DESCRIPTION

The AD8870A device is an H-bridge driver capable of powering various devices, including DC motors and solenoids. The output controlled via the PWM interface (IN1 and IN2) on the AD8870A serves as brushed DC motor drivers suitable for applications in robotics, appliances, and industrial equipment. Two logic inputs govern the H-bridge driver, which comprises four N-channel MOSFETs, enabling bidirectional control of the motor with peak currents of up to 10.0 A.
The inputs can utilize pulse width modulation (PWM) to control motor speed. Setting both inputs to low activates a low-power sleep mode. These devices significantly reduce the component count of the motor drive system by integrating the necessary drivers, MOSFETs, and control circuitry into a single chip.
The AD8870A operates based on an analog voltage applied to the VREF and ISEN pins, which is proportional to the motor current flowing through an external sense resistor. It features an integrated current regulation function that can limit the current to a predetermined level, significantly reducing system power requirements and minimizing the need for large capacitance to maintain system stability.
The protection features of the AD8870A include under-voltage lockout (UVLO), overcurrent protection (OCP), and overtemperature protection (OTP). The system automatically resumes normal operation once the fault has been cleared.
The AD8870A is available in the PSOP-8 package.

ORDERING INFORMATION

Package Type	Part Number	
PSOP-8 SPQ: 4,000psc/Reel	MP8	AD8870AMP8VR
Note	V: Halogen free Package R: Tape & Reel	
AiT provides all RoHS products		

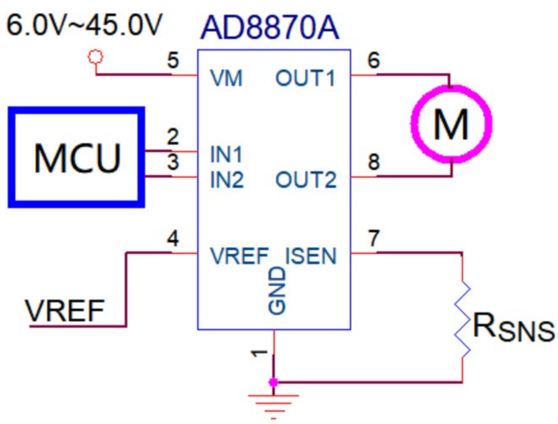
FEATURES

- 6.0 to 45.0 V Operating Voltage
- 95-mΩ Typical RDSON (HS + LS)
- 10.0A 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 (OTP)
  - Automatic Fault Recovery

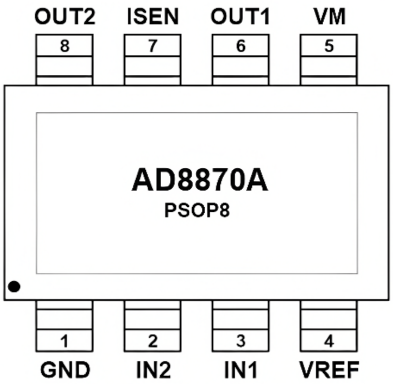
APPLICATION

- Appliances
- Industrial Equipment
- Robotics (Sweeping robot, R/C servo)
- 2-7 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	6.0 to 45.0V power supply. Connect a 22-μF bypass capacitor to the 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 the ground. If not using current regulations, connect ISEN directly to the 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	50.0	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	2		kV
Output current (100% duty cycle)	IOUT	0	6.5	A
Operating junction temperature,	T_J	-40	150	℃
Storage temperature,	T_{stg}	-65	150	℃
Thermal Impedance	θ_{JA}	30		℃/W
Recommended Operating Conditions				
Power supply voltage	VM	6.0	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	10.0	A

