

Evaluating the **ADN8834** Ultracompact 1.5 A Thermoelectric Cooler (TEC) Controller

FEATURES

Full featured evaluation boards for the **ADN8834**

Complete TEC controller with integrated 1.5 A TEC driver

Operating voltage range: $V_{IN} = 2.7\text{ V to }5.5\text{ V}$

TEC voltage and current operation monitoring

Independent TEC heating and cooling current-limit settings

Programmable maximum TEC voltage

External synchronization from 1.85 MHz to 3.25 MHz

Input for NTC thermistor connection

Output for TEC module wires

2.5 V reference output

Disable jumper

40 mm × 25 mm WLCSP evaluation board size

45 mm × 25 mm LFCSP evaluation board size

DOCUMENTS NEEDED

[ADN8834](#) data sheet

ADN8834CB-EVALZ AND ADN8834CP-EVALZ EVALUATION BOARDS



Figure 1. *ADN8834CB-EVALZ* WLCSP Evaluation Board

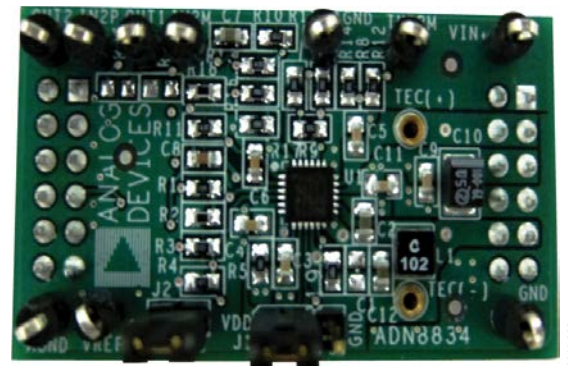


Figure 2. *ADN8834CP-EVALZ* LFCSP Evaluation Board

GENERAL DESCRIPTION

The **ADN8834CB-EVALZ** and **ADN8834CP-EVALZ** are configurable evaluation boards designed to work with various TEC modules and thermistors. The **ADN8834** on the evaluation board delivers and controls bidirectional current through a TEC controller using two pairs of the complementary integrated MOSFETs in an H bridge configuration.

The TEC cooling and heating current limits are set to 1.5 A, and the maximum TEC voltage is programmed to 3 V using two on-board resistor dividers. The temperature setpoint circuit is optimized to work with a 10 k Ω NTC thermistor. The on-board proportional integral differential (PID) compensation network

components can be replaced by soldering different value components that match the temperature control loop characteristic with the thermal load to achieve the required response time and temperature stability. The cooling and heating TEC current limits and maximum TEC voltage setting can also be modified by changing the values of the corresponding components.

In addition, the board can be plugged into the **ADN8834** base board, which has adjustable components for the tunable analog thermal PID network, the temperature setpoint, and maximum TEC current and TEC voltage limits.

TABLE OF CONTENTS

Features	1	Cooling and Heating TEC Current Limits	4
Documents Needed.....	1	PWM Operation Frequency	4
ADN8834CB-EVALZ and ADN8834CP-EVALZ Evaluation Boards.....	1	Read the TEC Voltage.....	5
General Description	1	Read the TEC Current	5
Revision History	2	TEC Driver Control	5
Using the Evaluation Board.....	3	Using the Base Board	6
Board Connection	3	Evaluation Board Schematics and Artwork.....	7
Maximum TEC Voltage.....	3	Ordering Information.....	14
		Bill of Materials.....	14

REVISION HISTORY

10/15—Revision 0: Initial Version

USING THE EVALUATION BOARD

BOARD CONNECTION

Apply a power source to the VIN (ADN8834CB-EVALZ)/VIN+ (ADN8834CP-EVALZ) and GND terminals. Connect the TEC module to TEC+ and TEC-. Connect the thermistor to the THERM and AGND terminals. The power source voltage must be between 2.7 V and 5.5 V, the power supply range of the ADN8834. Connect the EN/SY pin to VDD and remove the shunt from the VLIM/SD jumper to enable the controller.

MAXIMUM TEC VOLTAGE

The maximum TEC cooling voltage is set to 3 V by the values of $R_{V1} = 6.65 \text{ k}\Omega$ and $R_{V2} = 10 \text{ k}\Omega$.

To change the setting, modify the value of R_{V1} using the equations provided in the Using a Resistor Divider to Set the TEC Voltage Limit section (for more information, refer to the ADN8834 data sheet) or by following the recommended values in Table 1.

Using a Resistor Divider to Set the TEC Voltage Limit

Calculate the cooling and heating limits using the following equations:

$$V_{VLIM_COOLING} = V_{REF} \times R_{V2} / (R_{V1} + R_{V2})$$

where $V_{REF} = 2.5 \text{ V}$.

$$V_{VLIM_HEATING} = V_{VLIM_COOLING} - I_{SINK_VLIM} \times R_{V1} \parallel R_{V2}$$

where $I_{SINK_VLIM} = 10 \mu\text{A}$.

$$V_{TEC_MAX_COOLING} = V_{VLIM_COOLING} \times A_{VLIM}$$

where $A_{VLIM} = 2 \text{ V/V}$.

$$V_{TEC_MAX_HEATING} = V_{VLIM_HEATING} \times A_{VLIM}$$

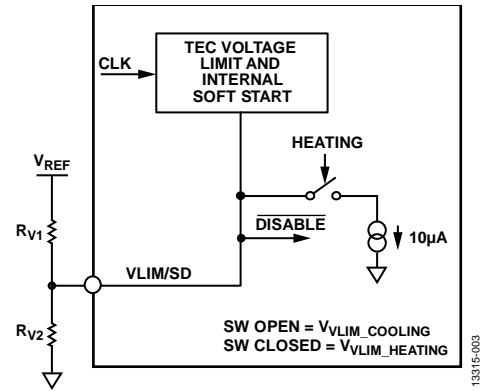


Figure 3. Programming the Maximum TEC Voltage

Table 1. Setting the Maximum TEC Voltage ($R_{V2} = 10 \text{ k}\Omega$)

