voltage at its programmed level. This unit will supply the LNB power.

**Charge Pump** Generates a supply voltage above the internal tracking regulator output to drive the linear regulator control.

**LNB and BOOST Current Limits** The LNB output current limit,  $I_{\text{LNB(MAX)}}$  can be set by connecting a resistor (RSET) from the ISET pin to GND as shown in the functional block diagram. For example 300 mA and 500 mA settings would correspond to

RSET values of 100 k $\Omega$  and 60.4 k $\Omega$  respectively, per equation 1. The LNB current limit has a set range of 250 to 950 mA, with the maximum value dependent on thermal design parameters of a given application. If the LNB current limit is exceeded for more than the Overcurrent Disable Time ( $t_{\text{DIS}}$ ) then the A8304 will be shut down and the OCP bit set, as shown in figure 1. The typical LNB output current limit can be set according to the following equation:

$$I_{\text{LNB(MAX)}} = 29,925 / R_{\text{SET}} \quad (1)$$

where  $I_{\text{LNB(MAX)}}$  is in mA and  $R_{\text{SET}}$  is in k $\Omega$ . If the voltage at the ISET pin is 0 V (that is, shorted to GND),  $I_{\text{LNB(MAX)}}$  will be clamped to a moderately high value (approximately 1.5 A). Care should be taken to ensure that ISET is not inadvertently grounded. If no resistor is connected to the ISET pin (that is, if ISET is open-circuit),  $I_{\text{LNB(MAX)}}$  will be set to approximately 0 A and the A8304 will not support any load (OCP will occur prematurely).

The BOOST pulse-by-pulse current limit,  $I_{\text{BOOST(MAX)}}$ , is automatically scaled along with the LNB output current limit. The typical BOOST current limit is set according to the following equation:

$$I_{\text{BOOST(MAX)}} = 3 \times I_{\text{LNB(MAX)}} + 1100 \text{ mA} \quad (2)$$

where both  $I_{\text{BOOST(MAX)}}$  and  $I_{\text{LNB(MAX)}}$  are in mA.

Automatically scaling the BOOST current limit allows the designer to choose the lowest possible saturation current of the boost inductor, reducing its physical size and PCB area, thus minimizing cost.

**Protection**

The A8304 has a wide range of protection features and fault diagnostics which are detailed in the Status Register section.

**Slew Rate Control** During either start-up, or when the output voltage at the LNB pin is transitioning, the output voltage rise and fall times can be set by the value of the capacitor connected from the TCAP pin to GND (C7 in the functional block diagram). Note that during start-up, the BOOST pin is pre-charged to the input voltage minus a voltage drop. As a result, the slew rate control for the BOOST pin occurs from this voltage.

The value of  $C_7$  can be calculated using the following formula:

$$C_7 = (I_{TCAP} \times 6) / SR, \quad (3)$$

where  $SR$  is the required slew rate of the LNB output voltage, in  $V/s$ , and  $I_{TCAP}$  is the TCAP pin current specified in the Electrical Characteristics table. The recommended value for  $C_7$ , 100 nF, should provide satisfactory operation for most applications.

The minimum value of  $C_7$  is 10 nF. There is no theoretical maximum value of  $C_7$ , however too large a value will probably cause the voltage transition specification to be exceeded. Tone generation is unaffected by the value of  $C_7$ .

**Pull-Down Rate Control** In applications that have to operate at very light loads and that require large load capacitances (in the order of tens to hundreds of microfarads), the output linear stage provides approximately 30 mA of pull-down capability, with  $TONECTRL = 0$ . This ensures that the LNB output voltage is ramped from 18 to 13 V in a reasonable amount of time. When the tone is on ( $TONECTRL = 1$ ), the output linear stage must increase its pull-down capability to approximately 60 mA. This

ensures that the tone signal meets all specifications, even with no load on the LNB output.

### ODT (Overcurrent Disable Time)

If the LNB output current exceeds the set output current, for more than  $t_{DIS}$ , then the LNB output will be disabled and the OCP bit will be set. See figure 1.

### Short Circuit Handling

A8304 has optional 25% bump-up on current limit for  $t_{DIS} / 4$  period. This feature is enabled / disabled by setting or resetting Control Register bit 0. When this bit is enabled, the output current limit will be 25% more than set current limit for  $t_{DIS} / 4$  period. After  $t_{DIS} / 4$  period, output current limit comes down to the set limit and the OCP\_25P bit is reset to zero. The user must set this bit again to enable 25% bump-up on the next current limit event. If the OCP\_25P bit is zero when LNB output is shorted to ground, the LNB output current will be clamped to  $I_{LNB(MAX)}$ . If the short circuit condition lasts for more than 45 ms, the A8304 will be disabled and the OCP bit will be set. Refer to figures 9 and 10.

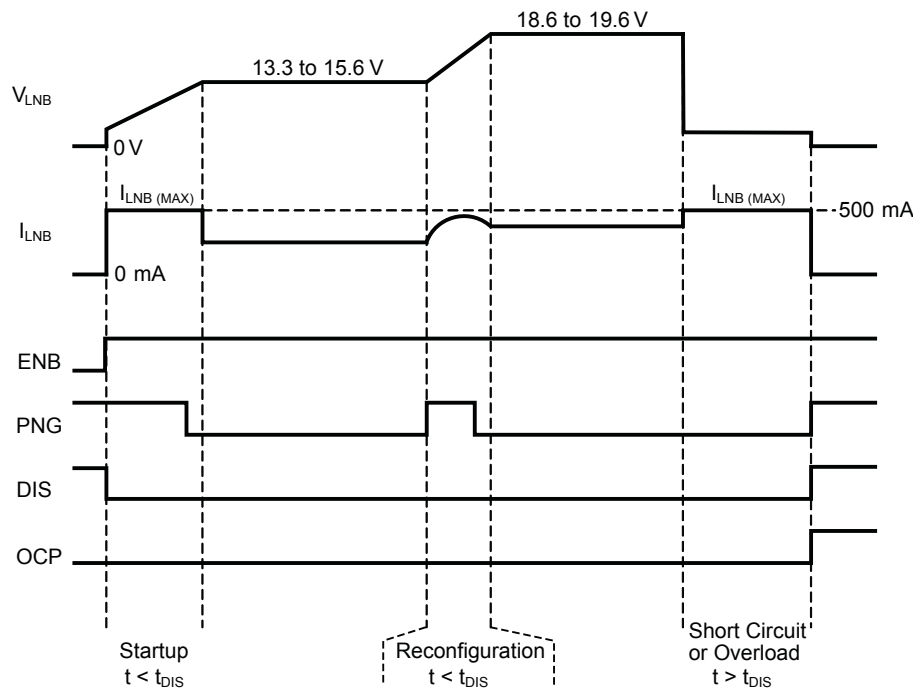


Figure 1. Startup, Reconfiguration, and Short Circuit operation using  $R_{SET} = 60.4 \text{ k}\Omega$ , and a capacitive load (OCP\_25P bit = 0).