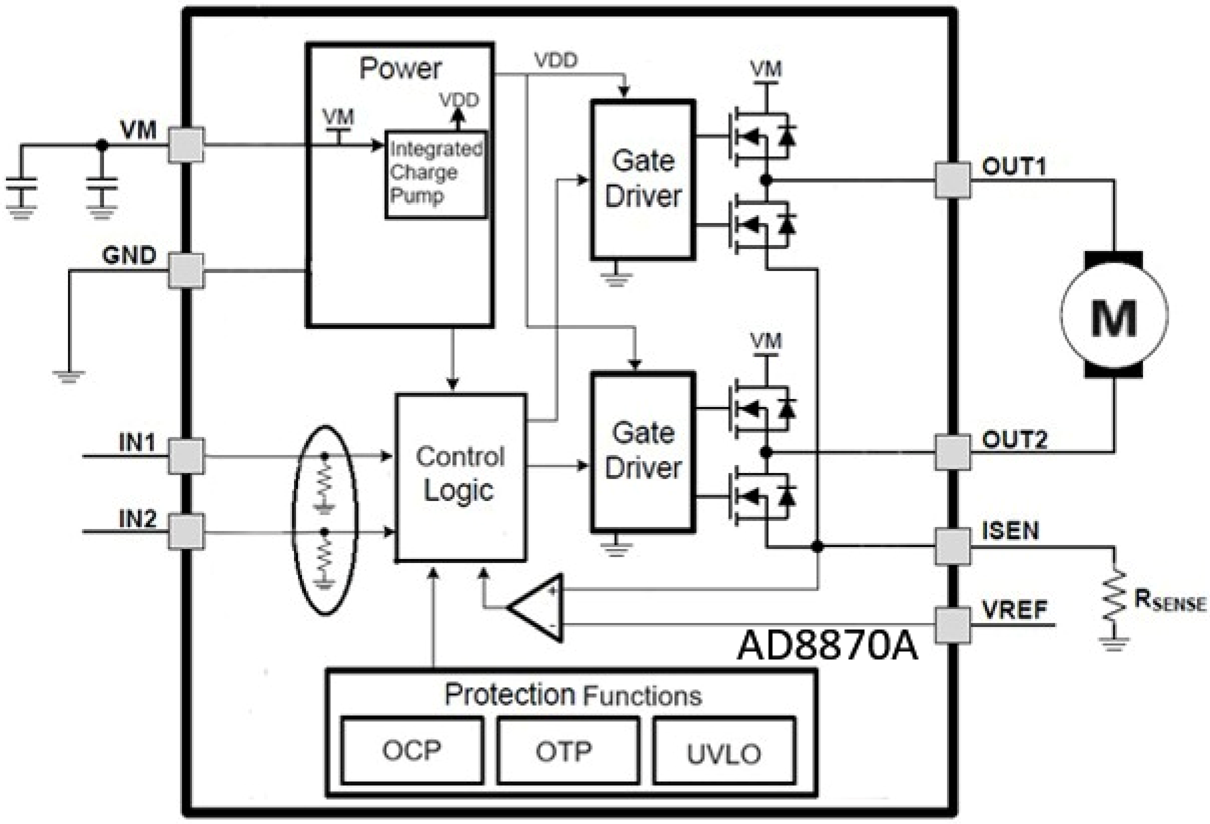
Stress beyond above listed “Absolute Maximum Ratings” may lead to permanent damage to the device. These are stress ratings only and operations of the device at these or any other conditions beyond those indicated in the operational sections of the specifications are not implied. Exposure to absolute 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		6.0	-	45	V
VM operating supply current	I_{VM_ON}	VM=24V	-	1.2	2.5	mA
VM sleep current	I_{VM_OFF}	VM=24V	-	1.5	10	uA
Turn-on time	Ton	VM>V_{UVLO} 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	-	95	-	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	uA
Pulldown resistance	R_{PD}	to GND	-	100	200	KΩ
Propagation delay	T_{PD}	INx to OUTx change	-	500	-	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	-	us
PROTECTION CIRCUITS						
VM rises until operation recovers	V_{UVLO_R}		-	5.80	-	V
VM falls until UVLO triggers	V_{UVLO_F}		-	5.25	-	V
VM undervoltage hysteresis	V_{UVLO_H}		-	0.55	-	V
Overcurrent protection trip level	I_{OCP}		10.0	13.0	-	A
Overcurrent deglitch time	T_{OCP}		-	2.0	-	us
Overcurrent retry time	T_{RETRY}		-	3.0	-	ms
Thermal shutdown temperature	T_{OTP}		-	160	-	°C
Thermal shutdown hysteresis	T_{HYS}		-	30	-	°C