$V_{TEC_MAX_COOLING} \text{ (V)}^1$	$V_{VLIM_COOLING} \text{ (V)}^2$	$R_{V1} \text{ (k}\Omega)^3$	$V_{TEC_COOLING} \text{ (V)}^4$	$R_{V1} \parallel R_{V2} \text{ (k}\Omega)^3$	$V_{VLIM_HEATING} \text{ (V)}^5$	$V_{TEC_MAX_HEATING} \text{ (V)}^6$	$V_{TEC_HEATING} \text{ (V)}^7$
4.750	2.375	0.53	2.438	0.5	2.370	4.740	0.065
4.500	2.250	1.11	2.375	1.0	2.240	4.480	0.130
4.250	2.125	1.76	2.313	1.5	2.110	4.220	0.195
4.000	2.000	2.50	2.250	2.0	1.980	3.960	0.260
3.750	1.875	3.33	2.188	2.5	1.850	3.700	0.325
3.500	1.750	4.29	2.125	3.0	1.720	3.440	0.390
3.250	1.625	5.38	2.063	3.5	1.590	3.180	0.455
3.000	1.500	6.67	2.000	4.0	1.460	2.920	0.520
2.750	1.375	8.18	1.938	4.5	1.330	2.660	0.585
2.500	1.250	10.00	1.875	5.0	1.200	2.400	0.650
2.250	1.125	12.22	1.813	5.5	1.070	2.140	0.715
2.000	1.000	15.00	1.750	6.0	0.940	1.880	0.780
1.750	0.875	18.57	1.688	6.5	0.810	1.620	0.845
1.500	0.750	23.33	1.625	7.0	0.680	1.360	0.910
1.250	0.625	30.00	1.563	7.5	0.550	1.100	0.975
1.000	0.500	40.00	1.500	8.0	0.420	0.840	1.040
0.750	0.375	56.67	1.438	8.5	0.290	0.580	1.105
0.500	0.250	90.00	1.375	9.0	0.160	0.320	1.170
0.250	0.125	190.00	1.313	9.5	0.030	0.060	1.235

¹ $V_{TEC_MAX_COOLING}$ is the maximum target TEC voltage when the ADN8834 operates in cooling mode.

² $V_{VLIM_COOLING}$ is the voltage set at the VLIM/SD input pin for cooling.

³ R_{V1} is the required value of Resistor R1. R_{V2} is the required value of Resistor R2.

⁴ $V_{TEC_COOLING}$ is the voltage at the VTEC output when the TEC voltage reaches the maximum in cooling mode.

⁵ $V_{VLIM_HEATING}$ is the voltage set at the VLIM/SD input pin for heating.

⁶ $V_{TEC_MAX_HEATING}$ is the maximum TEC voltage set when the ADN8834 operates in heating mode.

⁷ $V_{TEC_HEATING}$ is the voltage at the VTEC output when the TEC voltage reaches the maximum in heating mode.

COOLING AND HEATING TEC CURRENT LIMITS

The maximum TEC cooling and heating current limits are both set to 1.5 A by the values of the resistors, $R_{C3} = 210\text{ k}\Omega$ and $R_{C4} = 48.7\text{ k}\Omega$. To change the settings, use the equations provided in the Using a Resistor Divider to Set the TEC Current Limit section (for more information, refer to the ADN8834 data sheet) or use the values recommended in Table 3.

Using a Resistor Divider to Set the TEC Current Limit

Use the following equations to calculate the maximum TEC currents:

$$V_{ILIM_HEATING} = V_{REF} \times R_{C2} / (R_{C1} + R_{C2})$$

where $V_{REF} = 2.5\text{ V}$.

$$V_{ILIM_COOLING} = V_{ILIM_HEATING} + I_{SINK_ILIM} \times R_{C1} \parallel R_{C2}$$

where $I_{SINK_ILIM} = 40\text{ }\mu\text{A}$.

$$I_{TEC_MAX_COOLING} = \frac{V_{ILIM_COOLING} - 1.25\text{ V}}{R_{CS}}$$

where $R_{CS} = 0.525\text{ V/A}$.

$$I_{TEC_MAX_HEATING} = \frac{1.25\text{ V} - V_{ILIM_HEATING}}{R_{CS}}$$

$V_{ILIM_HEATING}$ must not exceed 1.2 V and $V_{ILIM_COOLING}$ must be more than 1.3 V to leave proper margins between the heating and the cooling modes.

Table 3. Values of the Resistor Divider for ILIM Settings

$I_{TEC_MAX_COOLING}\text{ (A)}^1$	$V_{ILIM_COOLING}\text{ (V)}^2$	$I_{TEC_MAX_HEATING}\text{ (A)}^3$	$V_{ILIM_HEATING}\text{ (V)}^4$	$R_{C1}\text{ (k}\Omega)^5$	$R_{C2}\text{ (k}\Omega)^5$	$R_{C1} \parallel R_{C2}\text{ (k}\Omega)^5$
1.6	2.090	-1.6	0.410	256.1	50.2	42.000
1.5	2.038	-1.5	0.463	212.8	48.3	39.375
1.4	1.985	-1.4	0.515	178.4	46.3	36.750
1.3	1.933	-1.3	0.568	150.3	44.1	34.125
1.2	1.880	-1.2	0.620	127.0	41.9	31.500
1.1	1.828	-1.1	0.673	107.3	39.5	28.875
1.0	1.775	-1.0	0.725	90.5	37.0	26.250
0.9	1.723	-0.9	0.778	76.0	34.3	23.625
0.8	1.670	-0.8	0.830	63.3	31.4	21.000
0.7	1.618	-0.7	0.883	52.1	28.4	18.375
0.6	1.565	-0.6	0.935	42.1	25.2	15.750
0.5	1.513	-0.5	0.988	33.2	21.7	13.125
0.4	1.460	-0.4	1.040	25.2	18.0	10.500
0.3	1.408	-0.3	1.093	18.0	14.0	7.875

¹ $I_{TEC_MAX_COOLING}$ is the maximum target TEC current when the ADN8834 operates in cooling mode.
² $V_{ILIM_COOLING}$ is the voltage set at the ILIM pin when the ADN8834 operates in cooling mode.
³ $I_{TEC_MAX_HEATING}$ is the maximum target TEC current when the ADN8834 operates in heating mode.
⁴ $V_{ILIM_HEATING}$ is the voltage set at the ILIM pin when the ADN8834 operates in heating mode.
⁵ R_{C1} is the required value of Resistor R3. R_{C2} is the required value of Resistor R4.

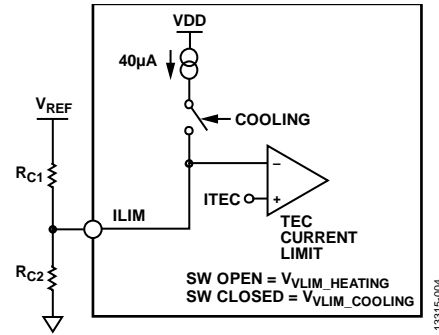


Figure 4. Programming the TEC Current Cooling and Heating Limits

PWM OPERATION FREQUENCY

The frequency of the PWM TEC driver stage can be configured at the 3-pin jumper, J1. Apply the external synchronization clock signal to the middle pin of the jumper. Note that the middle pin can also be used to shut down the device when it is pulled below 0.8 V. Therefore, when applying the external clock signal, ensure that the high level is greater than 2.1 V and the low level is less than 0.8 V. The combinations of EN/SY pin are shown in Table 2.

