DUAL STEPPER MOTOR CONTROLLER/DRIVER

Check for Samples: DRV8821

FEATURES

- **Dual PWM microstepping motor driver**
  - **Built-In Microstepping Indexers**
  - **Up to 1.5-A Current Per Winding**
  - **Three-Bit Winding Current Control Allows up to Eight Current Levels**
  - **Low MOSFET On-Resistance**
  - **Selectable Slow or Mixed Decay Modes**
- **8-V to 32-V Operating Supply Voltage Range**
- **Internal Charge Pump for Gate Drive**
- **Built-in 3.3-V Reference**
- **Simple Step/Direction Interface**
- **Fully Protected Against Undervoltage, Overtemperature, and Overcurrent**
- **Thermally Enhanced Surface Mount Package**

APPLICATIONS

- **Printers**
- **Scanners**
- **Office Automation Machines**
- **Gaming Machines**
- **Factory Automation**
- **Robotics**

DESCRIPTION/ORDERING INFORMATION

The DRV8821 provides a dual microstepping-capable stepper motor controller/driver solution for printers, scanners, and other office automation equipment applications.

Two independent stepper motor driver circuits include four H-bridge drivers and microstepping-capable indexer logic. Each of the motor driver blocks employ N-channel power MOSFETs configured as an H-bridge to drive the motor windings.

A simple step/direction interface allows easy interfacing to controller circuits. Pins allow configuration of the motor in full-step, half-step, quarter-step, or eighth step modes, and the selection of slow or mixed decay modes.

Internal shutdown functions are provided for over current protection, short circuit protection, under voltage lockout and overtemperature.

The DRV8821 is packaged in a 48-pin HTSSOP package (Eco-friendly : RoHS & no Sb/Br).

ORDERING INFORMATION(1)

T_A	PACKAGE(2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	PowerPad™ (HTSSOP) - DCA	Reel of 2000	DRV8821DCAR	DRV8821
		Tube of 40	DRV8821DCA	

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

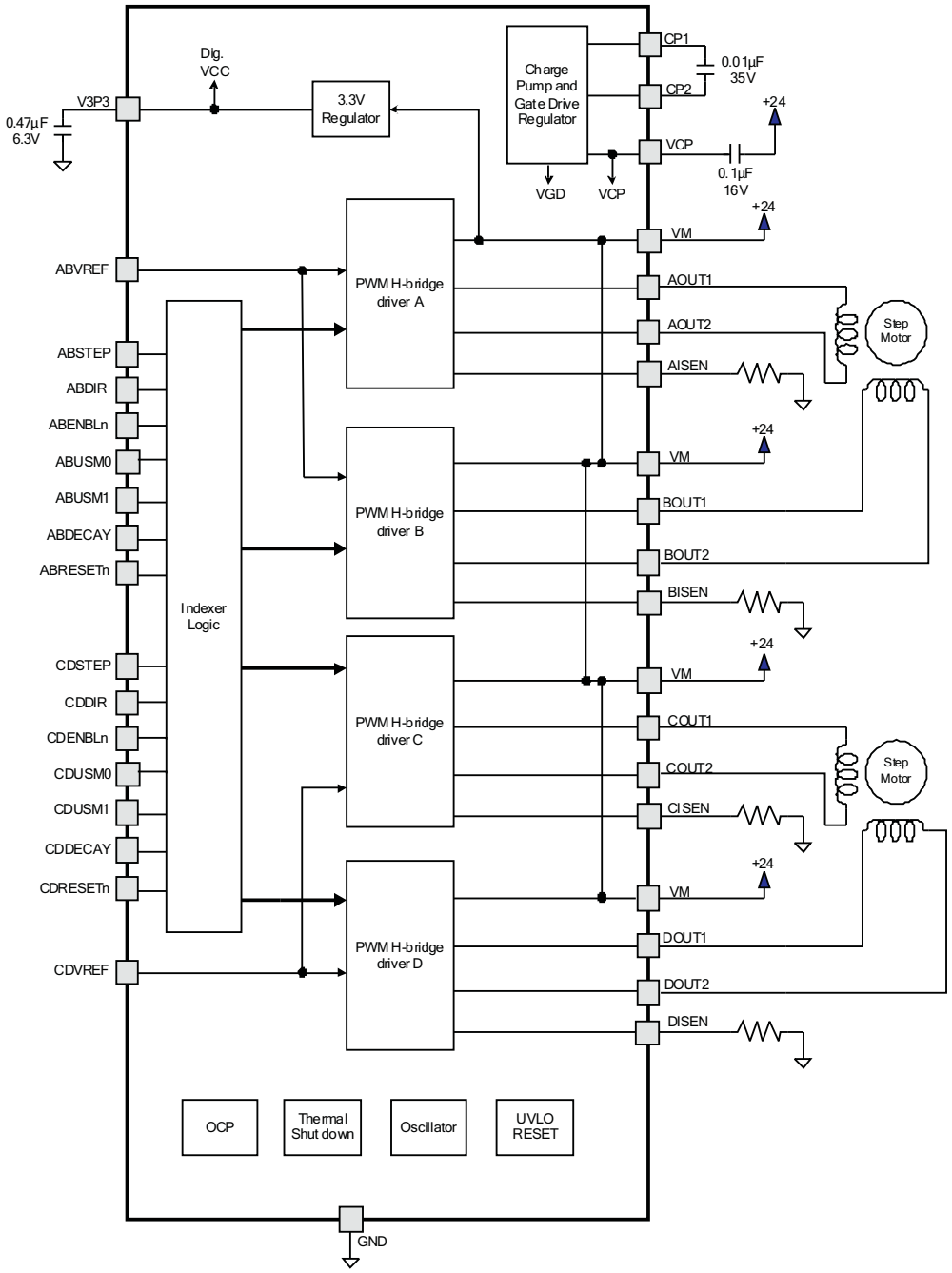
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FUNCTIONAL BLOCK DIAGRAM



