3.6A High Voltage H-Bridge DC Motor Driver

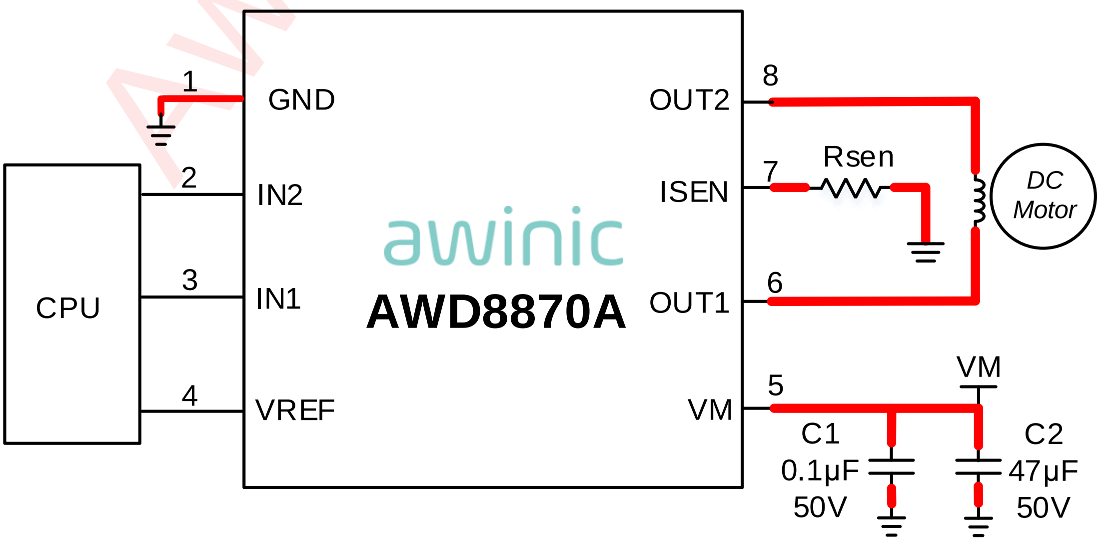
Features

- Drives a DC Motor or Other Loads
- Rdson HS + LS: 460mΩ
- 3.6-A Maximum Drive Current
- VM: 6.5V to 45V Operating Voltage Range
- PWM Control Interface
- Low-Power Sleep Mode
- Small Package and Footprint
  - 8-Pin SOP With Power PAD
  - WBESOP-8L
- Short-Circuit Protection (OCP)
- Over-Temperature Protection(OTP)
- Under-Voltage Protection(UVLO)
- Automatic Fault Recovery

Applications

- Printers
- Appliances
- Industrial Equipment
- Other Mechatronic Applications

Typical Application Circuit



General Description

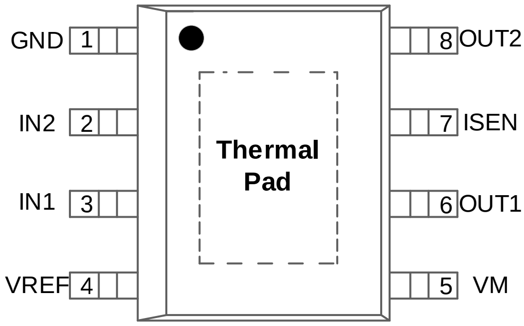
The AWD8870A provides an integrated motor driver solution for printers, appliances, industrial equipment, and other small machines. The device can supply up to 3.6A of output current. It operates on a motor power supply voltage from 6.5V to 45V. The output driver block consists of N-channel power MOSFETs configured as an H-bridge to drive the motor winding. The inputs can be pulse width modulated (PWM) to control motor speed, using a choice of current-decay modes. Setting both inputs low enters a low-power sleep mode.

The AWD8870A device 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.

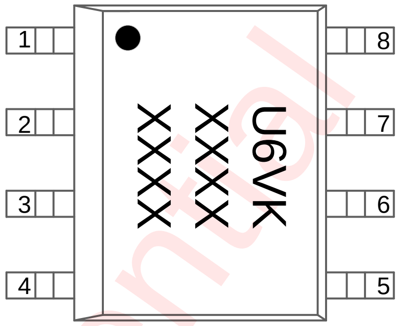
Internal shutdown functions are provided for Over-current protection (OCP), Short-circuit protection, Under-voltage lockout (UVLO), and Over-temperature protection (TSD). When the fault condition is removed, the device automatically resumes normal operation.

Pin Configuration And Top Mark

AWD8870ASPR
(Top View)



AWD8870ASPR Marking
(Top View)