Table 2. SYNC/EN Pin Settings

SYNC/EN Pin	PWM Operation Frequency
Low (< 0.8 V)	Shutdown
Open	Shutdown
High (> 2.1 V)	2 MHz
External Clock Signal (High > 2.1 V, Low < 0.8 V)	From 1.85 MHz to 3.25 MHz

READ THE TEC VOLTAGE

The voltage on the VTEC output pin is proportional to the voltage across the TEC and is measured at Connector J5/Pin 1 (ADN8834CB-EVALZ) or J6/Pin 11 (ADN8834CP-EVALZ). The relationship between the voltage on the VTEC output and the voltage across the TEC is as follows:

$$V_{TEC} = V_{LDR} - V_{SFB} = 4 \times (V_{VTEC} - 0.5 \times V_{REF})$$

where:

V_{TEC} is the voltage across the TEC.

V_{LDR} is the voltage measured at the LDR pin.

V_{SFB} is the voltage measured at the SFB pin.

V_{VTEC} is the voltage measured at the VTEC pin.

V_{REF} is the reference voltage, 2.5 V.

READ THE TEC CURRENT

The voltage on the ITEC output pin is proportional to the TEC current, and is measured at Connector J5/Pin 2 (ADN8834CB-EVALZ) or J6/Pin 12 (ADN8834CP-EVALZ). Calculate the TEC current from the ITEC pin voltage as follows:

$$I_{TEC} = \frac{V_{ITEC} - 0.5 \times V_{REF}}{R_{CS}}$$

where:

I_{TEC} is the TEC current; defined as the current flowing into the TEC positive terminal, TEC+, and out of the TEC negative terminal, TEC-.

V_{ITEC} is the voltage measured at the ITEC pin.

R_{CS} is the current sense gain, 0.525 V/A.

V_{REF} is the reference voltage, 2.5 V.

TEC DRIVER CONTROL

The TEC driver has a linear driver LDR and a PWM driver with an SW output and a voltage feedback input pin, SFB. It is controlled by the voltage signal at the OUT2 pin. The equations for the linear and PWM driver outputs, respectively, are as follows:

$$V_{LDR} = V_B - 40 (V_{OUT2} - 1.25 \text{ V}) \quad (1)$$

$$V_{SFB} = V_{LDR} + 5 (V_{OUT2} - 1.25 \text{ V}) \quad (2)$$

where:

V_{OUT2} is the voltage at the OUT2 pin.

V_B is determined by voltage at the VDD pin as

$$V_B = 1.5 \text{ V} (V_{VDD} < 4.0 \text{ V}) \quad (3)$$

$$V_B = 2.5 \text{ V} (V_{VDD} > 4.0 \text{ V}) \quad (4)$$

The V_{LDR} and V_{SFB} voltages are limited by the power supply voltage with the upper limit of V_{VDD} and the lower limit of 0 V.

The voltage at the OUT2 pin is determined by the compensation amplifier with the PID network. This amplifier receives the temperature setpoint voltage at the IN2P input and the thermistor voltage at the IN2N pin fed by the OUT1 pin of the error amplifier.

If the digital temperature control loop is used, configure the compensation amplifier as a unity-gain follower by connecting the OUT2 pin to IN2N, and then apply the control signal from a DAC to the IN2P input. Thus, the OUT2 pin voltage is equal to the DAC voltage at the IN2P pin, and the TEC driver outputs follow Equation 1 and Equation 2.

USING THE BASE BOARD

The [ADN8834](#) base board, which is available upon request, allows the user to tune the PID components in analog thermal control loop because it has a set of selectable R and C values. In addition, it offers adjustable components that allow the user to change the maximum TEC voltage and cooling and heating current limits. The temperature setpoint can be also changed manually. Connect a [ADN8834CB-EVALZ](#) or [ADN8834CP-EVALZ](#) board to the base board as the daughter card. To avoid duplication, remove several configuration components from the daughter card before connecting it into the [ADN8834](#) base board (see Table 4).

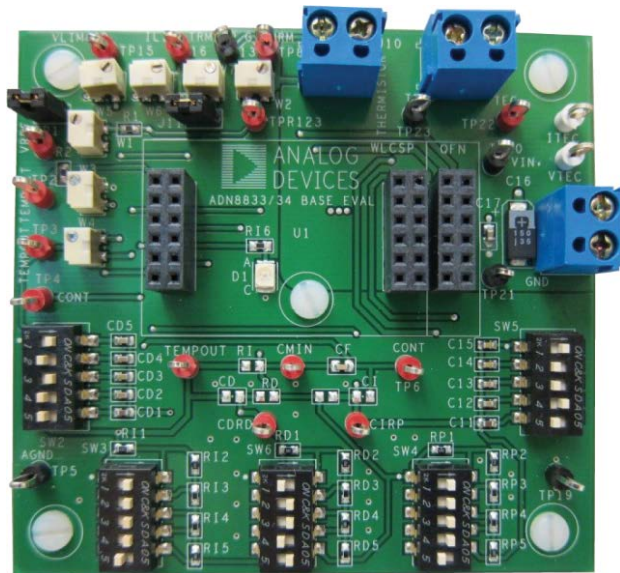


Figure 5. [ADN8834](#) Base Board

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Table 4. Configuration Components to Be Removed from [ADN8834CB-EVALZ](#) or [ADN8834CP-EVALZ](#) Board

Component	Value	Function
R1	6.65 kΩ	Voltage limit (VLIM)
R3	210 kΩ	Current limit (ILIM)
R4	48.7 kΩ	ILIM
R10	165 kΩ	PID compensation amplifier
C7	10 μF	PID compensation amplifier
R13	1.87 MΩ	PID compensation amplifier
R16	20 kΩ	Temperature setpoint (TEMPSET)
R17	20 kΩ	TEMPSET
R11	1.87 MΩ	PID compensation amplifier
C8	1.5 μF	PID compensation amplifier
C6	0.01 μF	PID compensation amplifier
R9	80.6 kΩ	Thermistor amplifier
R8	7.68 kΩ	Thermistor amplifier
R12	17.8 kΩ	Thermistor amplifier

