DESCRIPTION

The AD8870 is a brushed-DC motor driver for robotics, appliances, industrial equipment, and other small machines. Two logic inputs control the H-bridge driver, which consists of four N-channel MOSFETs that can control motors bidirectionally with up to 4.0A peak current. The inputs can be pulse width modulated (PWM) to control motor speed, using a choice of current-decay modes. Setting both inputs low enter a low-power sleep mode.

The AD8870 features integrated current regulation, based on the analog input VREF and the voltage on the ISEN pin, which is proportional to motor current through an external sense resistor. The ability to limit current to a known level can significantly reduce the system power requirements and bulk capacitance needed to maintain stable voltage, especially for motor startup and stall conditions.

The AD8870 is fully protected from faults and short circuits, including undervoltage (UVLO), overcurrent (OCP), and overtemperature (TSD). When the fault condition is removed, the device automatically resumes normal operation.

The AD8870 is available in PSOP-8 package.

ORDERING INFORMATION

Package Type	Part Number	
PSOP-8 SPQ: 4,000psc/Reel	MP8	AD8870MP8R
		AD8870MP8VR
Note	V: Halogen free Package R: Tape & Reel	
AiT provides all RoHS products		

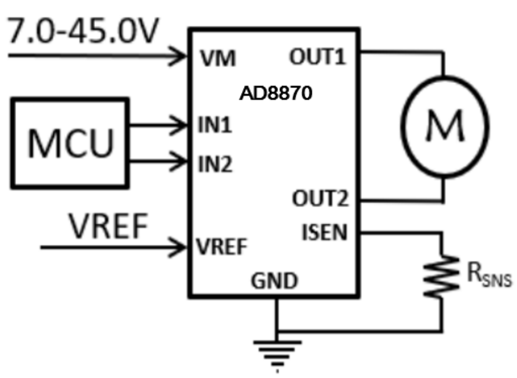
FEATURES

- 7.0 to 45.0 V Operating Voltage
- 600-mΩ Typical RDSON (HS + LS)
- 4.0A Peak Current Drive
- PWM Control Interface
- Integrated Current Regulation
- Low-Power Sleep Mode
- H-Bridge Motor Driver
  - Drives One DC Motor, One Winding of a Stepper Motor, or Other Loads
- Integrated Protection Features
  - VM Undervoltage Lockout (UVLO)
  - Overcurrent Protection (OCP)
  - Thermal Shutdown (TSD)
  - Automatic Fault Recovery

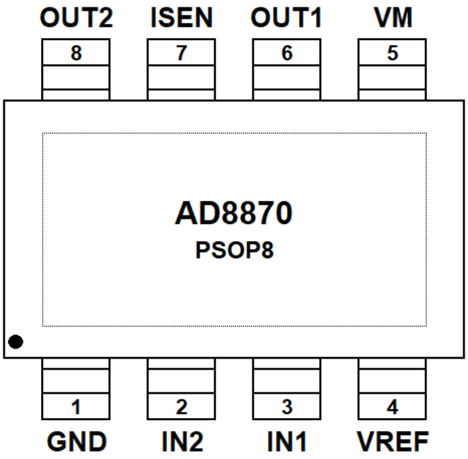
APPLICATION

- Printers
- Appliances
- Industrial Equipment
- Robotics (Sweeping robot, R/C servo)
- 2-4 Li Battery Motor Applications
- Any Relevant DC Motor Applications.

TYPICAL APPLICATION



PIN DESCRIPTION



PSOP8, MP8

Top View

Pin #	Symbol	Function
1	GND	Logic ground. Connect to board ground
2	IN2	Logic inputs. Controls the H-bridge output. Has internal pulldowns.
3	IN1	Logic inputs. Controls the H-bridge output. Has internal pulldowns.
4	VREF	Analog input. Apply a voltage between 0.3 to 5 V.
5	VM	8.0 to 45.0V power supply. Connect a 22-μF bypass capacitor to ground, as well as sufficient bulk capacitance, rated for the VM voltage.
6	OUT1	H-bridge output. Connect directly to the motor or other inductive load.
7	ISEN	High-current ground path. If using current regulation, connect ISEN to a resistor (low-value, high-power-rating) to ground. If not using current regulation, connect ISEN directly to ground.
8	OUT2	H-bridge output. Connect directly to the motor or other inductive load.
	PAD	Thermal pad. Connect to board ground. For good thermal dissipation, use large ground planes on multiple layers, and multiple nearby vias connecting those planes.