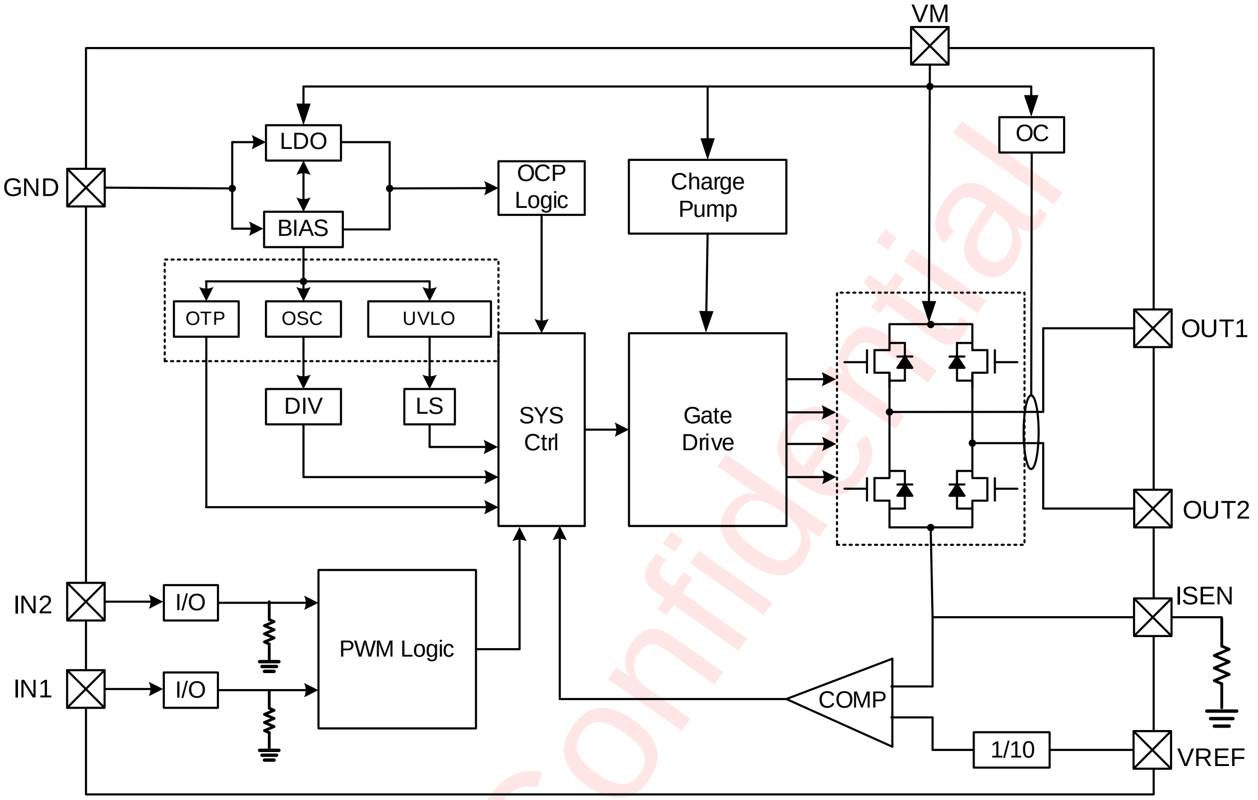


U6VK - AWD8870ASPR
XXXX/XXXX--Production Tracing code

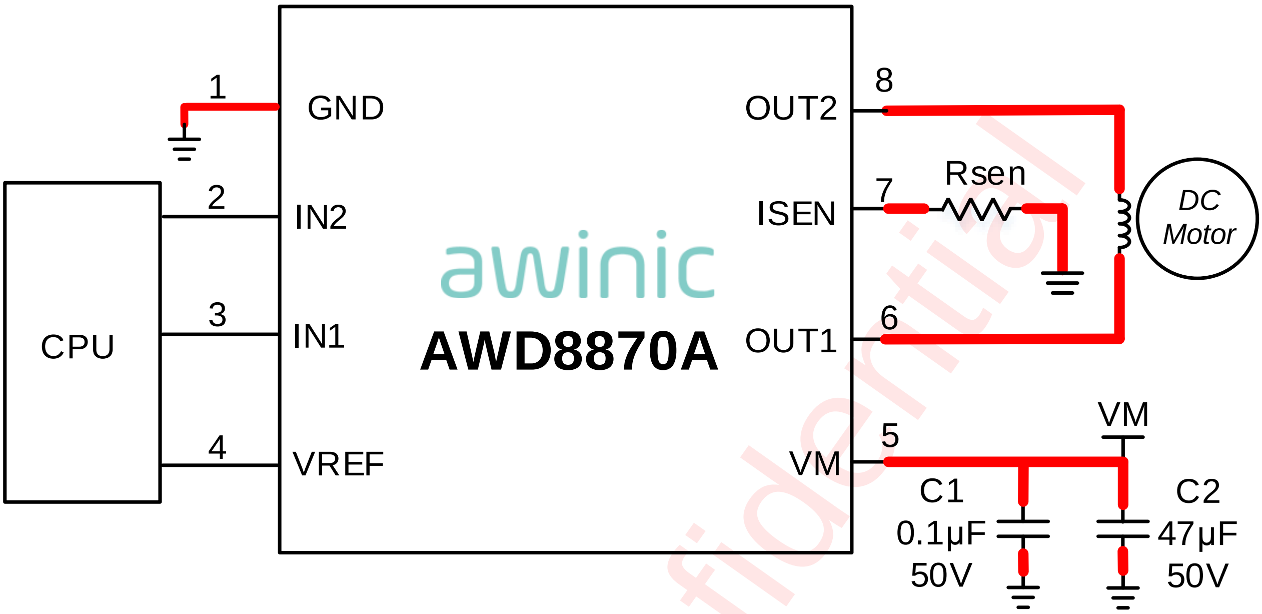
Pin Definition

No.	NAME	TYPE	DESCRIPTION
1	GND	PWR	Logic ground. Connect to board ground.
2	IN2	I	Logic inputs. Controls the H-bridge output. Has internal pulldowns.
3	IN1	I	
4	VREF	I	Analog input. Apply a voltage between 0.3 to 5 V. For information on current regulation, see the Current Regulation.
5	VM	PWR	6.5V to 45V power supply. Connect a 0.1μF bypass capacitor to ground, as well as sufficient bulk capacitance, rated for the VM voltage.
6	OUT1	O	H-bridge output. Connect directly to the motor.
7	ISEN	PWR	High-current ground path. If using current regulation, connect ISEN to a resistor (low-value, high-power-rating) to ground. If not using current
8	OUT2	O	H-bridge output. Connect directly to the motor.
-	Thermal Pad	-	Beneath the IC for heat dissipation. Always solder to the PCB ground for high-current power converter.

Functional Block Diagram



Typical Application Circuits



Notice for Typical Application Circuits:

1. Please place C1, C2 as close to the chip as possible. The capacitors should be placed in the same layer with the AWD8870A chip.
2. For the sake of driving capability, the power lines and output lines should be short and wide as possible.
3. The power path marked in red as shown in the figures above, please traces according to 4A power line alignment rules.
4. **Table 1** lists the recommended external components for the device.

Table 1 External Components

COMPONENT	PIN 1	PIN 2	RECOMMENDED
C_1	VM	GND	50V, 0.1μF ceramic capacitor rated for VM
C_2	VM	GND	50V, 47μF bulk capacitor rated for VM

Ordering Information

Part Number	Temperature	Package	Marking	Moisture Sensitivity Level	Environmental Information	Delivery Form
AWD8870ASPR	-40°C~125°C	WBESOP-8L	U6VK	MSL3	RoHS+HF	3000 units/ Tape and Reel

Absolute Maximum Ratings(NOTE1)

PARAMETERS	RANGE
Motor power-supply voltage (VM)	-0.3V to 50V
Control pin voltage (IN1, IN2)	-0.3V to 5.5V
Reference input pin voltage (VREF)	-0.3V to 5.5V
Continuous phase node pin voltage (OUT1, OUT2)	-0.7V to VM+0.7V
Current sense input pin voltage (ISEN)	-0.5V to 1V
Output current (100% duty cycle)	0A to 3.6A
Maximum operating junction temperature T_{JMAX}	160°C
Storage temperature TSTG	-65°C to 150°C
ESD(Including CDM HBM MM)(NOTE 2)	
HBM(Human Body Model)	±2kV
CDM(Charge Device Model)	±1.5kV
Latch-Up	
Test Condition: JEDEC STANDARD NO.78E	+IT：200mA -IT：-200mA

NOTE1: Conditions out of those ranges listed in "absolute maximum ratings" may cause permanent damages to the device. In spite of the limits above, functional operation conditions of the device should within the ranges listed in "recommended operating conditions". Exposure to absolute-maximum-rated conditions for prolonged periods may affect device reliability.

NOTE2: The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin. Test method: ANSI/ESDA/JEDEC JS-001.

Recommended Operating Conditions

PARAMETERS		Range	Unit
VM	Power supply voltage	6.5 to 45	V
V_I	Logic input voltage (IN1, IN2)	0 to 5	V
VREF	VREF input voltage	0.3(1) to 5 (1)	V
f_{PWM}	Logic input PWM frequency (IN1, IN2)	0 to 200(2)	kHz
I_{peak}	Peak output current(3)	0 to 3.6	A

(1) If VREF < 0.3V or VREF > 4.2V, the accuracy will be degraded.

(2) The voltages applied to the inputs should have at least 2500ns of pulse width to ensure detection. If the PWM frequency is 200 kHz, the usable duty cycle range is 50% to 80%.

(3) Power dissipation and thermal limits must be observed.