EVALUATION BOARD SCHEMATICS AND ARTWORK

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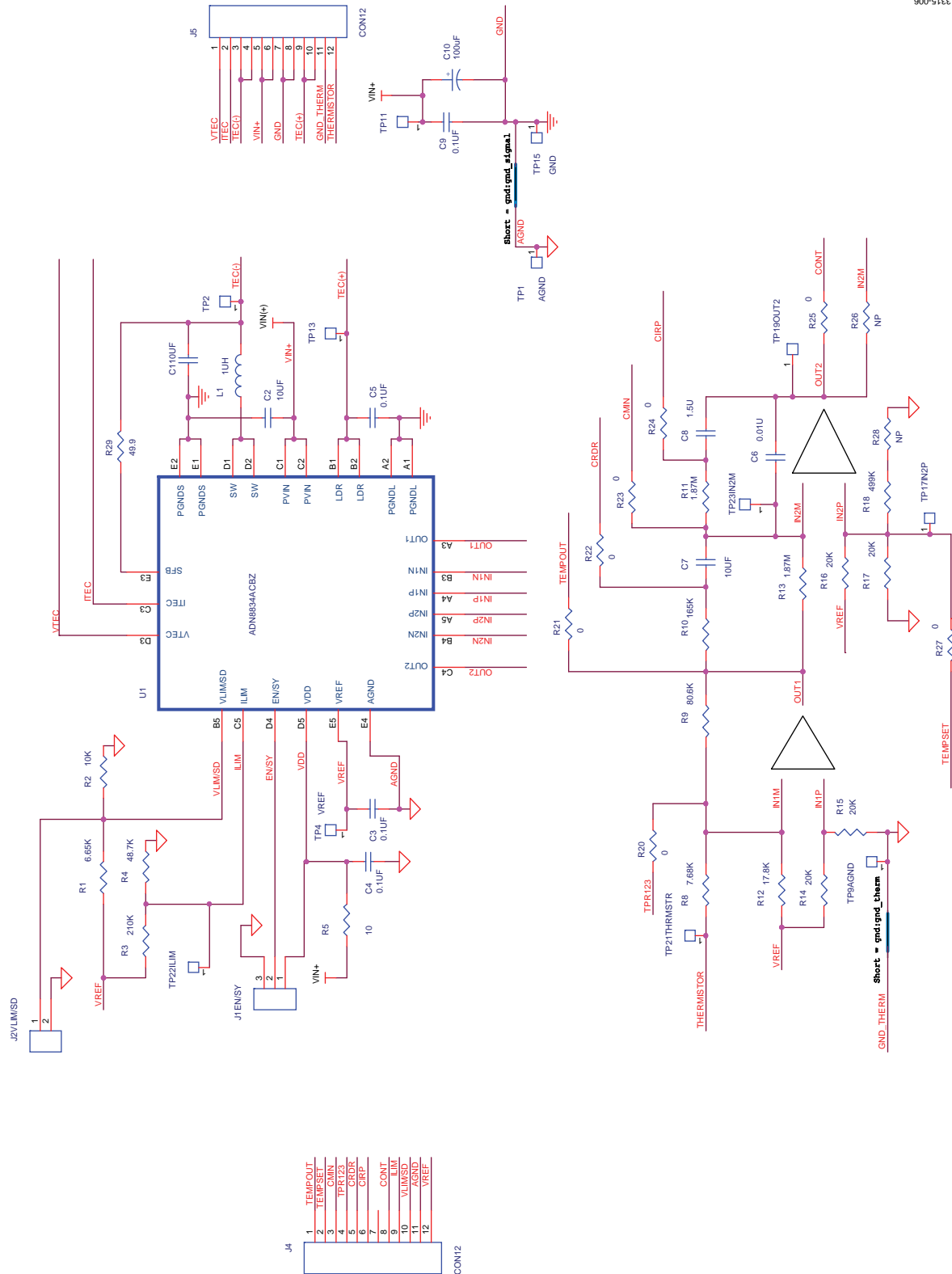