ABSOLUTE MAXIMUM RATINGS

T_A = 25°C, unless otherwise specified.

Parameter	Symbol	Min	Max	Unit
Power supply voltage	VM	-0.3	48.0	V
Logic input voltage	IN1, IN2	-0.3	7.0	V
Reference input pin voltage	VREF	-0.3	6.0	V
Continuous phase node pin voltage	OUT1, OUT2	-0.3	VM+0.7	V
Current sense input pin voltage	ISEN	-0.3	1	V
ESD (HBM)	VM, IN1, IN2, OUT1, OUT2, VREF, ISEN	4		kV
Output current (100% duty cycle)	IOUT	0	3.5	A
Operating junction temperature,	T_J	-40	150	℃
Storage temperature,	T_{stg}	-65	150	℃
Thermal Impedance	θ_{JA}		45	℃/W
Recommended Operating Conditions				
Power supply voltage	VM	7.0	45.0	V
Logic input voltage	IN1, IN2	0	5.5	V
Reference input pin voltage	VREF	0.3	5.0	V
Logic input PWM frequency	f_{PWM}	0	200	kHz
Peak output current	IPEAK	0	4.0	A

Stress beyond above listed “Absolute Maximum Ratings” may lead permanent damage to the device. These are stress ratings only and operations of the device at these or any other conditions beyond those indicated in the operational sections of the specifications are not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