Thermal Information

PARAMETERS		Range	Unit
$R_{θJA}$	Junction-to-ambient thermal resistance	55.25	°C/W
$R_{θJC(top)}$	Junction-to-case (top) thermal resistance	59.75	°C/W
$R_{θJB}$	Junction-to-board thermal resistance	2.43	°C/W
$ψ_{JT}$	Junction-to-top characterization parameter	5.94	°C/W
$ψ_{JB}$	Junction-to-board characterization parameter	2.15	°C/W
$R_{θJC(bot)}$	Junction-to-case (bottom) thermal resistance	1.65	°C/W

Electrical Characteristics

T_A=25°C for typical values (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLIES (VM)						
VM	VM operating voltage		6.5		45	V
IVM	VM operating supply current	VM = 12 V		3	10	mA
IVMQ	VM sleep mode supply current	VM = 12 V			10	μA
t_{ON}	Turn-on time	VM > V_{UVLO} with IN1 or IN2 high		45	65	μs
LOGIC-LEVEL INPUTS (IN1, IN2)						
VIL	Input logic low voltage				0.50	V
VIH	Input logic high voltage		1.5			V
VHYS	Input logic hysteresis			0.15		V
IIL	Input logic low current	VIN = 0 V	-1		1	μA
IIH	Input logic high current	VIN = 3.3 V		33	100	μA
R_{PD}	Pulldown resistance	To GND		100		kΩ
t_{PD1}	Propagation delay	INx to OUTx change (see Figure 6)		0.3	1	μs
t_{PD2}	Propagation delay	INx to OUTx change (see Figure 6)		0.4	1	μs
tsleep	Time to sleep	Inputs low to sleep		1.5	2	ms

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
MOTOR DRIVER OUTPUTS (OUT1, OUT2)						
R_{DSON}	High-side FET on-resistance	VM = 24 V; IO=1000mA;		270		mΩ
R_{DSON}	Low-side FET on-resistance	VM = 24 V; IO=1000mA;		190		mΩ
t_{DEAD1}	Output dead time	INx to OUTx change (see Figure 6)		210		ns
t_{DEAD2}	Output dead time			110		ns
Vd	Body diode forward voltage	IOUT=1A		0.93		V
CURRENT REGULATION						
A_V	ISEN gain	VREF=2.5V	9.5	10	10.5	V/V
t_{OFF}	PWM off-time			25		μs
tBLANK	PWM blanking time			2.4		μs
PROTECTION CIRCUITS						
V_{UVLO}	VM undervoltage lockout	VM falls until UVLO triggers		6.1	6.4	V
		VM rises until operation recovers		6.3	6.5	
$V_{UV,HYS}$	VM undervoltage hysteresis	Rising to falling threshold	100	270		mV
I_{OCP}	Overcurrent protection trip level		3.7	4.1	6.4	A
t_{OCP}	Overcurrent deglitch time			2		μs
t_{RETRY}	Overcurrent retry time			3		ms
T_{SD}	Thermal shutdown temperature	Die temperature T_J		175		°C
T_{HYS}	Thermal shutdown hysteresis			30		°C

Typical Characteristics

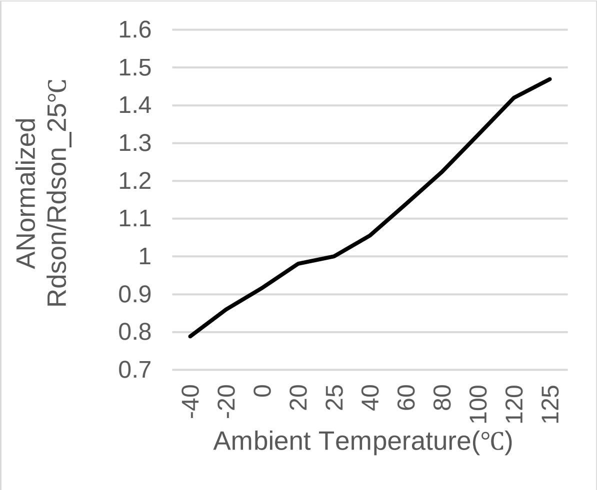


Figure 1 RDS(on) vs Temperature

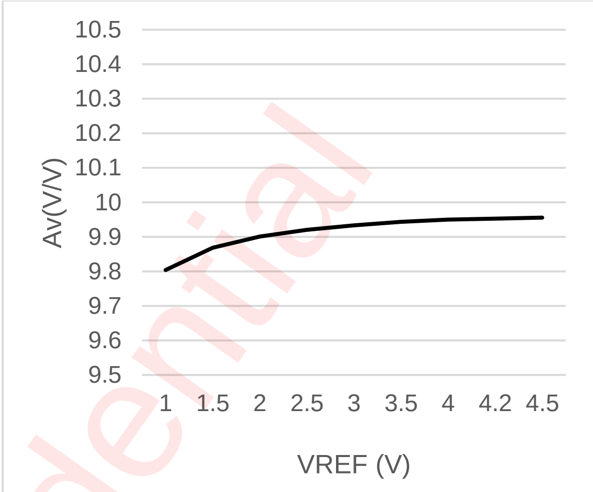


Figure 2 AV vs VREF

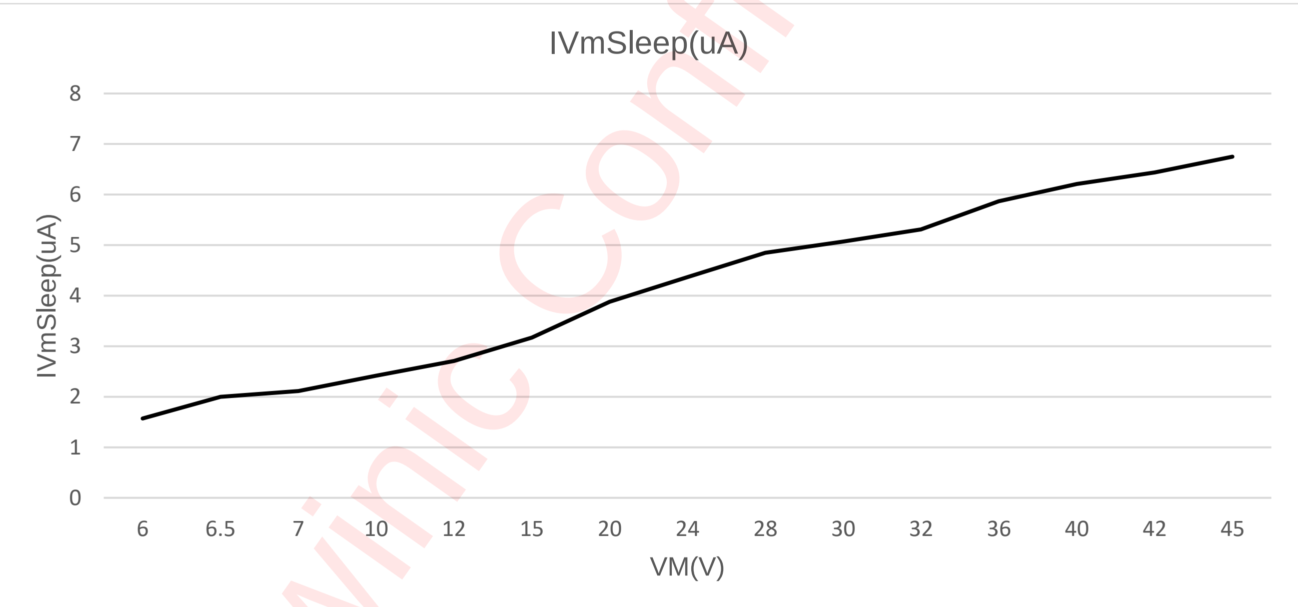


Figure 3 $I_{VMSLEEP}$ vs VM at 25°C

Detailed Functional Description

OVERVIEW

The AWD8870A device is a conventional 8-pin chip used to drive one brushed DC motors, with a maximum peak current of 3.6A.The H-bridge driver is controlled using a PWM interface (IN1 and IN2), which has a typical R_{dson} of 460mΩ (including one high-side and one low-side FET). PWM input can adjust the motor speed by changing the duty cycle and frequency. When the inputs are all low, the chip enters sleep mode after 1.5ms. The integrated charge pump of the device boosts VM internally and fully enhances the high-side FETs. In addition, the AWD8870A adds protection features beyond traditional discrete implementations: under-voltage lockout, overcurrent protection, and thermal shutdown.