Figure 6. ADN8834CB-EVALZ WLCSP Evaluation Board Schematic

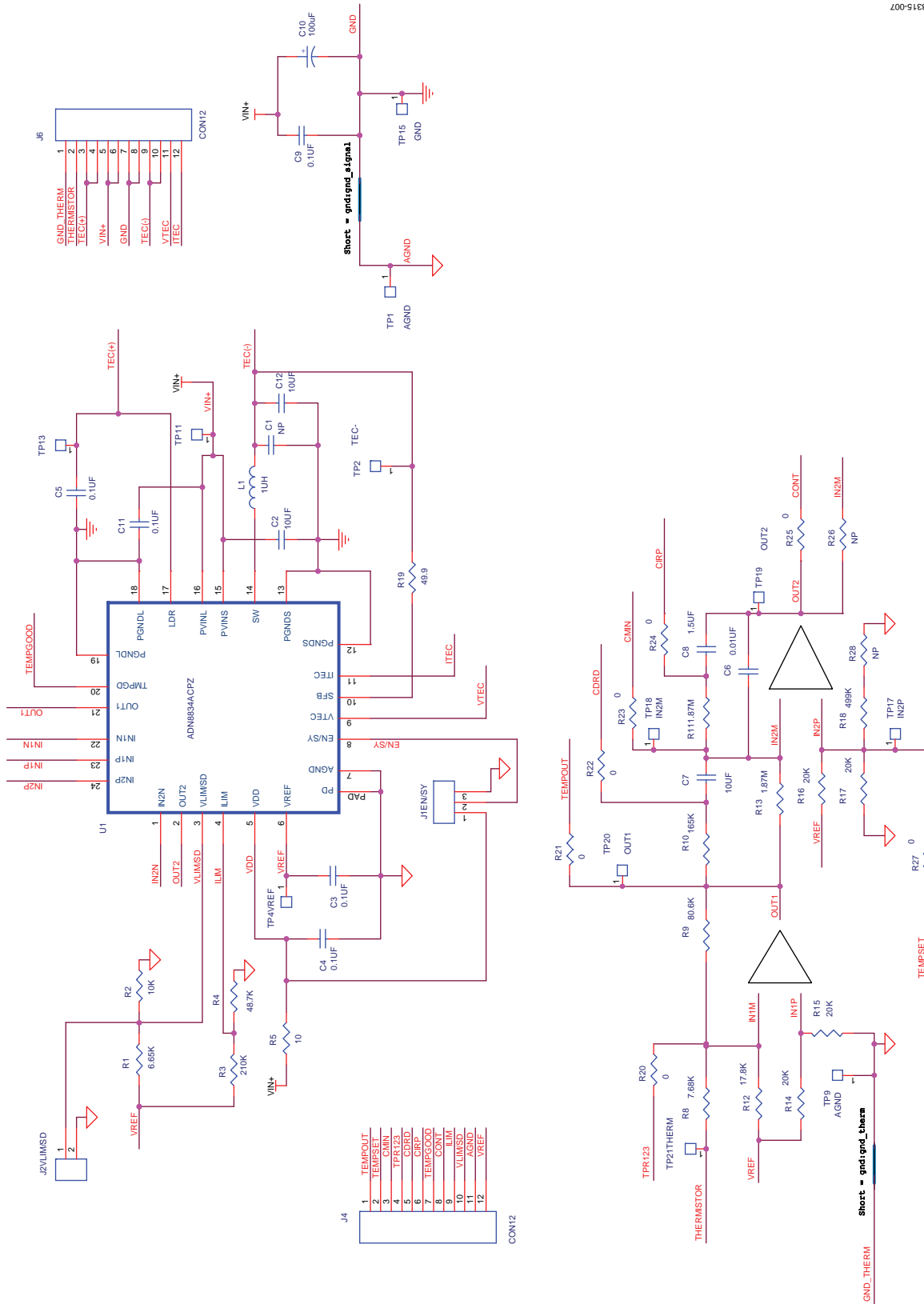


Figure 7. ADN8834CP-EVALZ LFCSP Evaluation Board Schematic

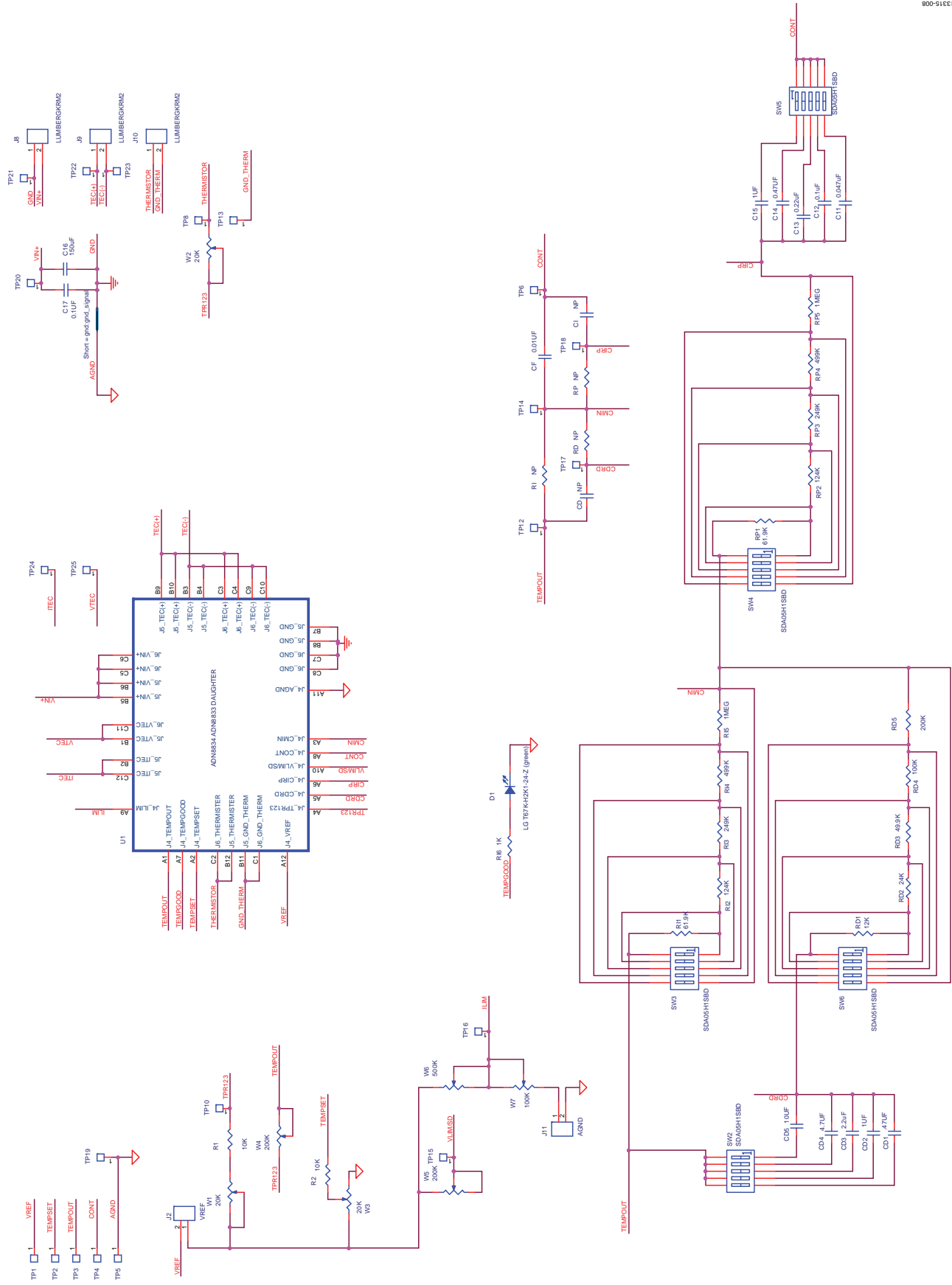


Figure 8. ADN8834 Base Board Schematic
Rev. 0 | Page 9 of 16

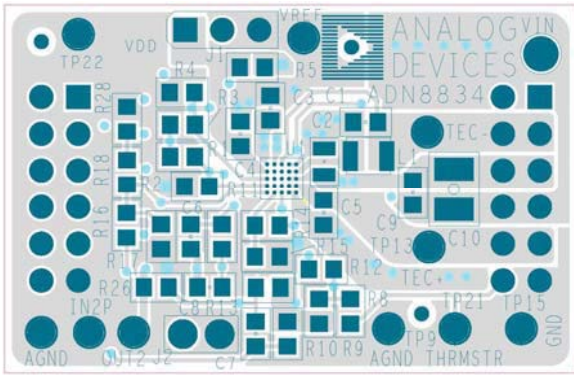


Figure 9. ADN8834CB-EVALZ Evaluation Board Top Layer

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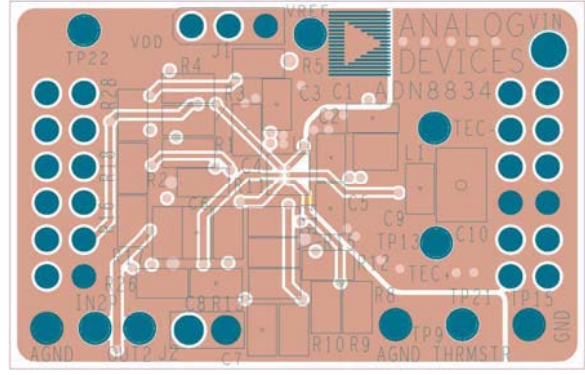