## In-Rush Current

At start-up or during an LNB reconfiguration event, a transient surge current above the normal DC operating level can be provided by the A8304. This current increase can be as high as the set output current, for as long as required, up to a maximum of 45 ms.

## Tone Generation

The A8304 offers two options for tone generation (figure 2). The TONECTRL pin with the TMODE control bit provides the necessary control. The TMODE bit controls whether the tone source is internal or external.

When the internal source is used (TMODE bit set to 0), the tone is gated with the TONECTRL pin. The internal tone frequency is 22 kHz. Note: This tone can be generated under no-load conditions and does not require an external DiSEqC™ filter.

When the TMODE bit is set to 1, an external 22-kHz tone signal can be applied to the TONECTRL pin. This tone frequency appears at the LNB output,  $V_{LNB}$  reaches the  $V_{LNBref}$  level after TONECTRL has been low for longer than 42  $\mu$ s.

## Component Selection

### Boost Inductor

The A8304 is designed to operate with a boost inductor value of 10  $\mu$ H  $\pm$ 50%. The error amplifier loop compensation, current sense gain, and PWM slope compensation were chosen for this value of inductor. The boost inductor must be able to support the peak currents required to maintain the maximum LNB output current without saturating. Figure 3 can be used to determine the peak current in the inductor given the LNB load current. The “typical” curve uses  $V_{IN} = 12$  V,  $V_{LNB} = 19$  V,  $L = 10$   $\mu$ H, and  $f = 704$  kHz, while the “maximum” curve assumes  $V_{IN} = 9$  V,  $V_{LNB} = 20$  V,  $L = 8$   $\mu$ H, and  $f = 633$  kHz.

### Boost Electrolytic Capacitor

The A8304 is designed to operate with a low-ESR electrolytic boost capacitor of 100  $\mu$ F  $\pm$ 25%. The ESR of the boost capacitor must be less than 140 m $\Omega$  or the boost converter will be unstable. General purpose electrolytic capacitors that do not specify an ESR should be avoided. Allegro recommends an electrolytic capacitor that is rated to support at least 35 V and has an rms current rating to support the maximum LNB load.

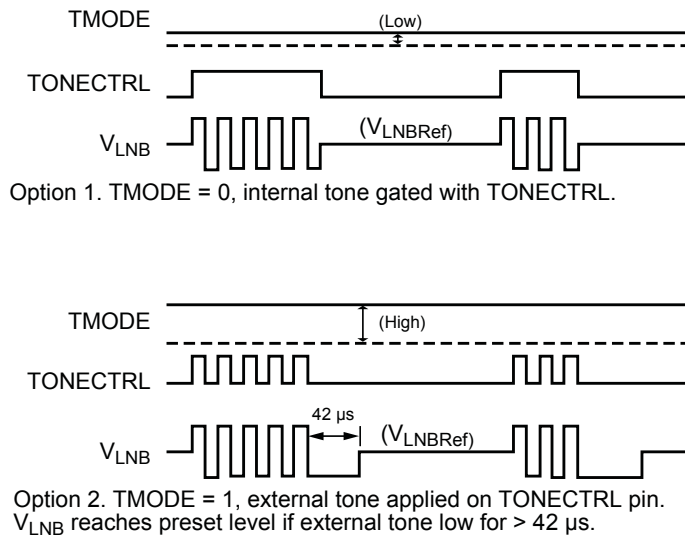


Figure 2. Tone generation options

Figure 4 can be used to determine the necessary rms current rating of the boost capacitor given the LNB load current. The “typical” curve uses  $V_{IN} = 12\text{ V}$ ,  $V_{LNB} = 19\text{ V}$ ,  $L = 10\text{ }\mu\text{H}$ , and  $f = 704\text{ kHz}$  while the “maximum” curve assumes  $V_{IN} = 9\text{ V}$ ,  $V_{LNB} = 20\text{ V}$ ,  $L = 8\text{ }\mu\text{H}$ , and  $f = 633\text{ kHz}$ .

### Boost Filtering and LNB Noise

The LNB output noise depends on the amount of high-frequency noise at the BOOST pin. To minimize the high-frequency noise at the BOOST pin, a high quality ceramic capacitor should be placed as close as possible to the BOOST pin. Allegro recommends a  $1\text{ }\mu\text{F}$ , 10% or 20%, X5R or X7R, 1206 size capacitor, with at least a 25 V rating.

For very noise-sensitive applications, a secondary inductor can be added between the  $100\text{ }\mu\text{F}$  and the  $1\text{ }\mu\text{F}$  boost capacitors, as shown in figure 5. This inductor should be approximately  $1\text{ }\mu\text{H}$  and have a DC current rating of at least 1 ADC. Adding the  $1\text{ }\mu\text{H}$  inductor has been shown to reduce the LNB output noise by as much as 50%. Allegro strongly recommends having provisions for this  $1\text{ }\mu\text{H}$  inductor in the PCB layout, but only populating it if the LNB output is found to have too much noise after measuring at the set-top box F-connector, at full-load.

### Surge Components

The circuit shown on page 1 of this datasheet includes D3 and D4 for surge protection. Component recommendations for D3 and D4 are given in the bill-of-materials at the end of this data-

sheet. This configuration and these components have successfully passed surge tests up to  $\pm 1000\text{ V}/500\text{ A}$ , with a  $1.2/50\text{ }\mu\text{s} - 8/20\text{ }\mu\text{s}$  combination wave. Every application will have its own surge requirements and the surge solution can be changed. However, Allegro strongly recommends incorporating a form of surge protection to prevent any pin of the A8304 from exceeding its Absolute Maximum voltage ratings shown in this datasheet.