FEATURE DESCRIPTION

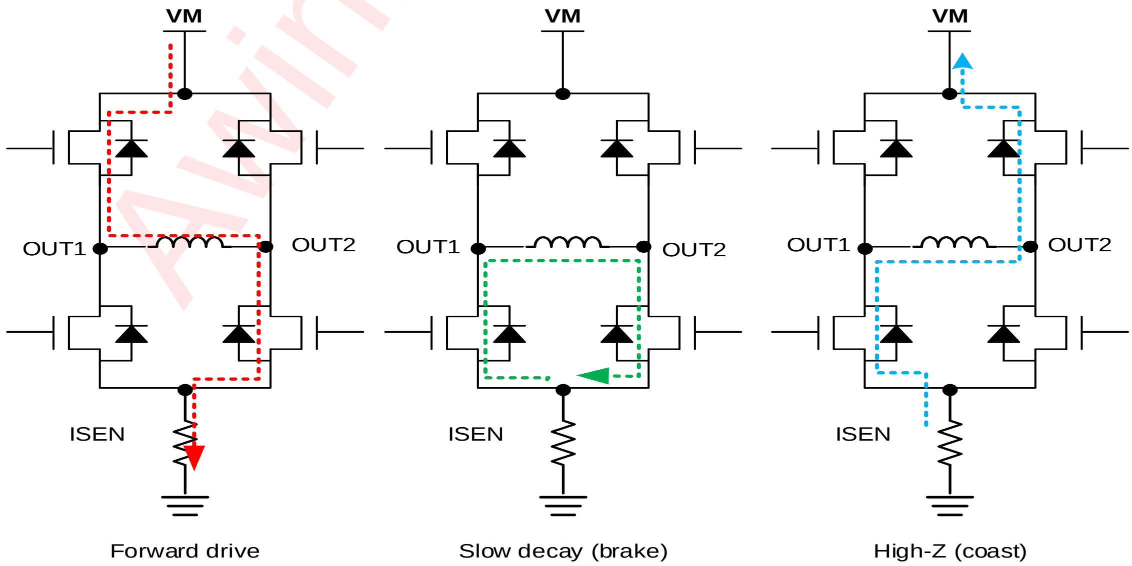
BRIDGE CONTROL

The AWD8870A is controlled using a PWM input interface. Each output is controlled by a corresponding input pin. **Table** 2 shows the logic for the AWD8870A device.

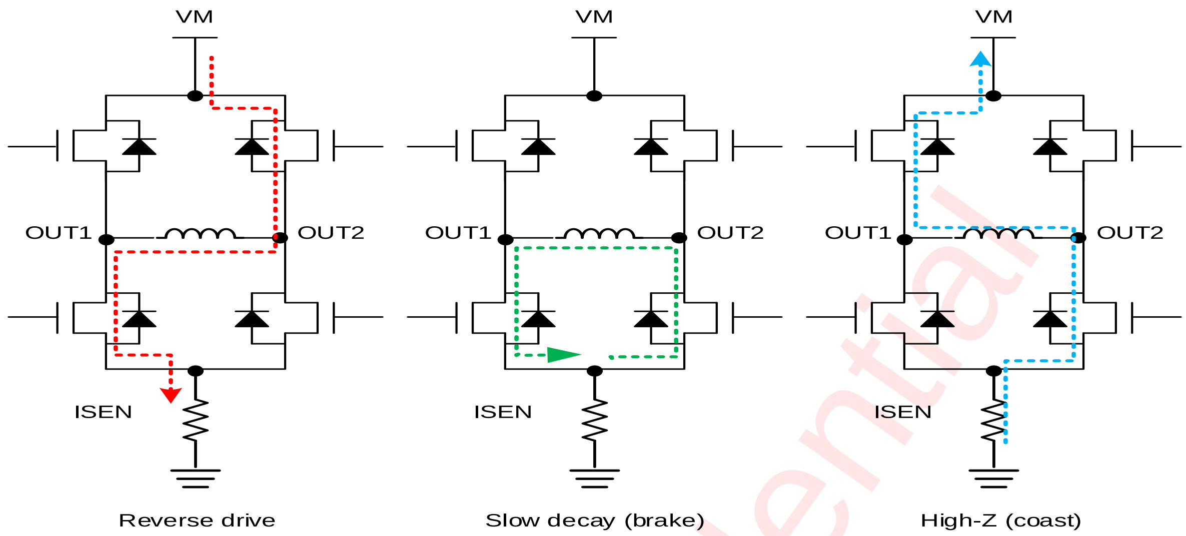
Table 2 AWD8870A Device Logic

IN1	IN2	OUT1	OUT2	FUNCTION (DC MOTOR)
0	0	Z	Z	Coast , sleep entered after 1.5ms
0	1	L	H	Reverse
1	0	H	L	Forward
1	1	L	L	Brake, low-side slow decay

The input pins can be powered before VM is applied. The H-bridge driver is controlled using a PWM interface (IN1 and IN2), and PWM input can adjust the motor speed by changing the duty cycle and frequency. The H-bridge current paths can be controlled by setting IN1 and IN2. Alternatively, the coast mode (IN1 = 0, IN2 = 0) for fast current.



H-Bridge Forward drive Paths



H-Bridge Reverse drive Paths

Figure 4 H-Bridge Current Paths

SLEEP MODE

If the inputs are all low, the outputs remain High-Z (the coast mode) and discharge quickly. After time t_{SLEEP} 1.5ms, the chip enters a low-power sleep mode. When the IN1 or IN2 pins are high for at least 5μs, the device is operational 65μs (t_{ON}) later.

CURRENT REGULATION

The AWD8870A device can adjust the output current by changing VREF and R_{ISEN} according to Equation 1:

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

Where

- VREF is the analog input voltage
- R_{ISEN} is the resistance of an external sense resistor on the ISEN pin
- I_{TRIP} is the threshold current

For example, when V_{REF} = 3.3V and R_{ISEN} = 0.15Ω, the threshold current I_{TRIP} is 2.2 A. If the motor current exceeds 2.2A for time t_{BLANK} (typically 2.4us) , the AWD8870A device enforces low-side slow decay (brake mode), and it does this for a time of t_{OFF} (typically 25 μs). After t_{OFF} elapses, the output is re-enabled according to the two inputs. Figure 5 shows Current-Regulation Time Periods. For guidelines on selecting a sense resistor, see the Sense Resistor section.