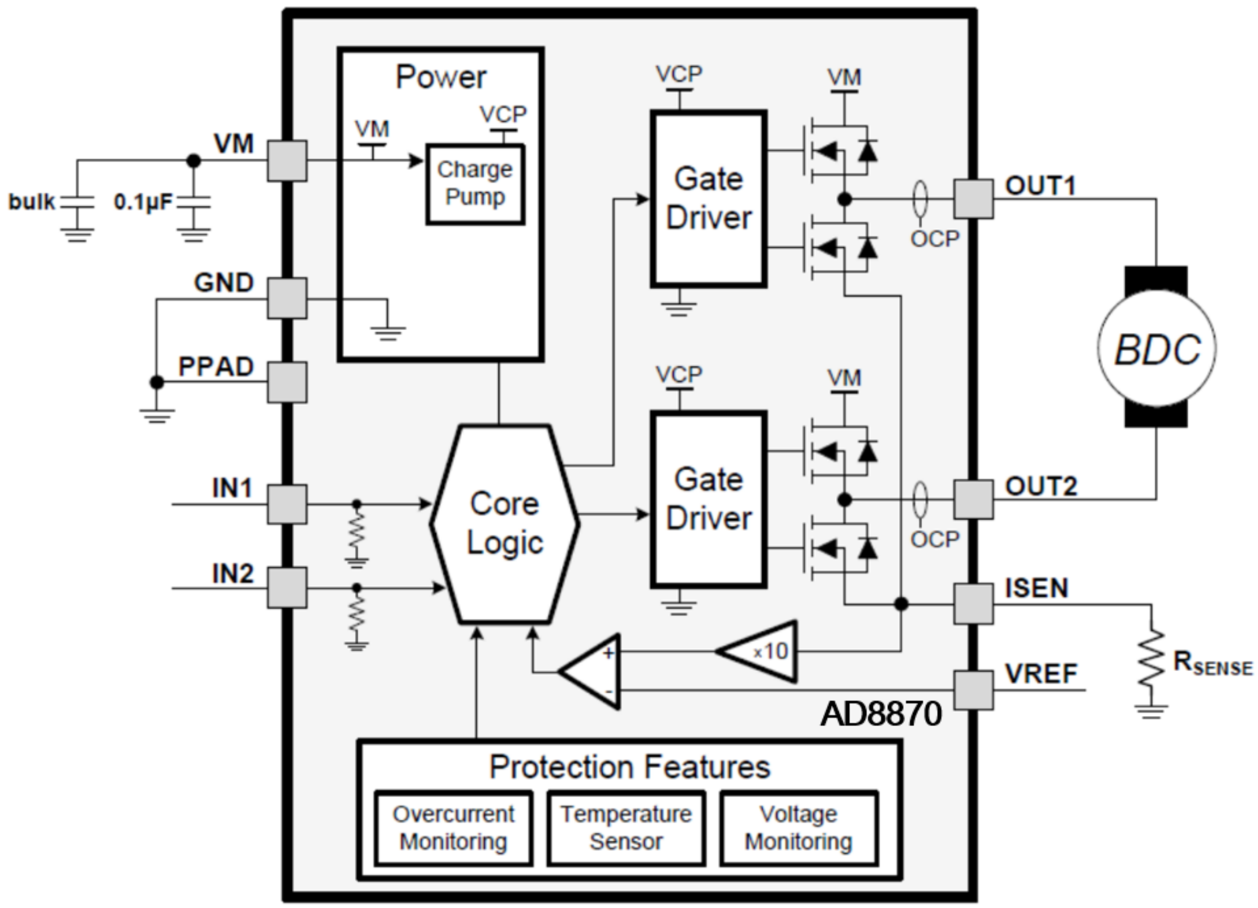
ELECTRICAL CHARACTERISTICS

V_{IN}=5V, T_A=25°C, R_{LOAD}=20, unless otherwise noted

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
POWER SUPPLY (VM)						
VM operating voltage	VM		7.0	-	45	V
VM operating supply current	IVM_ON	VM=17V	-	1.2	-	mA
VM sleep current	IVM_OFF	VM=17V	-	3.0	10	uA
Turn-on time	Ton	VM>VUVLO, with IN1 or IN2 high	-	30	50	us
MOTOR DRIVER OUTPUTS (OUT1, OUT2)						
High-side & Low-side FET on resistance	R_{DSON}	VM=12V, LS+HS, IOUT=1A	-	600	-	mΩ
Output dead time	T_{DEAD}		-	200	-	ns
Body diode forward voltage	V_D	IOUT=1A	-	0.8	1	V
LOGIC-LEVEL INPUTS (IN1, IN2)						
Input logic high voltage	V_{INH}		1.5	-	-	V
Input logic low voltage	V_{INL}		0	-	0.5	V
Input logic hysteresis	V_{IN_HYS}		-	0.1	-	V
Input logic high current	I_{INH}	IN=3.3V	-	33	50	uA
Input logic low current	I_{INL}	IN=0V	-	0	1	
Pulldown resistance	R_{PD}	to GND	-	100	200	KΩ
Propagation delay	T_{PD}	INx to OUTx change	-	20	-	ns
Time to sleep	T_{SLP}	Inputs low to sleep	-	1.0	-	ms
CURRENT REGULATION						
ISEN gain	A_V	VREF=2.5V	-	10	-	V/V
PWM off-time	T_{OFF}		-	20	-	us
PWM blanking time	T_{BLANK}		-	4.0	-	

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
PROTECTION CIRCUITS						
VM rises until operation recovers	V_{UVLO_R}		-	6.70	-	V
VM falls until UVLO triggers	V_{UVLO_F}		-	6.50	-	
VM undervoltage hysteresis	V_{UVLO_H}		-	0.20	-	
Overcurrent protection trip level	I_{OCP}		-	5.0	-	A
Overcurrent deglitch time	T_{OCP}		-	2.0	-	us
Overcurrent retry time	T_{RETRY}		-	2.0	-	ms
Thermal shutdown temperature	T_{SD}		-	160	-	°C
Thermal shutdown hysteresis	T_{HYS}		-	50	-	