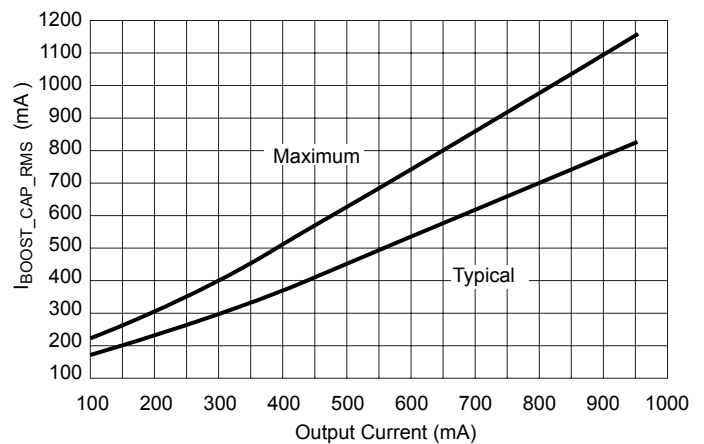


Figure 4. Boost capacitor rms current versus  $I_{LNB}$

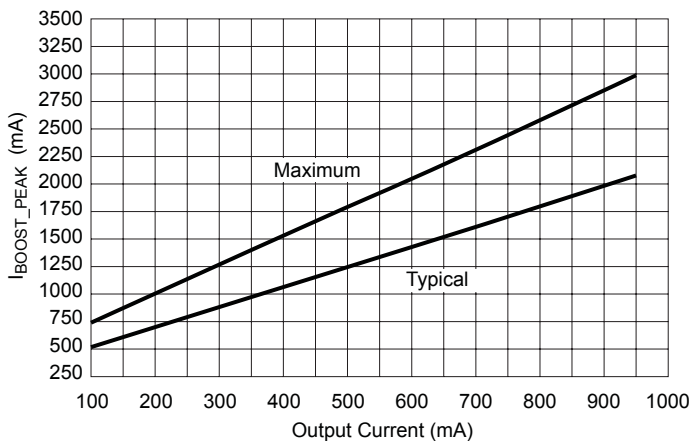


Figure 3. Boost inductor peak current versus  $I_{LNB}$

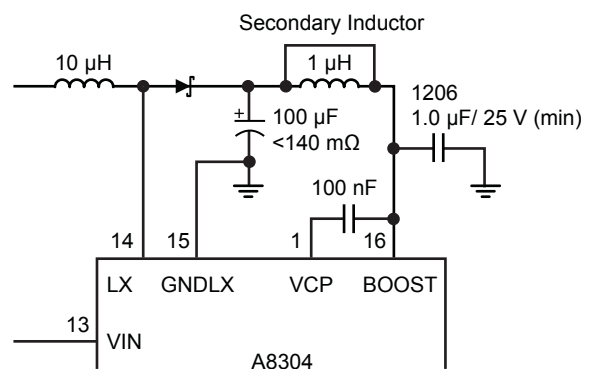


Figure 5. Application of the secondary boost inductor

## I<sup>2</sup>C™-Compatible Interface

The I<sup>2</sup>C™ interface is used to access the internal Control and Status registers of the A8304. This is a serial interface that uses two lines, serial clock (SCL) and serial data (SDA), connected to a positive supply voltage via a current source or a pull-up resistor. Data is exchanged between a microcontroller (master) and the A8304 (slave). The master always generates the SCL signal. Either the master or the slave can generate the SDA signal. The SDA and SCL lines from the A8304 are open-drain signals so multiple devices may be connected to the I<sup>2</sup>C™ bus. When the bus is free, both the SDA and the SCL lines are high.

**SDA and SCL Signals.** SDA can only be changed while SCL is low. SDA must be stable while SCL is high. However, an exception is made when the I<sup>2</sup>C™ Start or Stop condition is encountered. See the I<sup>2</sup>C™ Communication section for further details.

**Acknowledge (AK) Bit** The Acknowledge (AK) bit indicates a “good transmission” and can be used two ways. First, if the slave has successfully received eight bits of either an address or control data, it will pull the SDA line low (AK=0) for the ninth SCL pulse to signal “good transmission” to the master. Second, if the master has successfully received eight bits of status data from the A8304, it will pull the SDA line low for the ninth SCL pulse to

signal “good transmission” to the slave. The receiver (either the master or the slave) should set the AK bit high (AK=1 or NAK) for the ninth SCL pulse if eight bits of data are not received successfully.

**AK Bit During a Write Sequence** When the master sends control data (writes) to the A8304 there are three instances where AK bits are toggled by the A8304. First, the A8304 uses the AK bit to indicate reception of a valid seven-bit chip address plus a read/write bit (R/W=0 for write). Second, the A8304 uses the AK bit to indicate reception of a valid eight-bit Control register address. Third, the A8304 uses the AK bit to indicate reception of eight bits of control data. This protocol is shown in figure 6(A).

**AK Bit During a Read Sequence** When the master reads status data from the A8304 there are four instances where AK bits are sent—three sent by the A8304 and one sent by the master. First, the A8304 uses the AK bit to indicate reception of a valid seven-bit chip address plus a read/write bit (R/W=0 for write). Second, the A8304 uses the AK bit to indicate reception of a valid eight-bit Status register address. Third, the A8304 uses the AK bit to indicate reception of a valid seven-bit chip address plus a read/write bit (R/W=1 for read). Finally, the master uses the AK bit to indicate receiving eight bits of status data from the A8304. This protocol is shown in figure 6(B).

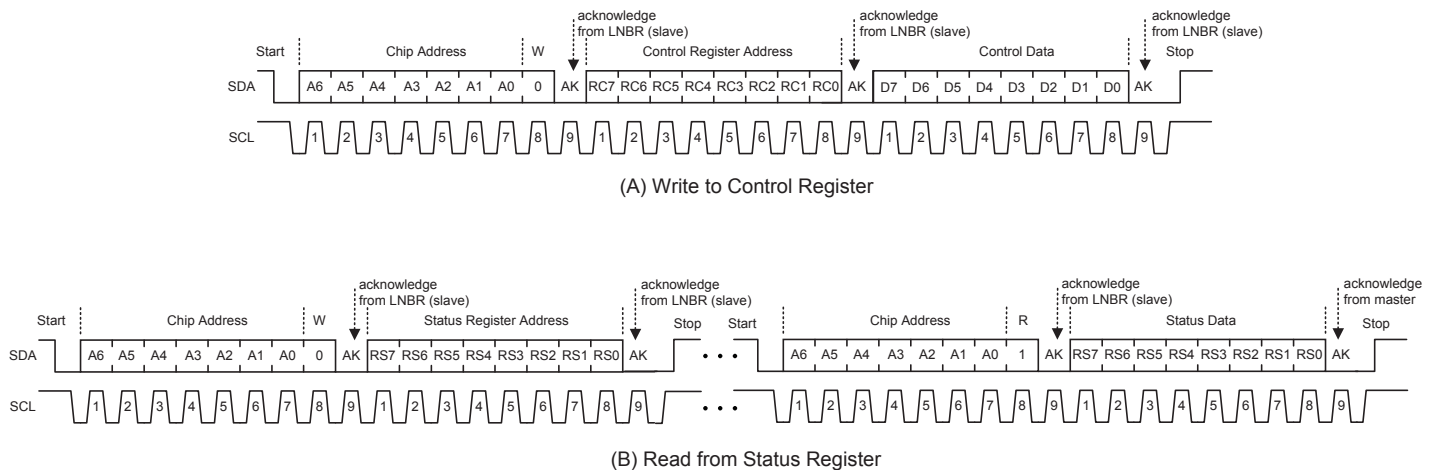


Figure 6. I<sup>2</sup>C™ Interface Read and Write Sequences. (A) for the I<sup>2</sup>C™ Write cycle and (B) for the I<sup>2</sup>C™ Read cycle.