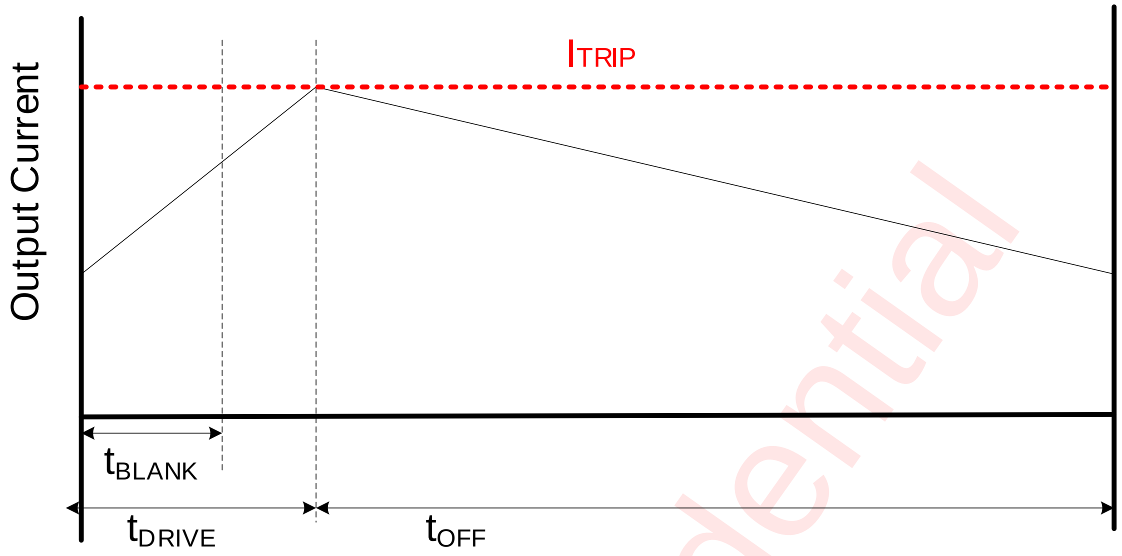


Figure 5 Current-Regulation Time Periods

TIMING REQUIREMENTS

When the input signal changes, the output signal will change after time t_{PD}(typically 400ns). In order to prevent the H-bridge from generating shoot-through current, dead time is necessary. 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.

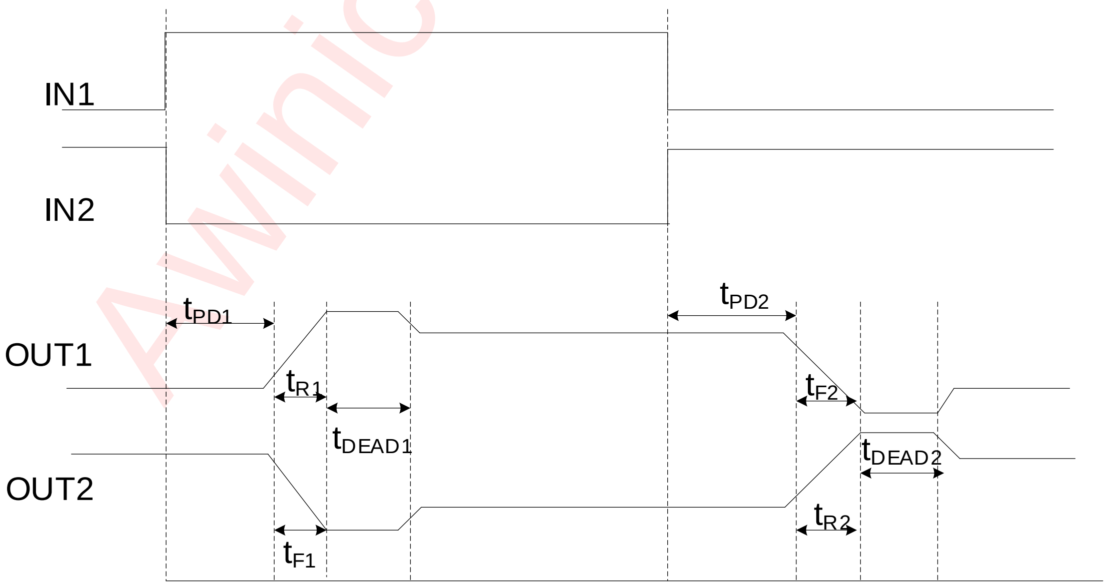


Figure 6 Propagation Delay Time

POWER SUPPLIE AND INPUT PINS

A single-power input, VM, serves as both device power and the motor winding bias voltage. No leakage current path will exist to the supply. Each input pin has a weak pulldown resistor (approximately 100 kΩ) to ground.

VM UNDERVOLTAGE LOCKOUT

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

OVERCURRENT PROTECTION

An analog current-limit circuit on each FET limits the current through the FET by removing the gate drive. If this analog current limit persists for longer than t_{DEG}, all FETs in the H-bridge are disabled. Operation resumes automatically after t_{RETRY} has elapsed. Overcurrent conditions are detected on both the high-side and low side FETs. A short to the VM pin, GND, or from the OUT1 pin to the OUT2 pin results in an overcurrent condition.

THERMAL SHUTDOWN

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

Table 2 Fault Behavior

FAULT	CONDITION	H-BRIDGE	RECOVERY
VM under-voltage (UVLO)	$VM<V_{UVLO}$	Disabled	$VM>V_{UVLO}+V_{HS}$
Overcurrent (OCP)	$I_{OUT}>I_{OCP}$	Disabled	t_{RETRY} elapses
Thermal Shutdown (TSD)	$T_J>T_{SD}$	Disabled	$T_J<T_{SD}-T_{HS}$

DEVICE FUNCTIONAL MODES

The AWD8870A is active unless the IN1 and IN2 are both logic low for time t_{SLEEP} (typically 1.5ms). In sleep mode, the H-bridge FETs are disabled Hi-Z. The AWD8870A is brought out of sleep mode automatically if the IN1 or IN2 pins are high for at least 5μs. The H-bridge outputs are disabled during under-voltage lockout, overcurrent, and over-temperature fault conditions.

PWM WITH CURRENT REGULATION

This scheme uses all of the capabilities of the device. The I_{TRIP} 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 3.6 A for a few hundred milliseconds (depending on PCB characteristics and the ambient temperature). If current exceeds 3.6 A, the device might reach overcurrent protection (OCP) or overtemperature shutdown (TSD). If that happens, the device disables and protects itself for about 3ms (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.

Application Information

The AWD8870A is used to drive one brushed dc motor. The following design procedure can be used to configure the AWD8870A device.

DESIGN REQUIREMENTS

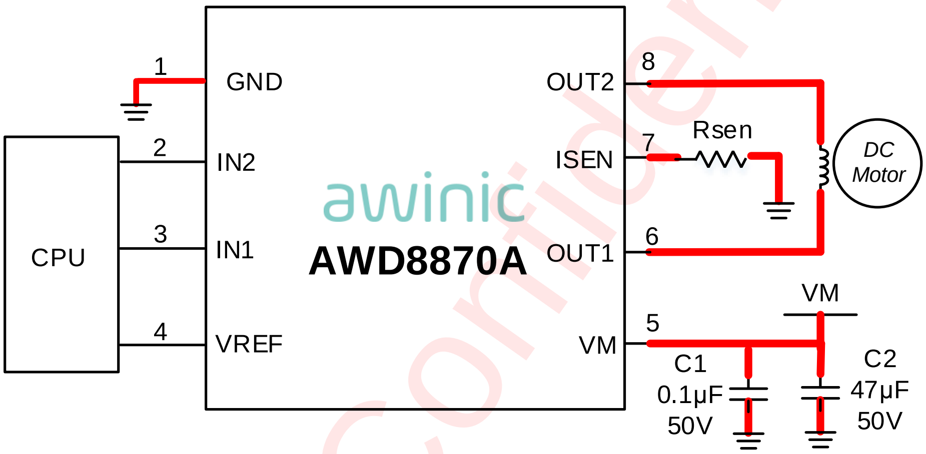


Table lists the required parameters for a typical usage case.

Table 3 System Design Requirements

DESIGN PARAMETER	REFERENCE	EXAMPLE VALUE
Motor supply voltage	VM	24V
Motor RMS current	I_{RMS}	0.8A
Motor startup current	I_{START}	2.0A
VREF voltage	VREF	3.3V
Sense resistance	R_{ISEN}	0.15Ω
Motor current trip point	I_{TRIP}	2.2A
PWM frequency	f_{PWM}	5 kHz

MOTOR VOLTAGE

The appropriate motor voltage depends on the ratings of the motor selected and the desired RPM. A higher voltage spins a brushed dc motor faster with the same PWM duty cycle applied to the power FETs. A higher voltage also increases the rate of current change through the inductive motor windings.