BLOCK DIAGRAM



DETAILED INFORMATION

Overview

The AD8870A is an optimized 8-pin device designed for driving brushed DC motors with a voltage range of 6.0 to 45.0 V and a peak current of up to 10.0 A. The integrated current regulation limits the motor current to a predefined maximum. Two logic inputs control the H-bridge driver, which consists of four N-channel MOSFETs, each with a typical $R_{DS(on)}$ of 95 mΩ (including one high-side and one low-side FET). A single power input, VM, serves both as the device power supply and the motor winding bias voltage. The integrated charge boosts the VM internally, fully enhancing the high-side FETs. Motor speed can be controlled using pulse-width modulation at frequencies ranging from 0 to 100 kHz. The device features an integrated sleep mode, which is activated by bringing both inputs low. A variety of protection features are included to prevent damage to the device in the event of a system fault.

Bridge Control

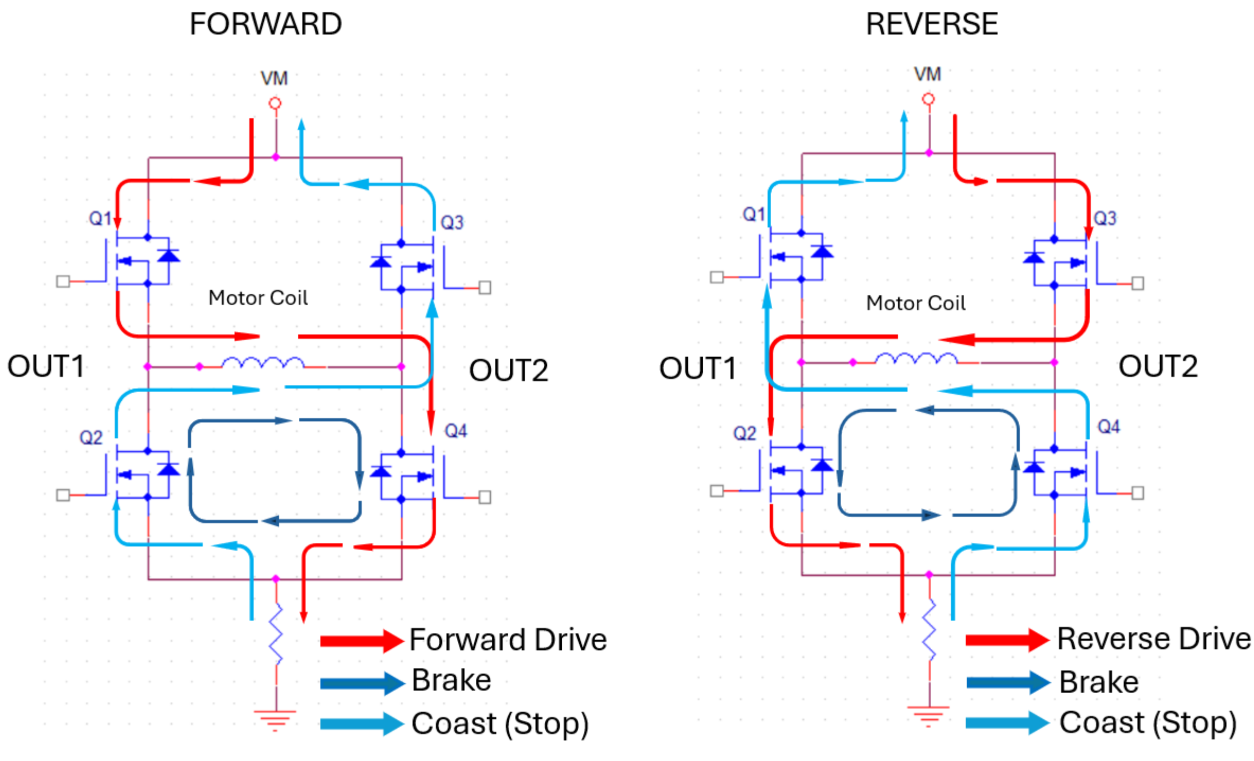
The AD8870A output consists of four N-channel MOSFETs that are designed to drive high current. These outputs are controlled by the two logic inputs IN1 and IN2 as listed in Table 1.