## I<sup>2</sup>C™ Communications

**I<sup>2</sup>C™ Start and Stop Conditions** The I<sup>2</sup>C™ Start condition is defined by a negative edge on the SDA line while SCL is high. Conversely, the Stop condition is defined by a positive edge on the SDA line while SCL is high. The Start and Stop conditions are shown in figure 6. It is possible for the Start or Stop condition to occur at any time during a data transfer. If either a Start or Stop condition is encountered during a data transfer, the A8304 will respond by resetting the data transfer sequence.

**I<sup>2</sup>C™ Write Cycle Description** Writing to the A8304 Control register requires transmission of a total of 27 bits—three 8-bit bytes of data plus an Acknowledge bit after each byte. Writing to the A8304 Control register is shown in figure 6(A). Writing to the A8304 Control register requires a chip address with R/W=0, a Control register address, and the control data, as follows:

- The Chip Address cycle consists of a total of nine bits—seven bits of chip address (A6 to A0) plus one read/write bit (R/W=0) to indicate a write from the master followed by an Acknowledge bit (AK=0 for reception of a valid chip address) from the slave. The chip address must be transmitted MSB (A6) first. The first five bits of the A8304 chip address (A6 to A2) are fixed as 00010. The remaining two bits (A1 and A0) are used to select one of four possible A8304 chip addresses. The DC voltage on the ADD pin programs the chip address. See the Electrical Characteristics table for the ADD pin voltages and the corresponding chip addresses.
- The Control Register Address cycle consists of a total of nine bits—eight bits of control register address (RC7 to RC0) from the master followed by an Acknowledge bit from the slave. The Control register address must be transmitted MSB (RC7) first. The A8304 only has one Control register so the Control register address is 0000 0000.
- The Control Data cycle consists of a total of nine bits—eight bits of control data (D7 to D0) from the master followed by an Acknowledge bit from the slave. The control data must be transmitted MSB first (D7). The Control register bits are identified in the Control Register section of this datasheet.

**I<sup>2</sup>C™ Read Cycle Description** Reading from the A8304 Status register requires transmission of a total of 36 bits—four 8-bit bytes of data plus an Acknowledge bit after each byte. Reading

the A8304 Status register requires a chip address with R/W=0, a Status register address, an I<sup>2</sup>C™ Stop condition, an I<sup>2</sup>C™ Start condition, a “repeated” chip address with R/W=1, and finally the status data from the A8304. Reading from the A8304 Status register is shown in figure 6(B).

- This 9-bit Chip Address cycle is identical to the Chip Address cycle previously described for the Write Control Register sequence. It consists of A6 to A0, plus one read/write bit (R/W=0) from the master, followed by an Acknowledge bit from the slave and finally an I<sup>2</sup>C™ Stop condition.
- The Status Register Address cycle consists of a total of nine bits—eight bits of Status register address (RS7 to RS0) from the master, followed by an Acknowledge bit from the slave. The Status register address must be transmitted MSB (RS7) first. The A8304 only has one Status register, so the Status register address is fixed at 0000 0000.
- The “Repeated” Chip Address cycle begins with an I<sup>2</sup>C™ Start condition followed by a 9-bit cycle identical to the Chip Address cycle previously described for the Write Control Register sequence. It consists of A6 to A0, plus one read/write bit (R/W=1) from the master, followed by an Acknowledge bit from the slave.
- The Status Data cycle consists of a total of nine bits—eight bits of status data (RD7 to RD0) from the slave, followed by an Acknowledge bit from the master. The status data is transmitted MSB (RD7) first. The Status register bits are identified in the Status Register section of this datasheet.

## Interrupt Request (IRQ) pin

The A8304 provides an interrupt request pin (IRQ), which is an open-drain, active low output. This output may be connected to a common IRQ line with a suitable external pull-up resistor and can be used with other I<sup>2</sup>C™ compatible devices to request attention from the master controller.

The IRQ output becomes active (logic low) when the A8304 recognizes a fault condition. The fault conditions that will force IRQ active include undervoltage lockout (UVLO), overcurrent

protection (OCP), and thermal shutdown (TSD). The UVLO, OCP, and TSD faults are latched in the Status register and will not be unlatched until the A8304 Status register is successfully transmitted to the master controller (an AK bit must be received from the master). See the description in the Status Register section and figure 7 for further details.

When the master device receives an interrupt, it should address all slaves connected to the interrupt line in sequence and read the

status register of each to determine which device is requesting attention. As shown in figure 7, the A8304 latches all conditions in the Status register and sets the IRQ to logic low when a fault occurs. The IRQ bit is reset to logic high and the Status register is unlatched when the master acknowledges the status data from the A8304 (an AK bit must be received from the master).

The disable (DIS) and Power Not Good (PNG) conditions do not cause an interrupt and are not latched in the Status register.

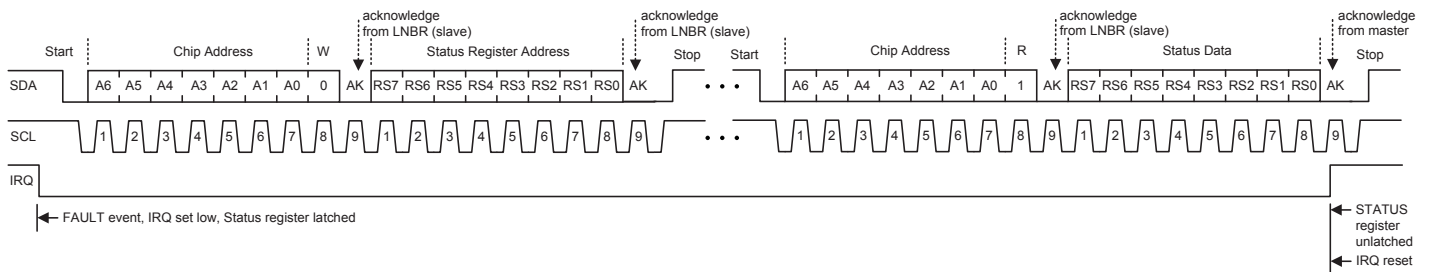


Figure 7. Fault, IRQ, and Status Register Timing. When a FAULT occurs, the IRQ bit is set to low and the Status register is latched. The IRQ bit is reset to high when the A8304 acknowledges it is being read. The Status register is unlatched when the master acknowledges the status data from the A8304.