DRIVE CURRENT

The current path is through the high-side sourcing NMOS power driver, motor winding, and low-side sinking NMOS power driver. Power dissipation losses in one source and sink NMOS power driver are shown in Equation 2:

$$P_D(W) = I^2(R_{DSON(HS)} + R_{DSON(LS)})$$

The AWD8870A device has been measured to be capable of 2A RMS current at 25°C on standard FR-4 PCBs.The maximum RMS current varies based on the PCB design, ambient temperature, and PWM frequency.

SENSE RESISTOR

For optimal performance, the sense resistor must have the following characteristics:

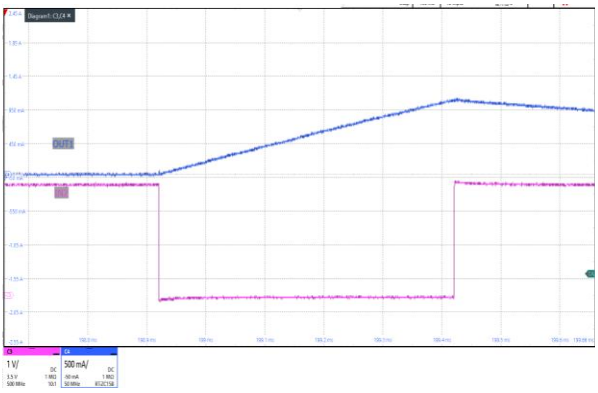
- Surface-mount
- Low inductance
- Rated for high enough power
- Placed closely to the motor driver

The power dissipated by the sense resistor equals I_{RMS}^2 × R. For example, if peak motor current is 3A, RMS motor current is 1.5A, and a 0.2Ω sense resistor is used, the resistor dissipates $(1.5A)^2$ × 0.2Ω = 0.45W. The power quickly increases with higher current levels.

Resistors typically have a rated power within some ambient temperature range, along with a derated power curve for high ambient temperatures. When a PCB is shared with other components generating heat, the system designer should add margin. Measuring the actual sense resistor temperature in a final system is always best.

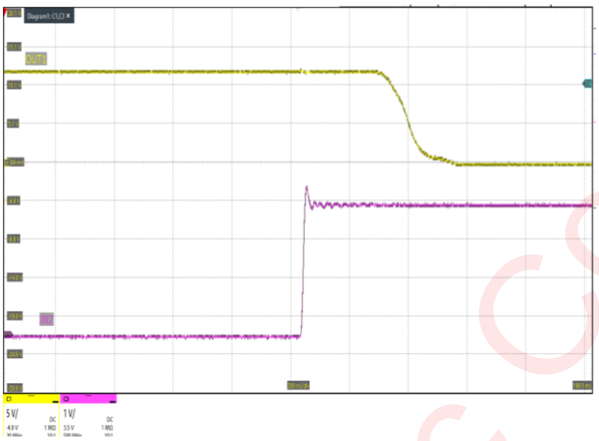
Because power resistors are larger and more expensive than standard resistors, using multiple standard resistors in parallel, between the sense node and ground, is common and distributes the current and heat dissipation.

APPLICATION CURVES

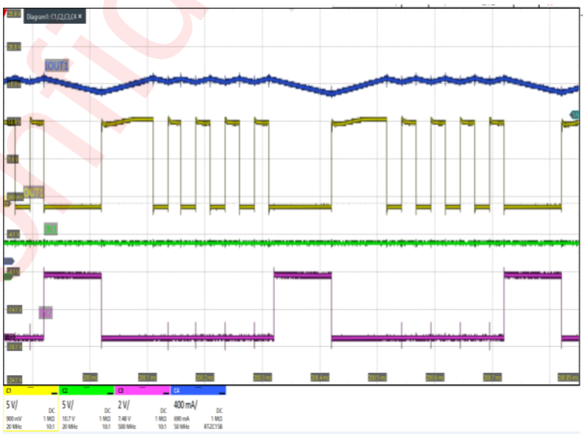


Current Ramp With a 2Ω, 5mH RL Load and VM = 12V

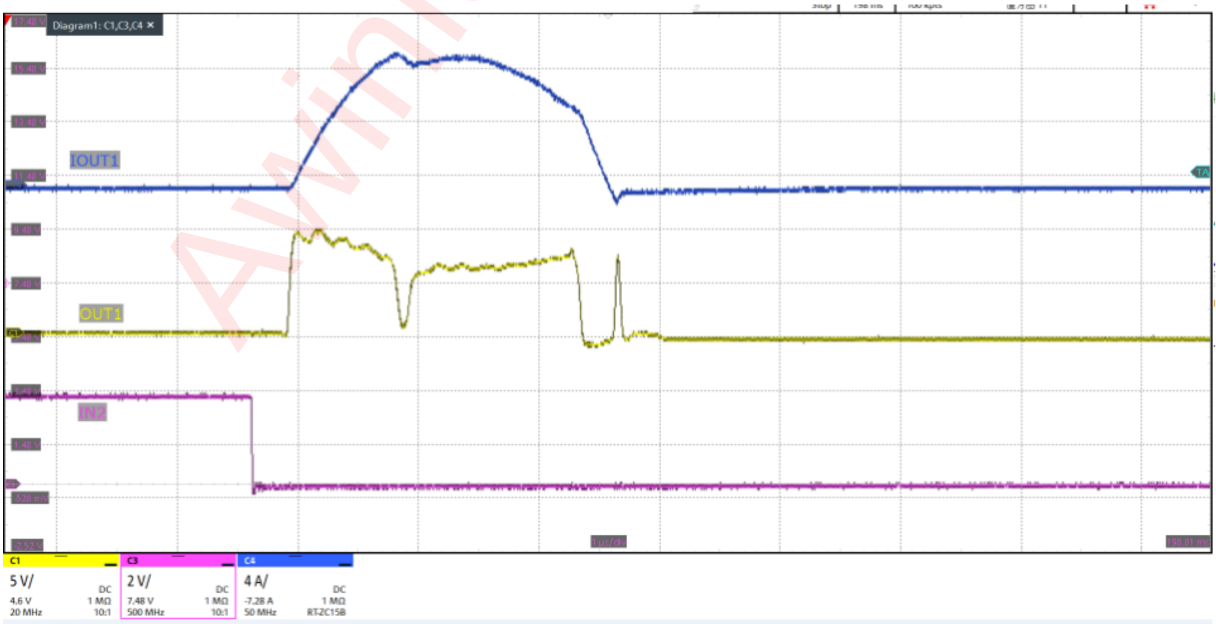
Current Ramp With a 2Ω, 5mH RL Load and VM = 24 V



t_{PD}



Current Regulation With VREF = 2 V and 200 mΩ



OCP With 45 V and the Outputs Shorted Together

POWER SUPPLY RECOMMENDATIONS

BULK CAPACITANCE

Having appropriate local bulk capacitance is an important factor in motor-drive system design. It is generally beneficial to have more bulk capacitance, while the disadvantages are increased cost and physical size.

The amount of local capacitance needed depends on a variety of factors, including:

- The highest current required by the motor system
- The power-supply capacitance and ability to source current
- The amount of parasitic inductance between the power supply and motor system
- The acceptable voltage ripple
- The type of motor used (brushed dc, brushless dc, stepper)
- The motor braking method

The inductance between the power supply and motor drive system limits the rate at which current can change from the power supply. If the local bulk capacitance is too small, the system responds to excessive current demands or dumps from the motor with a change in voltage. When adequate bulk capacitance is used, the motor voltage remains stable and high current can be quickly supplied.