BLOCK DIAGRAM



DETAILED INFORMATION

Overview

The AD8870 is an optimized 8-pin device for driving brushed DC motors with 5.5 to 45.0 V and up to 4.0-A peak current. The integrated current regulation restricts motor current to a predefined maximum. Two logic inputs control the H-bridge driver, which consists of four N-channel MOSFETs that have a typical $R_{DS(on)}$ of 600mΩ (including one high-side and one low-side FET). A single-power input, VM, serves as both device power and the motor winding bias voltage. The integrated charge pump of the device boosts VM internally and fully enhances the high-side FETs. Motor speed can be controlled with pulse-width modulation, at frequencies between 0 to 100 kHz. The device has an integrated sleep mode that is entered by bringing both inputs low. An assortment of protection features prevents the device from being damaged if a system fault occurs.

Bridge Control

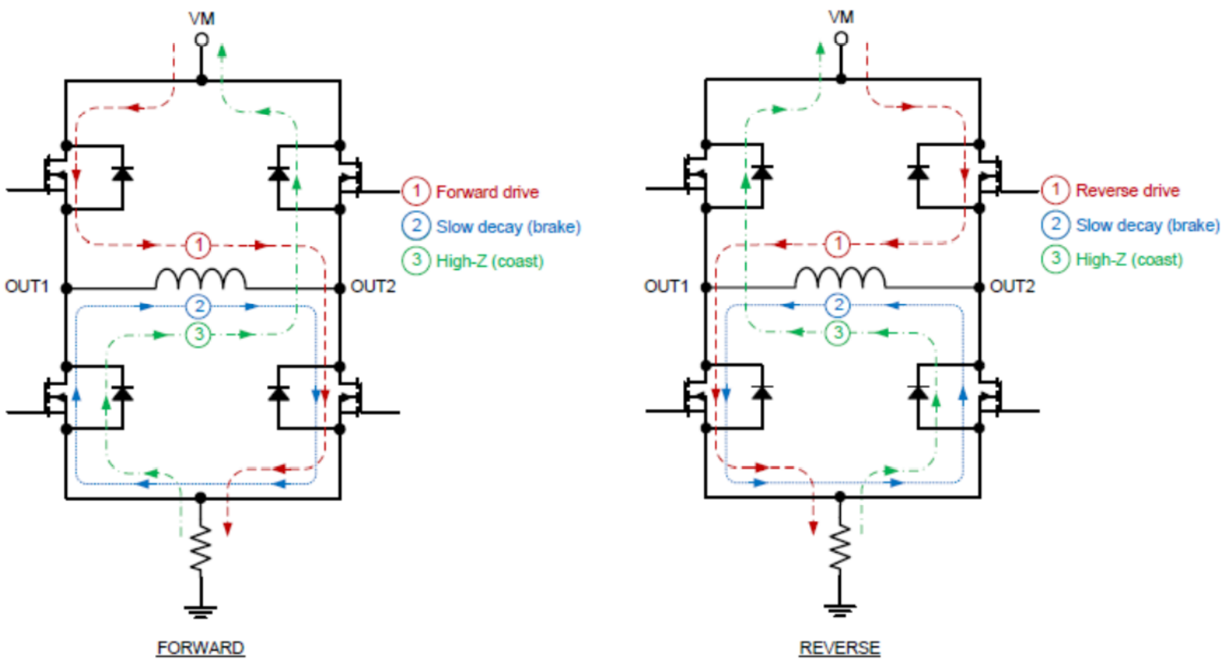
The AD8870 output consists of four N-channel MOSFETs that are designed to drive high current. These outputs are controlled by the two logic inputs IN1 and IN2as listed in Table 1.

Table 1. H-Bridge Control

IN1	IN2	OUT1	OUT2	DESCRIPTION
0	0	High-Z	High-Z	Coast, H-bridge disabled to High-Z (sleep entered after 1 ms)
0	1	L	H	Reverse (current OUT2 → OUT1)
1	0	H	L	Forward(current OUT1 → OUT2)
1	1	L	L	Brake; low-side slow decay

The inputs can be set to static voltages for 100% duty cycle drive, or they can be pulse-width modulated (PWM) for variable motor speed. When using PWM, switching between driving and braking typically works best. For example, to drive a motor forward with 50% of the maximum RPM, IN1 = 1 and IN2 = 0 during the driving period, and IN1 = 1 and IN2 = 1 during the other period. Alternatively, the coast mode (IN1 = 0, IN2 = 0) for fast current decay is also available. The input pins can be powered before VM is applied.