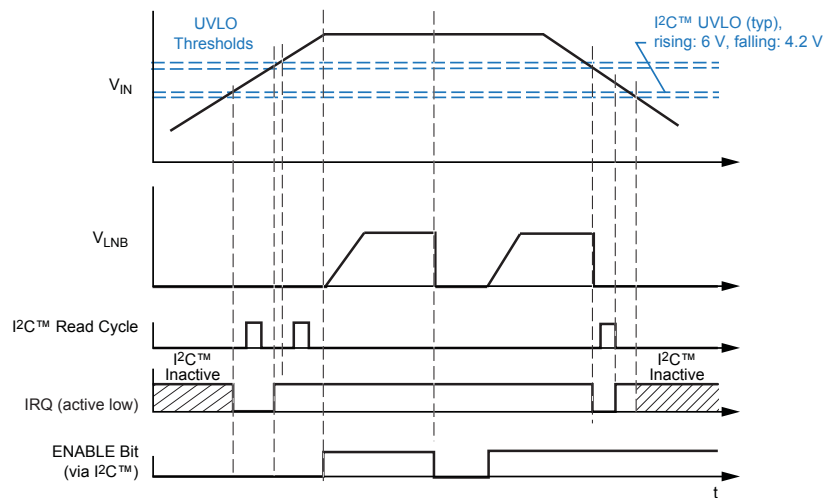


Figure 8. IRQ and Fault Clearing in Response to Under Voltage at VIN (UVLO), the I2C™ port is active when VIN is above I2C™ UVLO (6 V when VIN is rising). IRQ transitions low when VIN goes above I2C™ UVLO (6 V, VIN rising), and the I2C™ Read cycle resets IRQ to logic high even if VIN is below UVLO. Even though IRQ is cleared below UVLO, one more Read cycle is required after VIN goes above UVLO, to re-enable the A8304. While VIN is falling, IRQ transitions low when VIN goes below UVLO, and the I2C™ Read cycle resets IRQ to logic high.

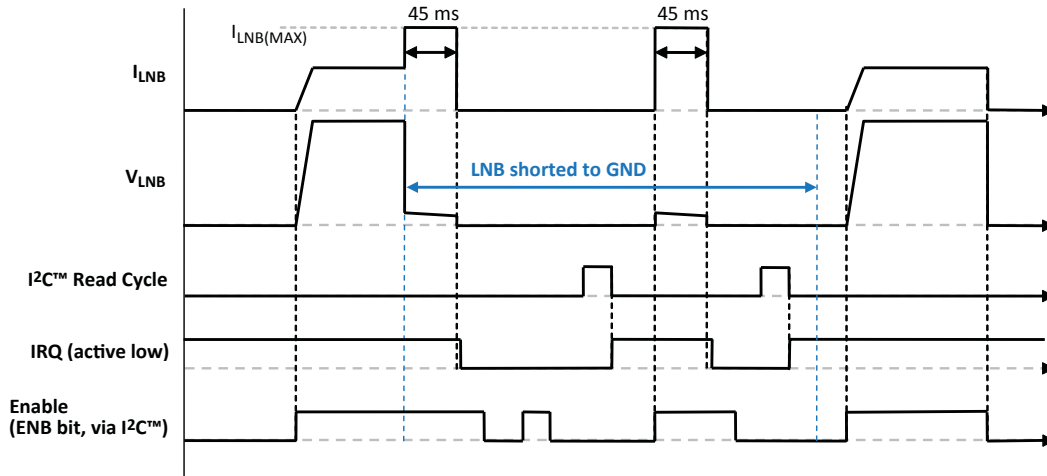


Figure 9. IRQ and Fault Clearing in Response to Overcurrent (OCP). If the LNB output is grounded for more than 45 ms, the LNB output will be shut off, an overcurrent fault (OCP) will be latched in the Status Register, and the IRQ pin will transition low. After an OCP fault, the LNB output does not respond to the Enable (ENB) bit until an I<sup>2</sup>C™ Read cycle is executed to report and clear the OCP fault. After a successful I<sup>2</sup>C™ Read, the IRQ pin transitions high and the A8304 can be re-enabled, provided the LNB output is no longer grounded. (OCP\_25P bit set to 0)

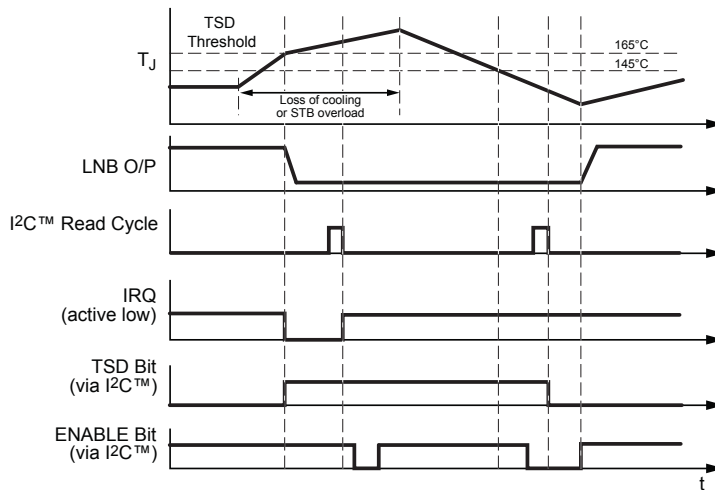


Figure 10. IRQ and Fault Clearing in Response to Thermal Shutdown (TSD). If the LNB junction temperature rises above 165°C (typ), the LNB output will be shut off, a thermal shutdown fault (TSD) will be latched in the Status Register, and the IRQ pin will transition low. After a TSD fault, the LNB output does not respond to the Enable (ENB) bit until an I<sup>2</sup>C™ Read cycle is executed to report and clear the TSD fault. After a successful I<sup>2</sup>C™ Read, the IRQ pin transitions high and the A8304 can be re-enabled, provided the junction temperature is below 145°C (typ).