The datasheet generally provides a recommended value, but system-level testing is required to determine the appropriate size of bulk capacitor.

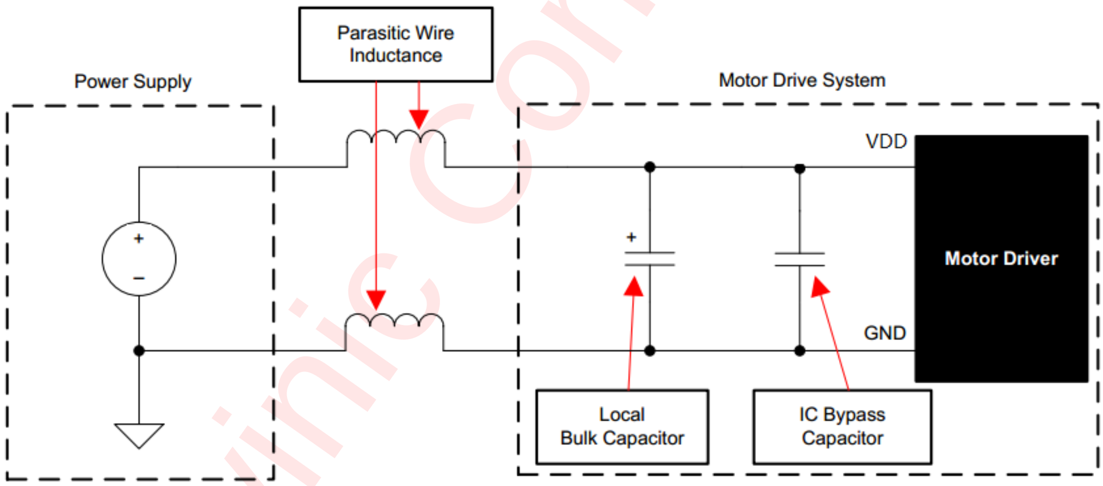


Figure 7 Example Setup of Motor Drive System With External Power Supply

The voltage rating for bulk capacitors should be higher than the operating voltage, to provide margin for cases when the motor transfers energy to the supply.

PCB Layout Consideration

EXTERNAL COMPONENTS PLACEMENT

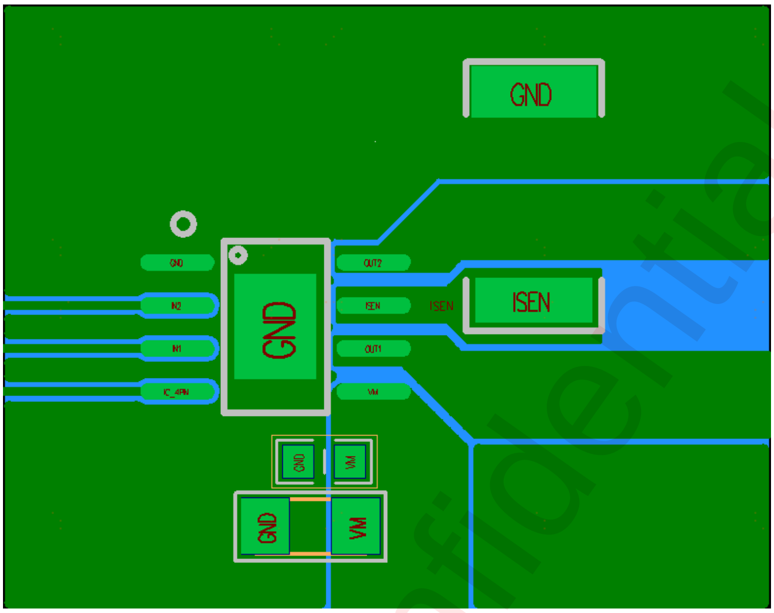


Figure 8 AWD8870A External Components Placement

LAYOUT CONSIDERATIONS

The bulk capacitor should be placed to minimize the distance of the high-current path through the motor driver device. The connecting metal trace widths should be as wide as possible, and numerous vias should be used when connecting PCB layers. These practices minimize inductance and allow the bulk capacitor to deliver high current.

Small-value capacitors should be ceramic, and placed closely to device pins.

The high-current device outputs should use wide metal traces.

The device thermal pad should be soldered to the PCB top-layer ground plane. Multiple vias should be used to connect to a large bottom-layer ground plane. The use of large metal planes and multiple vias help dissipate the $I^2 \times R_{DSON}$ heat that is generated in the device.

THERMAL CONSIDERATIONS

The AWD8870A device has thermal shutdown (TSD) as described in the Thermal Shutdown (TSD) section. If the die temperature exceeds approximately 175°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 AWD8870A is dominated by the power dissipated in the output FET resistance, or R_{DSON}. Use Equation to estimate the average power dissipation when running a stepper motor.

$$P_D(W) = I^2(R_{DSON(HS)} + R_{DSON(LS)})$$

Where

- P_D is the total power dissipation
- $I_{OUT(rms)}$ is the rms or dc output current being supplied to the load

The maximum amount of power that can be dissipated in the device is dependent on ambient temperature and heatsinking. Note that at startup, the current is much higher than normal running current; this peak current and its duration must be also be considered.

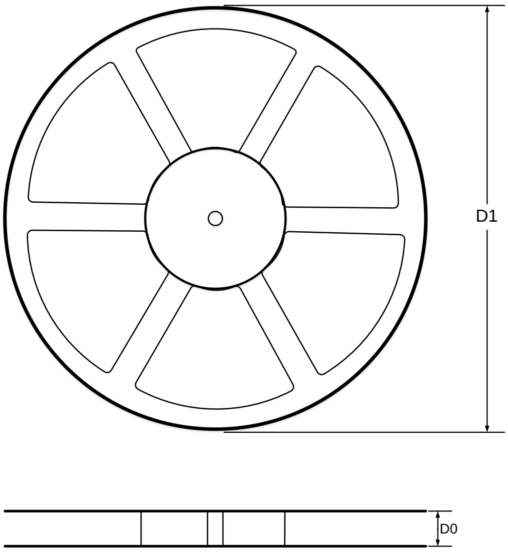
For this example, the ambient temperature is 58°C, and the junction temperature reaches 80°C. At 58°C, the sum of R_{DSON} is about 0.53 Ω. With an example motor current of 0.8 A, the dissipated power in the form of heat is $(0.8A)^2 \times 0.53\Omega = 0.34W$.