Figure 11. ADN8834CB-EVALZ Evaluation Board Second Layer

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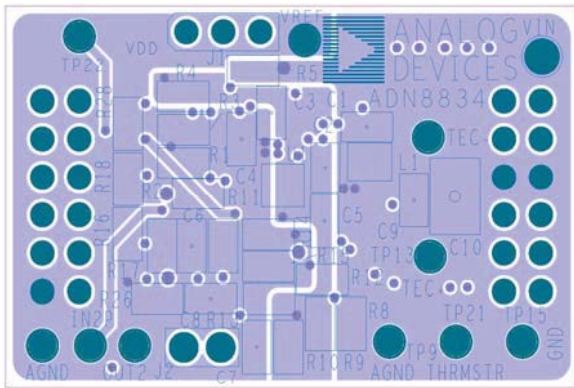


Figure 10. ADN8834CB-EVALZ Evaluation Board Third Layer

13315-010

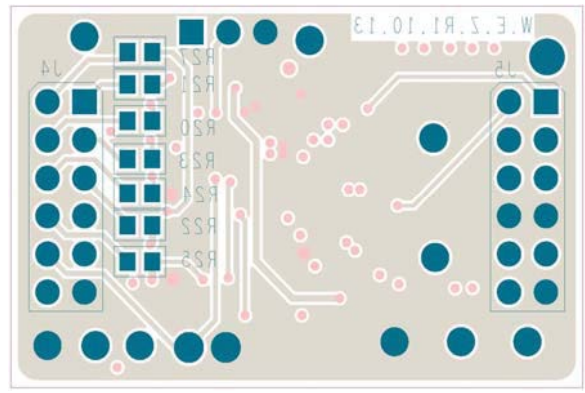
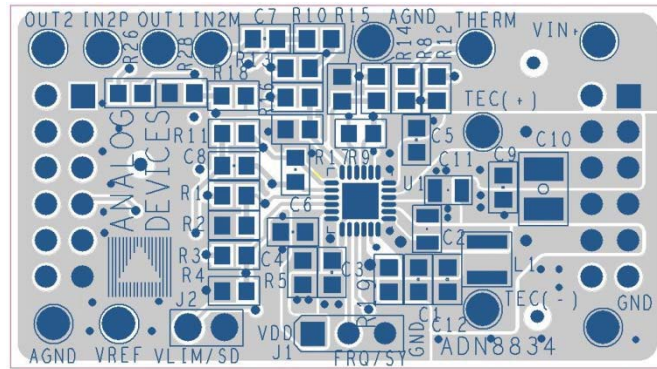


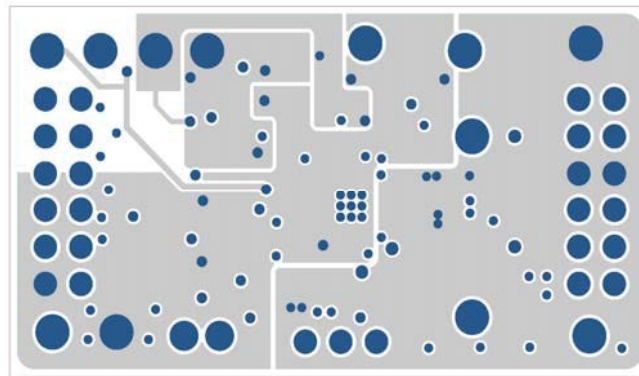
Figure 12. ADN8834CB-EVALZ Evaluation Board Bottom Layer

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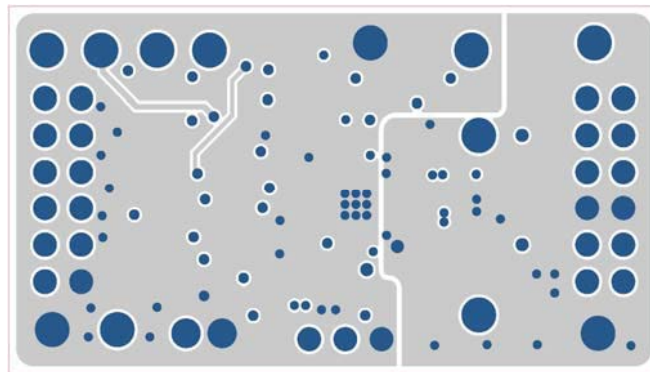
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Figure 13. ADN8834CP-EVALZ Evaluation Board Top Layer



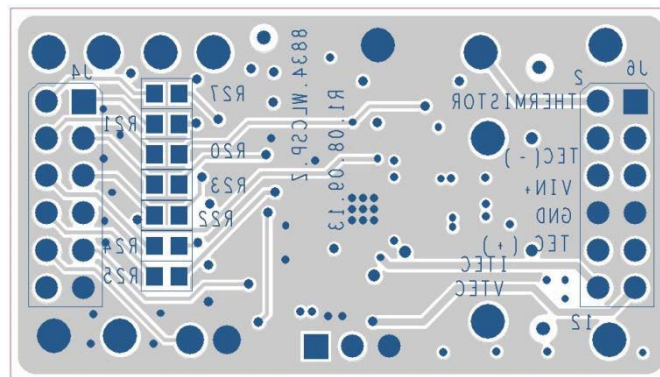
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Figure 14. ADN8834CP-EVALZ Evaluation Board Second Layer



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Figure 15. ADN8834CP-EVALZ Evaluation Board Third Layer



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Figure 16. ADN8834CP-EVALZ Evaluation Board Bottom Layer