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 configured for static voltages to achieve a 100% duty cycle drive, or they can utilize pulse-width modulation (PWM) for variable motor speed control. When employing PWM, alternating between driving and braking typically yields optimal performance. For instance, to drive a motor forward at 50% of its maximum RPM, set IN1 to 1 and IN2 to 0 during the driving phase, and then set both IN1 and IN2 to 1 during the braking phase. Alternatively, the coast mode (IN1 = 0, IN2 = 0) is available for rapid current decay. Additionally, the input pins can be powered before applying VM.

Fig4. H-Bridge Current Paths



Sleep Mode

When both the IN1 and IN2 pins are low for a duration of t_{SLP} (typically 1 ms), the AD8870A enters a low-power sleep mode. In this mode, the outputs remain in a high-impedance state (High-Z), and the device consumes a current of I_{VMOFF} (in μA). If the device is powered on while both inputs are low, it will immediately enter sleep mode. Once either the IN1 or IN2 pin is high for at least 5 μs, the device becomes operational 50 μs (t_{ON-MAX}) later.

Current Regulation

The AD8870A 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 V_{REF} = 3.3 V and a R_{ISEN} = 0.15 Ω, the AD8870A 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 I_{TRIP} 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).

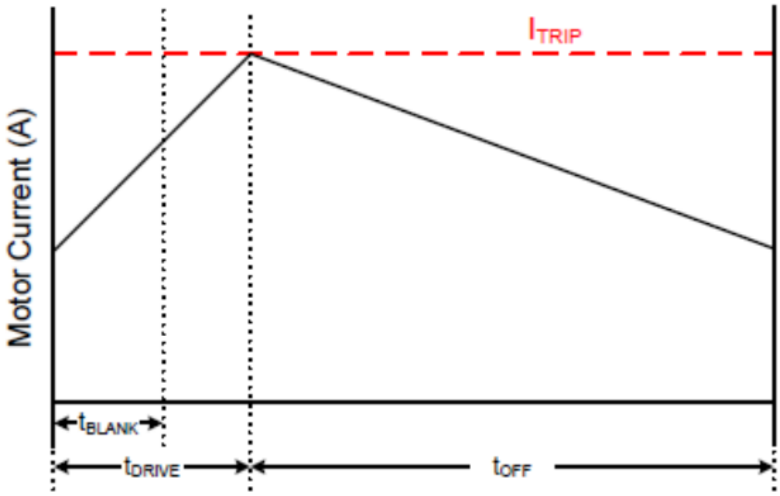


Fig.5 Current-Regulation Time Periods

After the t_{OFF} period elapses, the output is re-enabled based on the two inputs, INx. The drive time (t_{DRIVE}) until the next I_{TRIP} event is significantly influenced by the VM voltage, the back electromotive force (back-EMF) of the motor, and the motor's inductance.

Dead Time

When an output transitions from a high state to a low state, or from a low state to a high state, a dead time is automatically inserted to prevent shoot-through. The tDEAD time refers to the interval during which the output is in a High-Z (high impedance) state. If the output pin is measured during tDEAD, the voltage observed will depend on the direction of the current. If the current is flowing away from the pin, the voltage will be a diode drop below ground. Conversely, if the current is flowing into the pin, the voltage will be a diode drop above VM. This diode corresponds to the body diode of either the high-side or low-side FET.