The temperature that the AWD8870A 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 AWD8870A device had an effective thermal resistance $R_{\theta JA}$ of 55.25°C/W, and:

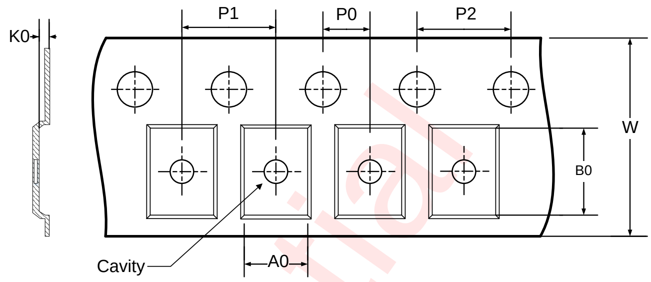
$$T_J = T_A + (P_D \times R_{JA}) = 58℃ + (0.34W \times 55.25℃/W) = 77℃$$

Tape And Reel Information

REEL DIMENSIONS

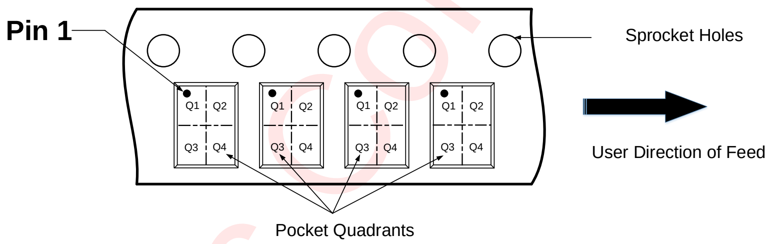


TAPE DIMENSIONS



A0：Dimension designed to accommodate the component width
B0：Dimension designed to accommodate the component length
K0：Dimension designed to accommodate the component thickness
W：Overall width of the carrier tape
P0：Pitch between successive cavity centers and sprocket hole
P1：Pitch between successive cavity centers
P2：Pitch between sprocket hole
D1：Reel Diameter
D0：Reel Width

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



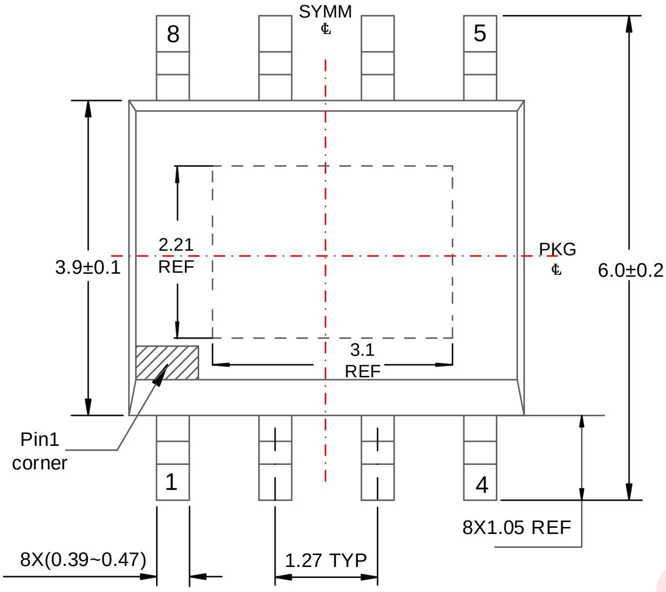
Note：The above picture is for reference only. Please refer to the value in the table below for the actual size

DIMENSIONS AND PIN1 ORIENTATION

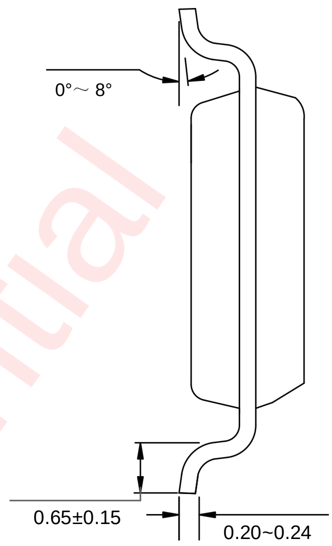
D1 (mm)	D0 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
330	12.4	6.55	5.3	2	2	8	4	12	Q1

All dimensions are nominal

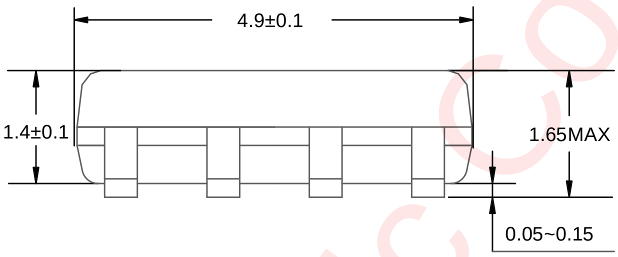
Package Description



Top View



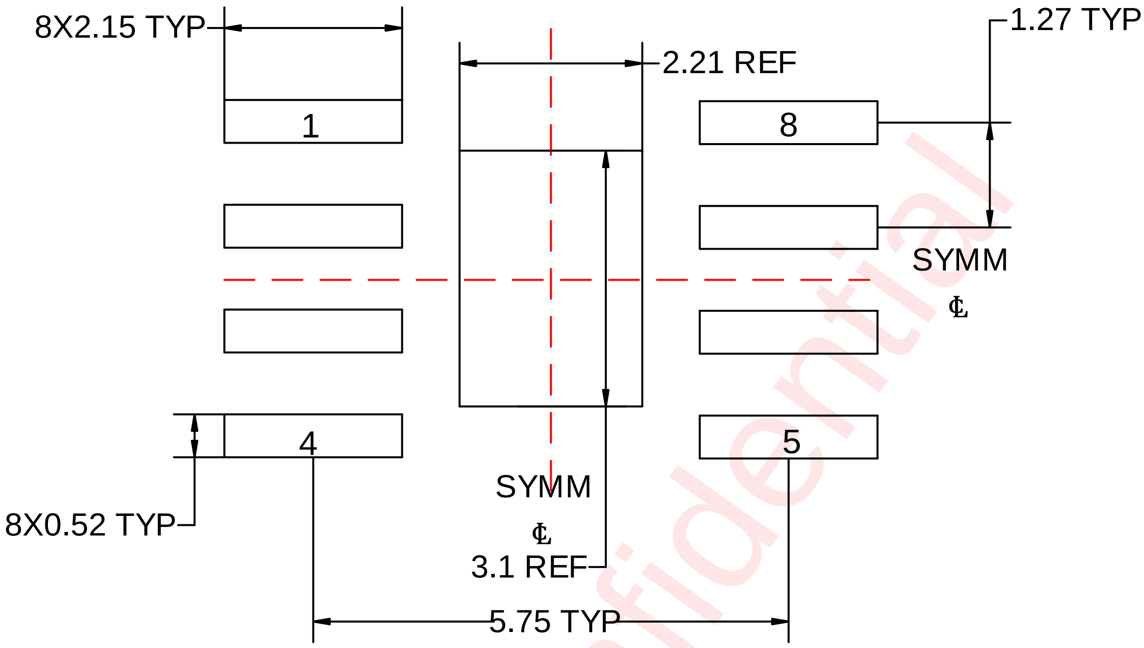
Side View

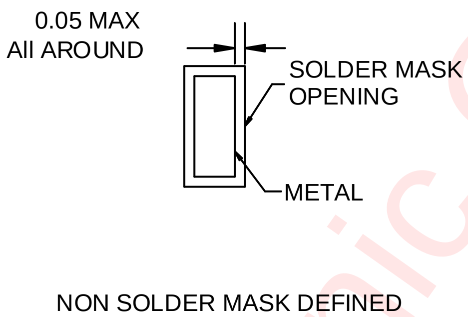


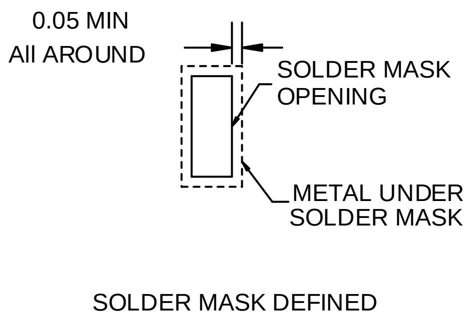
Side View

Unit: mm

Land Pattern Data







Unit： mm

REVISION HISTORY

Version	Date	Change Record
V1.0	Jul. 2023	Initial released
V1.1	May.2024	Motor startup current is changed from 2.0V to 2.0A

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