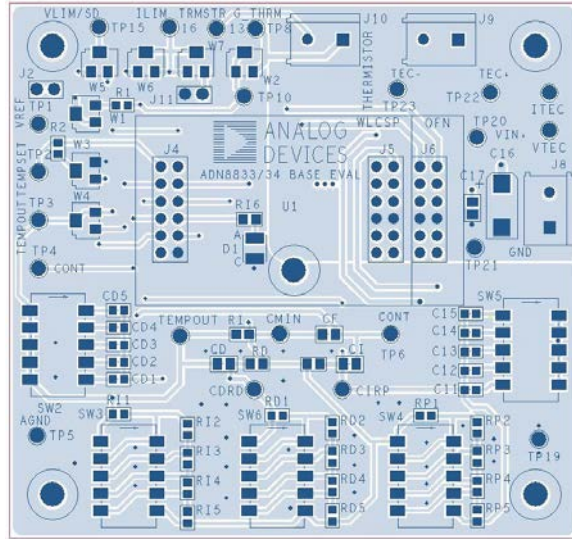


Figure 17. ADN8834 Base Board Top Layer

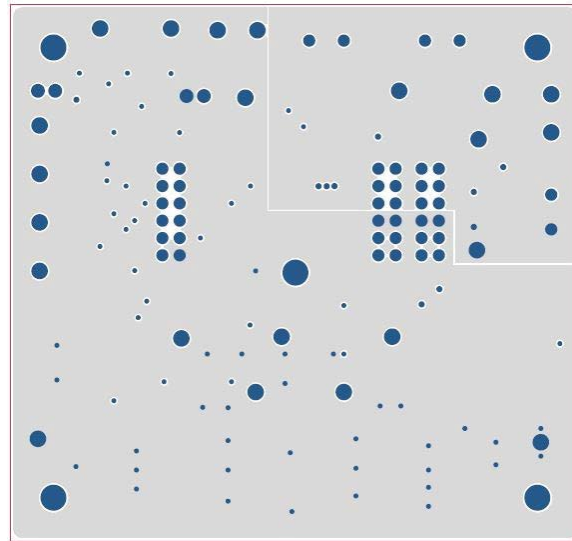
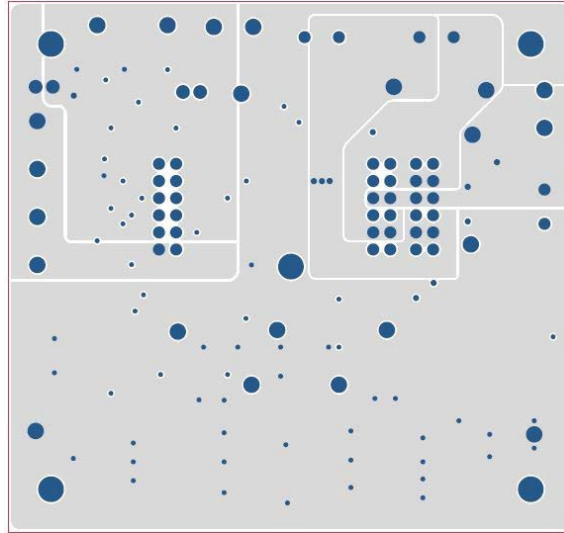
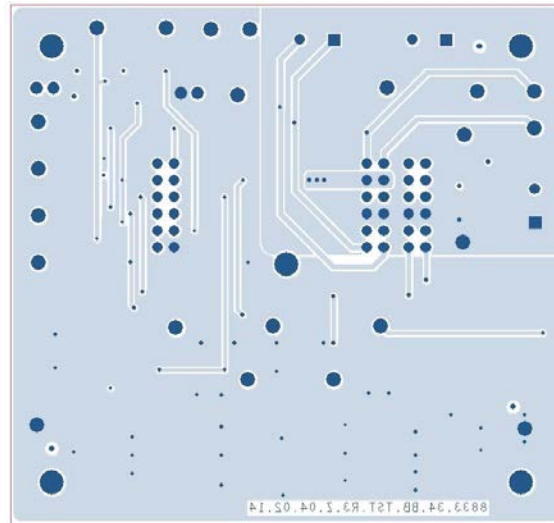


Figure 18. ADN8834 Base Board Layer 2



13315-019

Figure 19. ADN8834 Base Board Layer 3



13315-020

Figure 20. ADN8834 Base Board Bottom Layer

ORDERING INFORMATION

BILL OF MATERIALS

Table 5. ADN8834CB-EVALZ WLCSP Evaluation Board

Quantity	Reference	Description	Manufacturer	Part Number
3	C1, C2, C8	Ceramic capacitor, 10 μ F, 10 V, 10%, X7R, 0805	Taiyo Yuden	LMK212B7106KG-TD
5	C3, C4, C5, C9, C11	Ceramic capacitor, 0.1 μ F, 10 V, 10%, X7R, 0603	Kemet	C0603C104K8RACTU
2	C6, C7	Ceramic capacitor, 0.01 μ F, 50 V, 10%, X7R, 0603	Kemet	C0603C103K5RACTU
1	C10	Tantalum capacitor, 100 μ F, 6.3 V, 20%, 1411	Vishay	293D107X06R3B2T
1	J1	Jumper, 3-pin	Samtec	TSW-103-08-G-S
1	J2	Jumper, 2-pin	Samtec	TSW-103-08-G-S
2	J4, J5	Connector, double row, male, 12-pin	Samtec	TSW-112-08-G-D
1	L1	Inductor, 1 μ H	TOKO	1286AS-H-1R0M
1	R1	Resistor, 6.65 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW06036K65FKEA
1	R2	Resistor, 10 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	ERJ-3EKF1002V
1	R3	Resistor, 210 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW0603210KFKEA
1	R4	Resistor, 48.7 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060348K7FKEA
1	R5	Resistor, 10.0 Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060310R0FKEA
1	R8	Resistor, 7.68 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW06037K68FKEA
1	R9	Resistor, 80.6 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060380K6FKEA
1	R12	Resistor, 17.8 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060317K8FKEA
1	R10	Resistor, 374 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW0603165KFKEA
1	R11	Resistor, 100 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW0603100KFKEA
1	R13	Resistor, 64.9 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060364K9FKEA
4	R14, R15, R16, R17	Resistor, 20.0 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060320K0FKEA
1	R18	Resistor, 499 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	ERJ-3EKF4993V
7	R20, R21, R22, R23, R24, R25, R27	Resistor, 0.0 Ω , 1/10 W, 0603, SMD	Vishay	ERJ-3GEY0R00V
11	TP1, TP4, TP9, TP11, TP15, TP17, TP18, TP19, TP20, TP21, TP22	Test point	Samtec	TSW-103-08-G-S
1	U1	Ultracompact, 1.5 A, TEC controller, WLCSP package	Analog Devices, Inc.	ADN8834ACBZ-R7