Fig4. H-Bridge Current Paths



Sleep Mode

When the IN1 and IN2 pins are both low for time t_{SLEEP} (typically 1 ms), the AD8870 enters a low-power sleep mode, where the outputs remain High-Z and the device uses I_{VMOFF} (µA) of current. If the device is powered up while both inputs are low, it immediately enters sleep mode. After the IN1 or IN2 pins are high for at least 5µs, the device is operational 50µs (t_{ON}) later.

Current Regulation

The AD8870 limits the output current based on the analog input, VREF, and the resistance of an external sense resistor on the ISEN pin according to Equation 1:

$$I_{TRIP}(A)=\frac{VREF(V)}{A_V \times R_{ISEN}(\Omega)}=\frac{VREF(V)}{10 \times R_{ISEN}(\Omega)}$$

For example, if VREF = 3.3 V and a R_{ISEN} = 0.15 Ω, the AD8870 device limits motor current to 2.2 A no matter how much load torque is applied. For guidelines on selecting a sense resistor, see the Sense Resistor section. When ITRIP is reached, the device enforces slow current decay by enabling both low-side FETs, and it does this for a time of t_{OFF} (typically 20 µs).

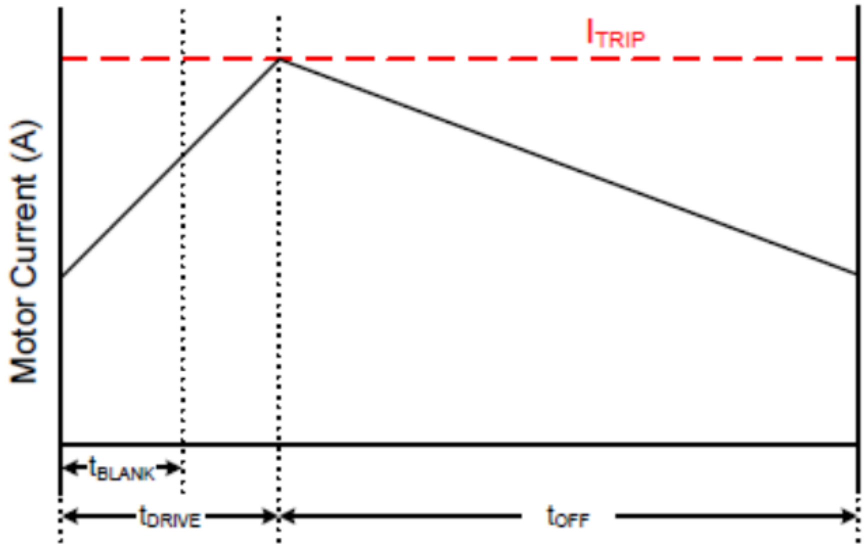


Fig.5 Current-Regulation Time Periods

After t_{OFF} elapses, the output is re-enabled according to the two inputs, INx. The drive time (t_{DRIVE}) until reaching another I_{TRIP} event heavily depends on the VM voltage, the back-EMF of the motor, and the inductance of the motor.

Dead Time

When an output changes from driving high to driving low, or driving low to driving high, dead time is automatically inserted to prevent shoot-through. The t_{DEAD} time is the time in the middle when the output is High-Z. If the output pin is measured during t_{DEAD}, the voltage depends on the direction of current. If the current is leaving the pin, the voltage is a diode drop below ground. If the current is entering the pin, the voltage is a diode drop above VM. This diode is the body diode of the high-side or low-side FET.