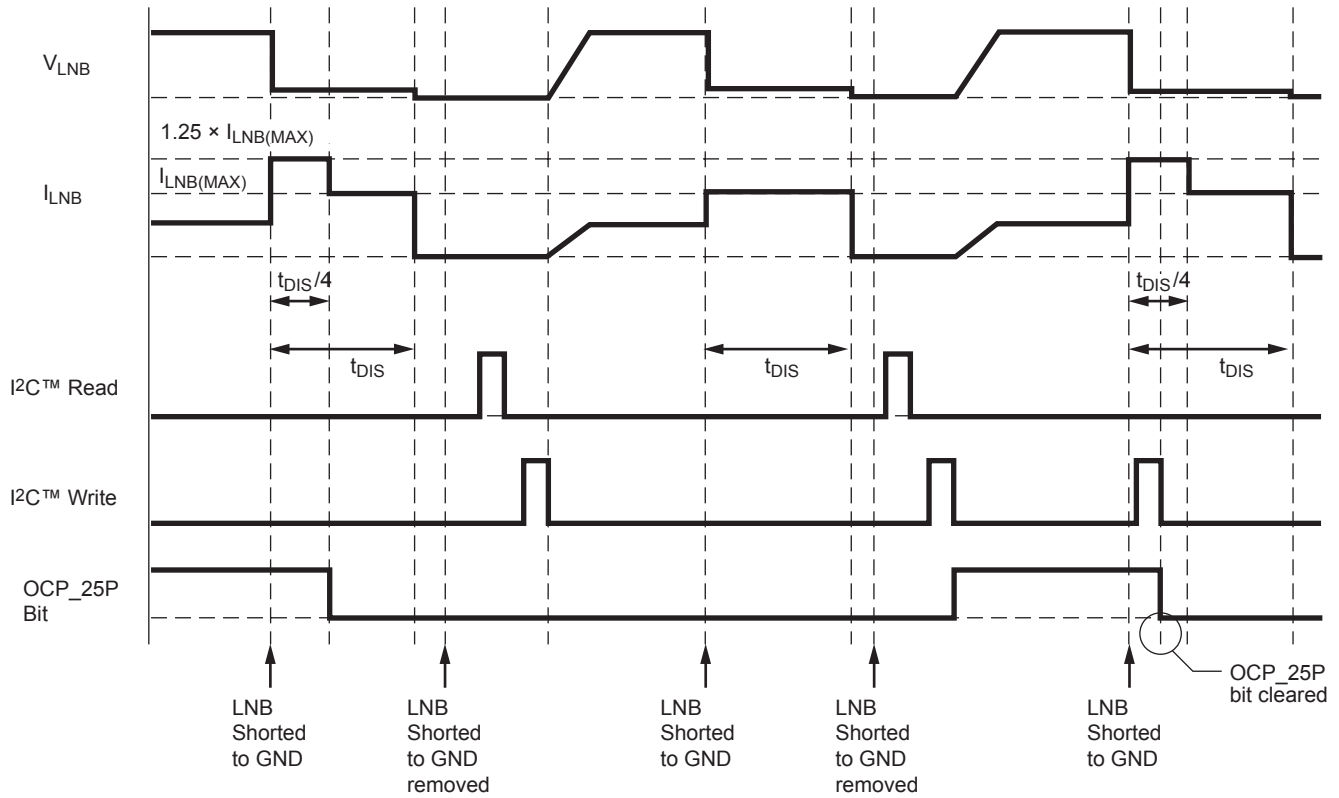


Figure 11. Initial 25% current limit bump up with OCP\_25P bit enabled, disabled, and changed during current limit condition with OCP period >  $t_{DIS}$ .

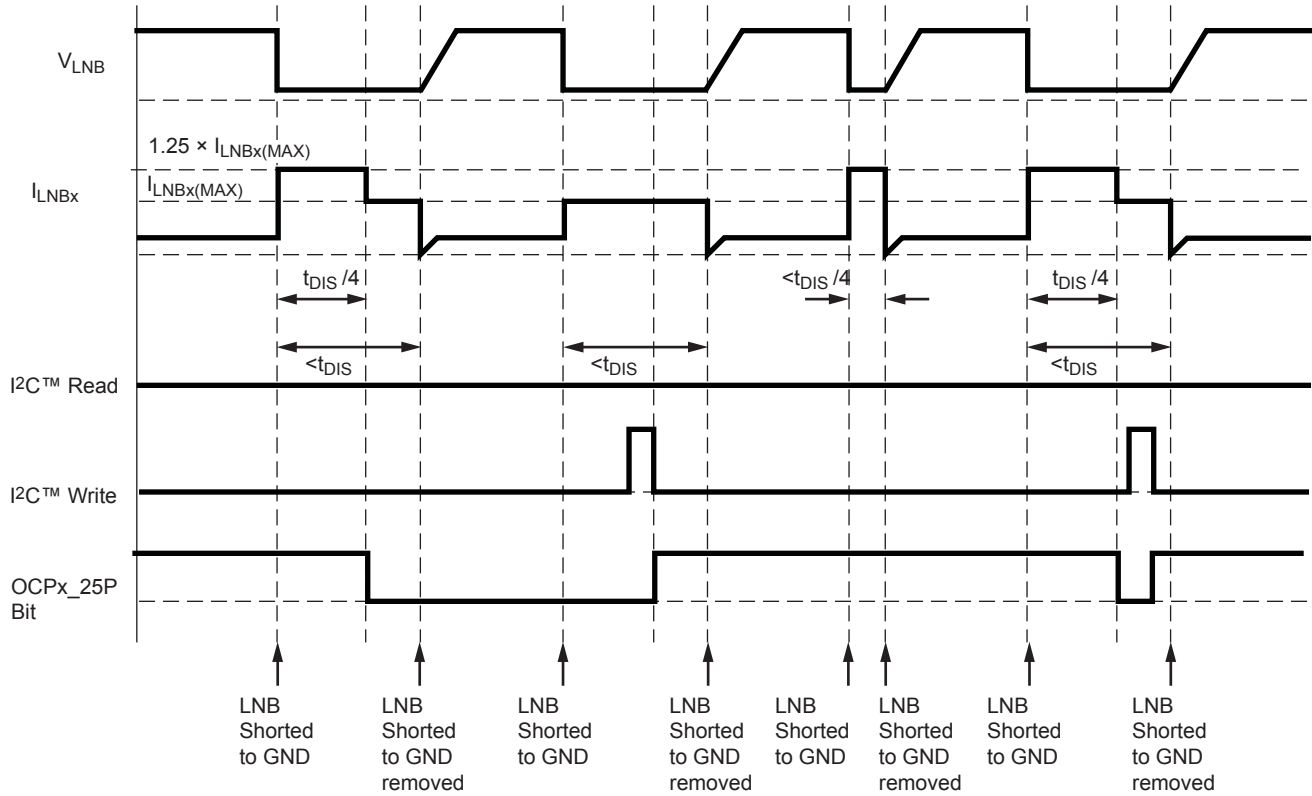
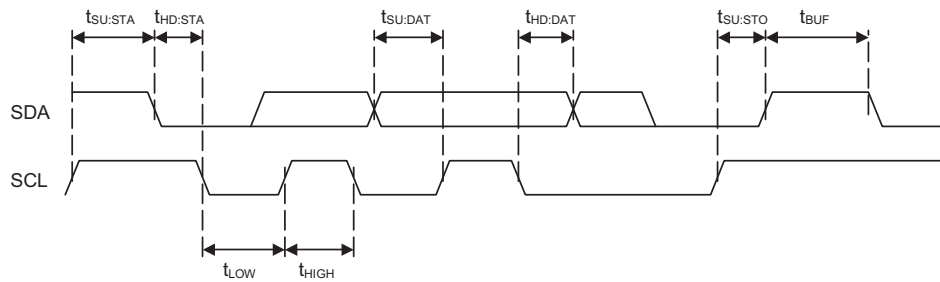