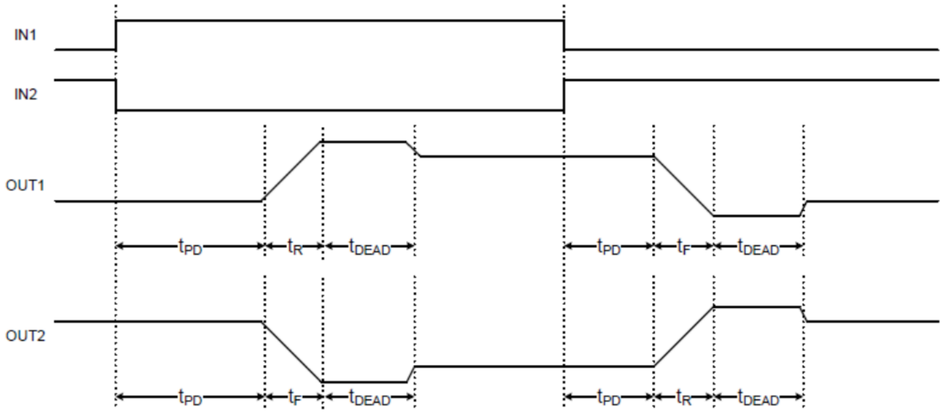


Fig 6. Propagation Delay Time

Protection Circuits

The AD8870A is fully protected against undervoltage, overcurrent, and overtemperature events related to VM.

VM Undervoltage Lockout (UVLO)

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

Overcurrent Protection (OCP)

If the output current exceeds the overcurrent protection (OCP) threshold, IOCP, for longer than the specified duration, t_{OCP}, all field-effect transistors (FETs) in the H-bridge are disabled for a period of t_{RETRY}. After this period, the H-bridge is re-enabled based on the state of the INx pins. If the overcurrent fault persists, the cycle repeats; otherwise, normal device operation resumes.

Thermal Shutdown (Over Temperature Protection)

If the die temperature exceeds safe limits, all FETs in the H-bridge are disabled. Once the die temperature has fallen to a safe level, the 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	$T_J < T_{OTP} - T_{HYS}$

Device Functional Modes

The AD8870A can be utilized in various ways to drive a brushed DC motor.

PWM with Current Regulation

This scheme utilizes all the capabilities of the device. The I_{TRIP} current is set above the normal operating current, ensuring an adequate spin-up time while remaining low enough to limit the current to a desired level. Motor speed is regulated by the duty cycle of one input, while the other input remains static. Typically, breaking or slow decay is employed 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 remain between 0.3 V and 5 V, with higher voltages providing a greater noise margin. This mode allows for the highest possible peak current, which can reach up to 4.5 A for a few hundred milliseconds, depending on PCB characteristics and ambient temperature. If the current exceeds 4.5 A, the AD8870A may activate overcurrent protection (OCP) or overtemperature shutdown (OTP). In such cases, the device will disable itself to protect against damage for approximately 2 ms (t_{RETRY}) before resuming normal operation.

Static Inputs with Current Regulation

The IN1 and IN2 pins can be set to high or low for a 100% duty cycle drive, while ITRIP can be utilized to control the motor's current, speed, and torque capabilities.

VM Control

In certain systems, varying the voltage of the motor (VM) to adjust motor speed is advantageous. Please refer to the Motor Voltage section for additional information

Thermal Considerations

The AD8870A features thermal shutdown (OTP) as outlined in the Thermal Shutdown (OTP) section. If the die temperature exceeds approximately 160°C, the device will be disabled until the temperature falls below the hysteresis level. A tendency for the device to enter OTP indicates either excessive power dissipation, inadequate heatsinking, or excessively high ambient temperatures.

Power Dissipation

Power dissipation in the AD8870A is primarily influenced by the power dissipated in the output FET resistance, $R_{DS(on)}$. Utilize the equation provided 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 the normal running current; this peak current and its duration must also be considered.

The maximum amount of power that can be dissipated by the device depends on ambient temperature and heat sinking.

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

The power dissipation of the AD8870A device depends on the root mean square (RMS) motor current and the FET resistance ($R_{DS(ON)}$) of each output.

$$POWER \cong I_{RMS}^2 \times (\text{High-side } R_{DS(ON)} + \text{Low – Side } R_{DS(ON)})$$

For this example, the ambient temperature is 58°C, and the junction temperature reaches 66°C. At 58°C, the total $R_{DS(ON)}$ is approximately 0.26 Ω. With a motor current of 0.8 A, the power dissipated as heat is calculated as follows: 0.8 A² × 0.26 Ω = 0.17 W.