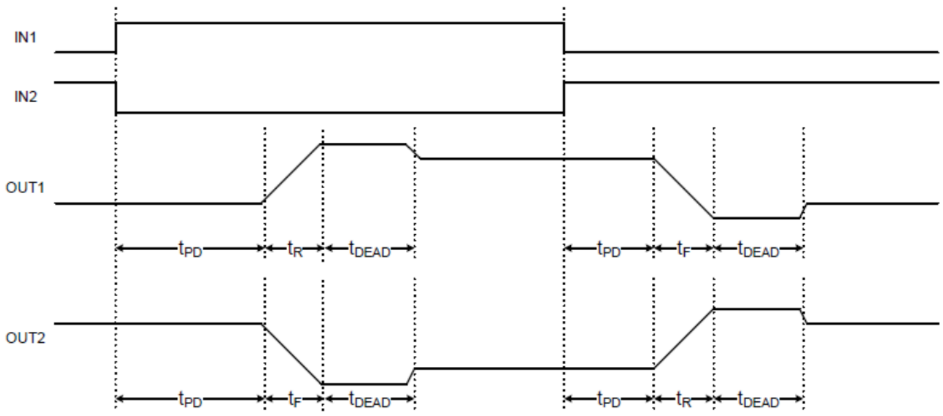


Fig 6. Propagation Delay Time

Protection Circuits

The AD8870 is fully protected against VM undervoltage, overcurrent, and overtemperature events.

VM Undervoltage Lockout (UVLO)

If at any time the voltage on the VM pin falls below the undervoltage-lockout threshold voltage, all FETs in the H-bridge will be disabled. Operation resumes when VM rises above the UVLO threshold.

Overcurrent Protection (OCP)

If the output current exceeds the OCP threshold, IOCP, for longer than t_{OCP}, all FETs in the H-bridge are disabled for a duration of t_{RETRY}. After that, the H-bridge is re-enabled according to the state of the INx pins. If the overcurrent fault is still present, the cycle repeats; otherwise normal device operation resumes.

Thermal Shutdown (TSD)

If the die temperature exceeds safe limits, all FETs in the H-bridge are disabled. After the die temperature has fallen to a safe level, operation automatically resumes.

Table 2. Protection Functionality

FAULT	CONDITION	H-BRIDGE BECOMES	RECOVERY
VM undervoltage lockout (UVLO)	$VM < V_{UVLO}$	Disabled	$VM > V_{UVLO}$
Overcurrent (OCP)	$I_{OUT} > I_{OCP}$	Disabled	t_{RETRY}
Thermal Shutdown	$T_J > 150℃$	Disabled	$T_J < T_{SD} - T_{HYS}$

Device Functional Modes

The AD8870 can be used in multiple ways to drive a brushed DC motor.

PWM With Current Regulation

This scheme uses all of the capabilities of the device. The ITRIP current is set above the normal operating current, and high enough to achieve an adequate spin-up time, but low enough to constrain current to a desired level. Motor speed is controlled by the duty cycle of one of the inputs, while the other input is static. Brake or slow decay is typically used during the off-time.

PWM Without Current Regulation

If current regulation is not required, the ISEN pin should be directly connected to the PCB ground plane. The VREF voltage must still be 0.3 to 5 V, and larger voltages provide greater noise margin. This mode provides the highest-possible peak current which is up to 4.0 A for a few hundred milliseconds (depending on PCB characteristics and the ambient temperature). If current exceeds 4.0 A, the AD8870 might reach overcurrent protection (OCP) or overtemperature shutdown (TSD). If that happens, the device disables and protects itself for about 2ms (t_{RETRY}) and then resumes normal operation.

Static Inputs with Current Regulation

The IN1 and IN2 pins can be set high and low for 100% duty cycle drive, and ITRIP can be used to control the current of the motor, speed, and torque capability.

VM Control

In some systems, varying VM as a means of changing motor speed is desirable. See the Motor Voltage section for more information.

Thermal Considerations

The AD8870 as thermal shutdown (TSD) as described in the Thermal Shutdown (TSD) section. If the die temperature exceeds approximately 160°C, the device is disabled until the temperature drops below the temperature hysteresis level. Any tendency of the device to enter TSD is an indication of either excessive power dissipation, insufficient heatsinking, or too high of an ambient temperature.