Figure 12. Initial 25% current limit bump up with OCP\_25P bit enabled, disabled, and changed during current limit condition with OCP period  $< t_{DIS}$ .



I<sup>2</sup>C™-Compatible Interface Timing DiagramI<sup>2</sup>C™-Compatible Timing Requirements

Characteristics	Symbol	Min.	Typ.	Max.	Units
Bus Free Time Between Stop/Start	$t_{BUF}$	1.3	–	–	$\mu$ s
Hold Time Start Condition	$t_{HD:STA}$	0.6	–	–	$\mu$ s
Setup Time for Start Condition	$t_{SU:STA}$	0.6	–	–	$\mu$ s
SCL Low Time	$t_{LOW}$	1.3	–	–	$\mu$ s
SCL High Time	$t_{HIGH}$	0.6	–	–	$\mu$ s
Data Setup Time	$t_{SU:DAT}$	100	–	–	ns
Data Hold Time*	$t_{HD:DAT}$	0	–	900	ns
Setup Time for Stop Condition	$t_{SU:STO}$	0.6	–	–	$\mu$ s
Output Fall Time ( $V_{f12COut(H)}$ to $V_{f12COut(L)}$ )	$t_{f12COut}$	–	–	250	ns

\*For  $t_{HD:DAT}(\text{min})$ , the master device must provide a hold time of at least 300 ns for the SDA signal in order to bridge the undefined region of the SCL signal falling edge.

**Control Register (I<sup>2</sup>C™-Compatible Write Registers)**

All main functions of the A8304 are controlled through the I<sup>2</sup>C™ compatible interface via the 8-bit Control register. Table 1 shows the functionality and bit definitions of the Control register. At power-up, the Control register is initialized to all 0s.

The LNB output will be programmed according the status of the VSEL3, VSEL2, VSEL1, and VSEL0 bits in the I<sup>2</sup>C™ Control register 0 as outlined in table 2.

**Table 1. Control Register 0 Definition, Address: 0000 0000**

Bit	Name	Function	Description
0	VSEL0	The available voltages provide levels for all the common standards plus the ability to add line compensation. VSEL0 is the LSB and VSEL3 is the MSB to the internal DAC.	LNB output voltage control See table 2 for available output voltage selections
1	VSEL1		
2	VSEL2		
3	VSEL3		
4	ENB	Turns the LNB output on or off.	0: Disable LNB Output 1: Enable LNB Output
5	TMODE	Controls tone mode.	0: Internal tone, gated with TONCTRL pin 1: External 22 kHz logic pulse, on TONCTRL pin
6	OCP_25P		25% bump up over the current limit for $t_{DIS} / 4$ period; bit resets automatically after $t_{DIS} / 4$ period
7	SINK_DIS	Controls use of internal sinks.	0: Enable internal sinks 1: Disable internal sinks

**Table 2. Output Voltage Selection**

VSEL3	VSEL2	VSEL1	VSEL0	LNB (V)
0	0	1	0	13.333
0	0	1	1	13.667
0	1	0	1	14.333
0	1	1	1	15.667
1	0	1	1	18.667
1	1	0	0	19.000
1	1	0	1	19.333
1	1	1	0	19.667

## Status Registers (I<sup>2</sup>C™-Compatible Read Register)

The main fault conditions: undervoltage lockout (UVLO), overcurrent (OCP), and thermal shutdown (TSD) are all indicated by setting the relevant bits in the Status register. In all fault cases, after the bit is set, it remains latched until the I<sup>2</sup>C™ master has successfully read the A8304, assuming the fault has been resolved.

The undervoltage lockout (UVLO) bit indicates either the input voltage at the VIN pin is too low or the A8304 internal supply voltage (VREG) is too low.

The Disable bit (DIS) indicates the status of the LNB output. The DIS is set when either a fault occurs (UVLO, OCP, TSD, or CPOK) or when the LNB output is turned off using the Enable

bit (ENB) via the I<sup>2</sup>C™ interface. The DIS bit is latched and is only reset when there are no faults and the A8304 output is turned back on using the Enable (ENB) bit via the I<sup>2</sup>C™ interface.

The Power Not Good (PNG) and Charge Pump OK (CPOK) bits are set based on the conditions sensed at the LNB output and VCP pins, respectively. These bits are not latched and, unlike the other fault bits, may become reset without an I<sup>2</sup>C™ read sequence. The PNG and CPOK bits are continuously updated.

There are three methods to detect when the Status register changes: responding to the interrupt request (IRQ) pin going low, continuously polling the Status register via the I<sup>2</sup>C™ interface, or detecting a fault condition external to the A8304 and performing a diagnostic poll of the A8304. In any case, the master should read and re-read the Status register until the status changes.