Table 6. ADN8834CP-EVALZ LFCSP Evaluation Board

Quantity	Reference	Description	Manufacturer	Part Number
3	C2, C8, C12	Ceramic capacitor, 10 μ F, 10 V, 10%, X7R 0805	Taiyo Yuden	LMK212B7106KG-TD
5	C3, C4, C5, C9, C11	Ceramic capacitor, 0.1 μ F, 10 V, 10%, X7R 0603	Kemet	C0603C104K8RACTU
2	C6, C7	Ceramic capacitor, 0.01 μ F, 50 V, 10%, X7R 0603	Kemet	C0603C103K5RACTU
1	C10	Tantalum capacitor, 100 μ F, 6.3 V, 20%, 1411	Vishay	293D107X06R3B2T
1	J1	Jumper, 3-pin	Samtec	TSW-103-08-G-S
1	J2	Jumper, 2-pin	Samtec	TSW-103-08-G-S
2	J4, J6	Connector, double row, male, 12-pin	Samtec	TSW-112-08-G-D
1	L1	Inductor, 1 μ H	Coilcraft	XFL3012-102ME
1	R1	Resistor, 6.65 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW06036K65FKEA
1	R2	Resistor, 10 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	ERJ-3EKF1002V
1	R3	Resistor, 210 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW0603210KFKEA
1	R4	Resistor, 48.7 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060348K7FKEA
1	R5	Resistor, 10.0 Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060310R0FKEA
1	R8	Resistor, 7.68 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW06037K68FKEA
1	R9	Resistor, 80.6 k Ω 1/10 W, 1%, 0603, SMD	Vishay	CRCW060380K6FKEA
1	R12	Resistor, 17.8 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060317K8FKEA
1	R10	Resistor, 374 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW0603165KFKEA

Quantity	Reference	Description	Manufacturer	Part Number
1	R11	Resistor, 562 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW06031M87FKEA
1	R13	Resistor, 64.9 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060364K9FKEA
4	R14, R15, R16, R17	Resistor, 20.0 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060320K0FKEA
1	R18	Resistor, 499 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	ERJ-3EKF4993V
1	R19	Resistor, 49.9 Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060349R9FKEA
7	R20, R21, R22, R23, R24, R25, R27	Resistor, 0.0 Ω , 1/10 W, 0603, SMD	Vishay	ERJ-3GEY0R00V
10	TP1, TP4, TP9, TP13, TP15, TP17, TP18, TP19, TP20, TP21	Test point	Keystone	5010
2	TP2, TP11	Connector	Mill-Max	3102-2-00-21-00-08-0
1	U1	Ultracompact, 1.5 A, TEC controller, LFCSP package	Analog Devices	ADN8834ACPZ-R7

Table 7. ADN8834 Base Board

Quantity	Reference	Description	Manufacturer	Part Number
2	CD1, C14	Ceramic capacitor, 0.47 μ F, 16 V, 10%, X5R, 0603	TDK	C1608X5R1C474K080AA
2	CD2, C15	Ceramic capacitor, 1 μ F, 16 V, 10%, X5R, 0603	Murata	GRM188R61C105KA
1	CD3	Ceramic capacitor, 2.2 μ F, 16 V, 10%, X5R, 0603	Murata	GRM188R61C225KE
1	CD4	Ceramic capacitor, 4.7 μ F, 6.3 V, 10%, X5R, 0603	Murata	GRM188R60J475KE19D
1	CD5	Ceramic capacitor, 10 μ F, 6.3 V, 20%, X5R, 0603	Panasonic	ECJ-1VB0J106M
1	CF	Ceramic capacitor, 0.01 μ F, 50 V, 10%, X7R, 0603	Kemet	C0603C103K5RACTU
1	C11	Ceramic capacitor, 0.047 μ F, 6.3 V, 10%, X5R, 0603	Murata	GRM033R60J473KE19D
2	C12, C17	Ceramic capacitor, 0.1 μ F, 50 V, 10%, X7R, 0603	AVX	06035C104KAT2A
1	C13	Ceramic capacitor, 0.22 μ F, 6.3 V, 10%, X5R, 0603	TDK	C0603X5R0J224K030BB
1	C16	Tantalum capacitor, 150 μ F, 6.3 V, 20%, 2917	Sanyo	6TPE150MI
1	D1	LED, green, 570 nm, clear, 2-PLCC	OSRAM	LG T67K-H2K1-24-Z
2	J2, J11	Jumper, 2-pin	Samtec	TSW-150-07-G-S
3	J8, J9, J10	Connector, PCB terminal, black, 2-pin	On Shore	OSTVN02A150
1	RD1	Resistor, 12 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060312K0FKEA
1	RD2	Resistor, 24.3 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060324K3FKEA
1	RD3	Resistor, 49.9 k Ω , 1/10 W, 1%, 0603, SMD	Panasonic	ERJ-3EKF4992V
1	RD4	Resistor, 100 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW0603100KFKEA
1	RD5	Resistor, 200 k Ω , 1/10 W, 1%, 0603, SMD	Panasonic	ERJ-3EKF2003V
2	RP1, RI1	Resistor, 61.9 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW060361K9FKEA
2	RP2, RI2	Resistor, 124 k Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW0603124KFKEA
2	RP3, RI3	Resistor, 249 k Ω , 1/10 W, 1%, 0603, SMD	Panasonic	ERJ-3EKF2493V
2	RP4, RI4	Resistor, 499 k Ω , 1/10 W, 1%, 0603, SMD	Panasonic	ERJ-3EKF4993V
2	RP5, RI5	Resistor, 1 M Ω , 1/10 W, 1%, 0603, SMD	Vishay	CRCW06031M00FKEA
1	RI6	Resistor, 1 k Ω , 1/10 W, 1%, 0603, SMD	Panasonic	ERJ-6ENF4123V
2	R1, R2	Resistor, 10 k Ω , 1/10 W, 1%, 0603, SMD	Panasonic	ERJ-3EKF1002V
5	SW2, SW3, SW4, SW5, SW6	Switch, low profile DIP, top slide, 5-position	C&K	SDA05H1SBD
18	TP1, TP2, TP3, TP4, TP5, TP6, TP8, TP10, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21	Test point	Keystone	5010
1	U1	Connector ¹	Samtec	SSW-106-01-G-D
3	W1, W2, W3	Trimmer, 20 k Ω , 0.25 W, SMD	Murata	PVG5A203C03R00
2	W4, W5	Trimmer, 200 k Ω , 0.25 W, SMD	Murata	PVG5A204C03R00
1	W6	Trimmer, 500 k Ω , 0.25 W, SMD	Murata	PVG5A504C03R00
1	W7	Trimmer, 100 k Ω , 0.25 W, SMD	Murata	PVG5A104C03R01

¹ U1 has a reserved area to plug in the daughter board. The silkscreen mark includes three 12-pin female connectors and several other components.

NOTES

**ESD Caution**

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

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