Power Dissipation

Power dissipation in the AD8870 is dominated by the power dissipated in the output FET resistance, RDS(on). Use the equation in the Drive Current section to calculate the estimated average power dissipation when driving a load.

Note that at startup, the current is much higher than normal running current; this peak current and its duration must be also be considered.

The maximum amount of power that can be dissipated in the device is dependent on ambient temperature and heatsinking.

Note: $R_{DS(ON)}$ increases with temperature, so as the device heats, the power dissipation increases. This fact must be taken into consideration when sizing the heatsink

The power dissipation of the AD8870 device is a function of RMS motor current and the FET resistance (RDS(ON)) of each output.

POWER = I_{RMS}^2×(High-side RDSON + Low – Side RDSON)

For this example, the ambient temperature is 58°C, and the junction temperature reaches 66°C. At 58°C, the sum of RDS(ON) is about 0.26Ω. With an example motor current of 0.8 A, the dissipated power in the form of heat is 0.8 A2 × 0.26 Ω = 0.17 W.

The temperature that the AD8870 reaches will depend on the thermal resistance to the air and PCB. It is important to solder the device PowerPAD to the PCB ground plane, with vias to the top and bottom board layers, in order dissipate heat into the PCB and reduce the device temperature. In the example used here, the AD8870 device had an effective thermal resistance RθJA of 48°C/W, and:

$T_J = T_A + (P_D \times R_{\theta JA})$ = 58℃+ (0.17W × 48℃/W) = 66℃ (4)

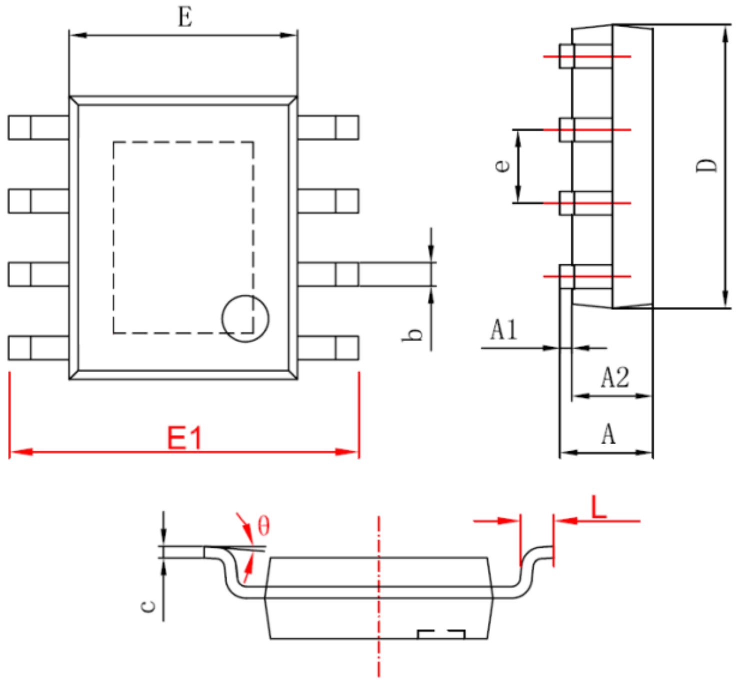
Heatsinking

The Power PAD package uses an exposed pad to remove heat from the device. For proper operation, this pad must be thermally connected to copper on the PCB to dissipate heat. On a multi-layer PCB with a ground plane, this connection can be accomplished by adding a number of vias to connect the thermal pad to the ground plane.

On PCBs without internal planes, a copper area can be added on either side of the PCB to dissipate heat. If the copper area is on the opposite side of the PCB from the device, thermal vias are used to transfer the heat between top and bottom layers.

PACKAGE INFORMATION

Dimension in PSOP8 (Unit: mm)



Symbol	Min.	Max.
A	1.550	1.700
A1	0.000	0.150
A2	1.550	1.700
b	0.310	0.510
c	0.100	
D	4.800	5.000
E	3.800	4.000
E1	5.800	6.200
e	1.270(BSC)	
L	1.270	0.400
θ	0°	8°

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