**Table 3. Status Register Description and IRQ Operation**

Bit	Name	Function	Latched?	Reset Condition	Effect on IRQ Pin
0	DIS	LNB output disabled	Yes	LNB enabled and no faults	None
1	CPOK	Charge pump OK	No	$V_{CP} > V_{BOOST} + 5V$	None
2	OCP	Overcurrent	Yes	I <sup>2</sup> C™ read and fault removed	IRQ set low
3	–	Not used	–	–	–
4	PNG	Power Not Good	No	LNB voltage within range	None
5	–	Not used	–	–	–
6	TSD	Thermal shutdown	Yes	I <sup>2</sup> C™ read and fault removed	IRQ set low
7	UVLO	VIN or VREG undervoltage	Yes	I <sup>2</sup> C™ read and fault removed	IRQ set low

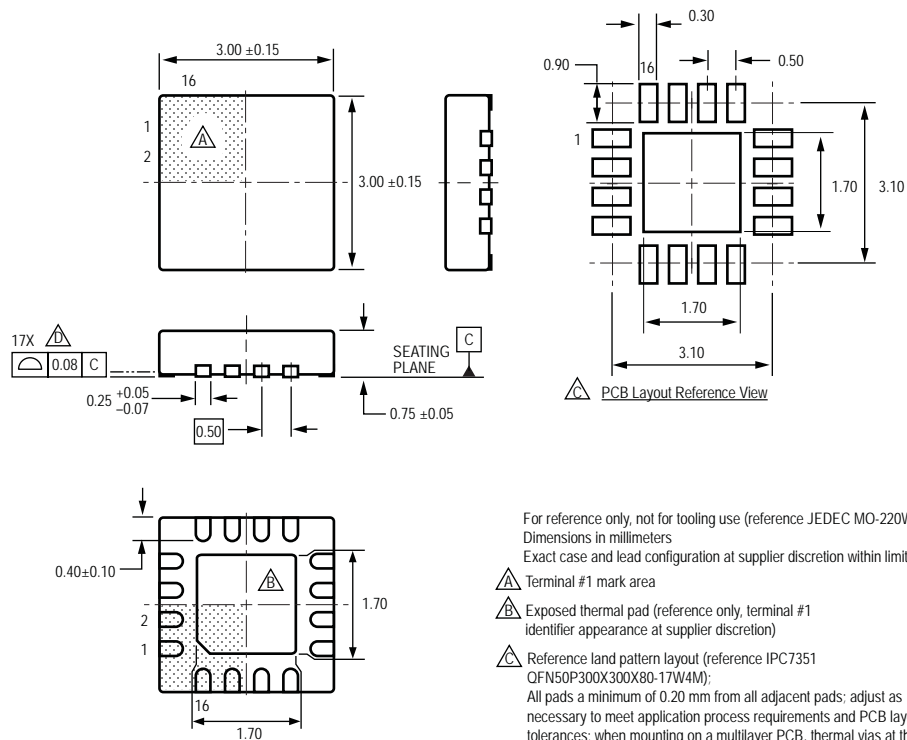
**Table 4. Status Register Bit Descriptions**

Bit	Name	Description
0	DIS	The DIS bit is set to 1 when the A8304 is disabled, (ENB = 0) or there is a fault: UVLO, OCP, CPOK, or TSD.
1	CPOK	If this bit is set low, the internal charge pump is not operating correctly (VCP). If the charge pump voltage is too low, the LNB output is disabled and the DIS bit is set.
2	OCP	This bit will be set to a 1 if the LNB output current exceeds the overcurrent threshold ( $I_{LNB(MAX)}$ ) for more than the overcurrent disable time ( $t_{DIS}$ ). If the OCP bit is set to 1, then the DIS bit is also set to 1.
3	–	Not used.
4	PNG	Set to 1 when the A8304 is enabled and the LNB output voltage is either too low or too high (nominally $\pm 9\%$ from the LNB DAC setting). Set to 0 when the A8304 is enabled and the LNB voltage is within the acceptable range (nominally $\pm 5\%$ from the LNB DAC setting).
5	–	Not used.
6	TSD	The TSD bit is set to 1 if the A8304 has detected an overtemperature condition. If the TSD bit is set to 1, then the DIS bit is also set to 1.
7	UVLO	The UVLO bit is set to 1 if either the voltage at the VIN pin or the voltage at the VREG pin is too low. If the UVLO bit is set to 1, then the DIS bit is also set to 1.

Table 5. Component Selection Table

Component	Characteristics	Manufacturer Device
C1, C4, C7, C8	100 nF, 50 V, X5R or X7R, 0603	
C2, C5	100 $\mu$ F, 35 V <sub>MIN</sub> , ESR < 140 m $\Omega$ , I <sub>RIPPLE</sub> > 550 mA	Panasonic: EEU-FM1H101B ChemiCon: EKZE500ELL101MHB5D Nichicon: UHC1V101MPT
C3	220 nF, 10 V <sub>MIN</sub> , X5R or X7R, 0402 or 0603	
C6	1.0 $\mu$ F, 25 V <sub>MIN</sub> , X5R or X7R, 1206	TDK: C3216X7R1E105K Murata: GRM31MR71E105KA01 Taiyo Yuden: TMK316BJ105KL-T Kemet: C1206C105K3RACTU
C9	10 nF, 50 V, X5R or X7R, 0402 or 0603	
C10	220 nF, 50 V, X5R or X7R, 0805	
D1, D2	Schottky diode, 40 V, 1 A, SOD-123	Diodes, Inc: B140HW-7 Central Semi: CMMSH1-40
D3	Schottky diode, 40 V, 3 A, SMA	Sanken: SFPB-74 Vishay: B340A-E3/5AT Diodes, Inc.: B340A-13-F Central Semi: CMSH3-40MA
D4	TVS, 20 V <sub>RM</sub> , 32 V <sub>CL</sub> at 500 A (8/20 $\mu$ s), 3000 W	ST: LNBTVS6-221S, Littelfuse: 3.0SMCJ20A
L1	10 $\mu$ H, $\pm$ 20%, 3.4 A <sub>SAT</sub> , 45 m $\Omega$	Taiyo Yuden- NR8040T100M
R1 to R5	Determined by V <sub>DD</sub> , bus capacitance, etc.	

## Package ES 16-Pin QFN



- For reference only, not for tooling use (reference JEDEC MO-220WEED)  
 Dimensions in millimeters  
 Exact case and lead configuration at supplier discretion within limits shown
- Terminal #1 mark area
  - Exposed thermal pad (reference only, terminal #1 identifier appearance at supplier discretion)
  - Reference land pattern layout (reference IPC7351 QFN50P300X300X80-17W4M); All pads a minimum of 0.20 mm from all adjacent pads; adjust as necessary to meet application process requirements and PCB layout tolerances; when mounting on a multilayer PCB, thermal vias at the exposed thermal pad land can improve thermal dissipation (reference EIA/JEDEC Standard JESD51-5)
  - Coplanarity includes exposed thermal pad and terminals