The temperature that the AD8870A reaches will depend on the thermal resistance to the air and the PCB. It is important to solder the device's PowerPAD to the PCB ground plane, with vias connecting to the top and bottom board layers, to dissipate heat into the PCB and reduce the device's temperature. In the example used here, the AD8870A device had an effective thermal resistance $R_{\theta JA}$ of 48°C/W, and:

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

Heatsinking

The Power PAD package employs an exposed pad to efficiently dissipate heat from the device. For optimal performance, this pad must be thermally connected to copper on the printed circuit board (PCB) to enhance heat dissipation. In a multi-layer PCB with a ground plane, this connection can be established by incorporating multiple vias to link the thermal pad to the ground plane.

On printed circuit boards (PCBs) without internal planes, a copper area can be added to either side of the PCB to improve heat dissipation. If the copper area is positioned on the side opposite the device, thermal vias are utilized to transfer heat between the top and bottom layers.

PCB Design Notice:

A. Path Diameter of PCB Layout:

When designing a printed circuit board (PCB), ensuring the safe transmission of electrical current is crucial. When a current of 10 A passes through the copper track of a PCB, it is essential to select the appropriate copper foil thickness and trace width. Generally, for a copper foil thickness of 1 oz/ft² (35 μm) with 10 A, the required trace width must be greater than 3.5 mm.

B. Filter Capacitors:

To minimize input voltage fluctuations and noise, a large-capacity electrolytic capacitor (ranging from 22 to 1000 μF) is connected in parallel with several 0.1 μF ceramic bypass capacitors at the power input. This configuration effectively stabilizes the voltage.

C. Grounding Considerations:

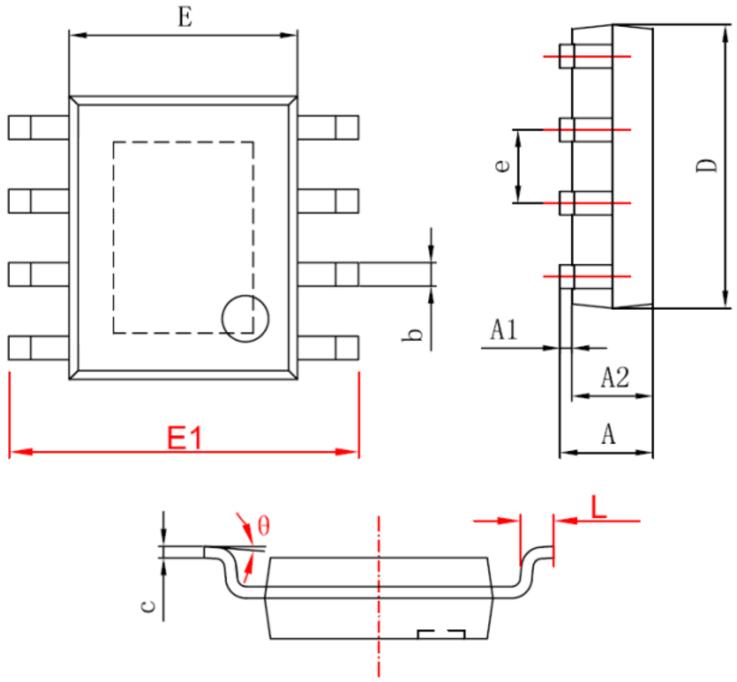
Ground Resistance: Ensure that the ground resistance is sufficiently low to provide an effective grounding path, thereby reducing voltage drop and heat buildup caused by excessive resistance. Use a ground wire and vias with an adequate diameter, and select an appropriate grounding point to minimize ground loops and electromagnetic interference (EMI).

D. Temperature Considerations:

Ensure that there is no overheating at a 10A current. Select a PCB wire diameter that is sufficiently large for effective conduction, and ensure that the circuit board or system incorporates a robust heat dissipation design. This may include design elements such as heat sinks, cooling fans, or provisions for natural convection. Maintain adequate air circulation around circuit components and wires to prevent overheating. Additionally, consider the impact of ambient temperature on the current-carrying capacity of the wire. If the current-carrying capacity decreases in a high-temperature environment, it will be necessary to select a wire with a larger diameter.

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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