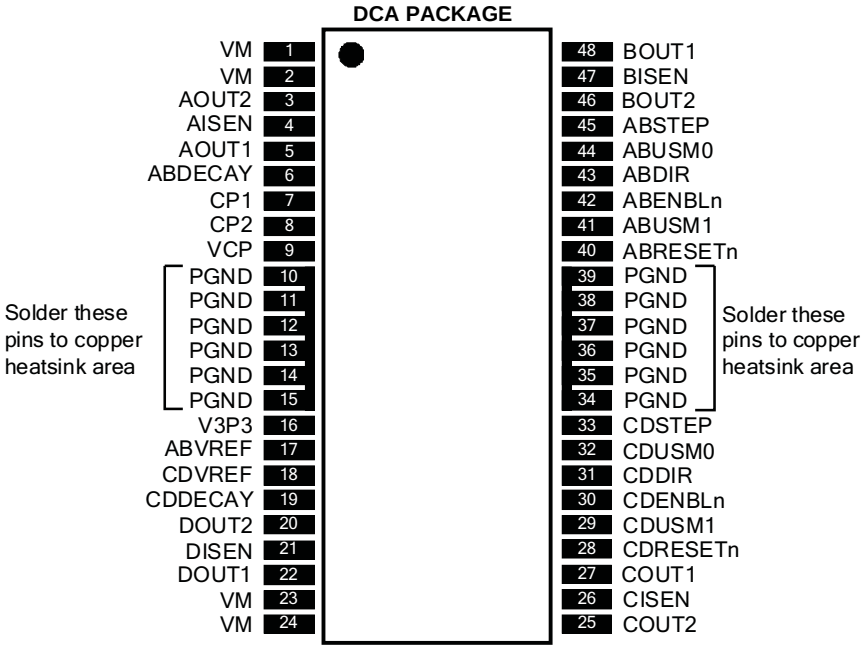
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TERMINAL FUNCTIONS

NAME	NO.	I/O[1]	DESCRIPTION	EXTERNAL COMPONENTS OR CONNECTIONS
POWER AND GROUND				
VM (4 pins)	1,2, 23, 24	-	Motor supply voltage (multiple pins)	Connect all VM pins together to motor supply voltage. Bypass to GND with several 0.1-μF, 35-V ceramic capacitors.
V3P3	16	-	3.3 V regulator output	Bypass to GND with 0.47-μF, 6.3-V ceramic capacitor.
GND	10-15, 34-39	-	Power ground (multiple pins)	Connect all PGND pins to GND and solder to copper heatsink areas.
CP1	7	IO	Charge pump flying capacitor	Connect a 0.01-μF capacitor between CP1 and CP2
CP2	8	IO		
VCP	9	IO	Charge pump storage capacitor	Connect a 0.1-μF, 16 V ceramic capacitor to V_M
MOTOR AB				
ABSTEP	45	I	Motor AB step input	Rising edge causes the indexer to move one step.
ABDIR	43	I	Motor AB direction input	Level sets the direction of stepping.
ABUSM0	44	I	Motor AB microstep mode 0	USM0 and USM1 set the step mode - full step, half step, quarter step, or eight microsteps/step.
ABUSM1	41	I	Motor AB microstep mode 1	
ABENBLn	42	I	Motor AB enable input	Logic high to disable motor A outputs, logic low to enable.
ABRESETn	40	I	Motor AB reset input	Active-low reset input initializes the indexer logic and disables the H-bridge outputs for motor A.
ABDECAY	6	I	Motor AB decay mode	Logic low for slow decay mode, high for mixed decay.
ABVREF	17	I	Motor AB current set reference voltage	Sets current trip threshold.
AOUT1	5	O	Bridge A output 1	Connect to first coil of bipolar stepper motor 1, or DC motor winding.
AOUT2	3	O	Bridge A output 2	
AISEN	4	-	Bridge A current sense	Connect to current sense resistor for bridge A.
BOUT1	48	O	Bridge B output 1	Connect to second coil of bipolar stepper motor 1, or DC motor winding.
BOUT2	46	O	Bridge B output 2	
BISEN	45	-	Bridge B current sense	Connect to current sense resistor for bridge B.
MOTOR CD				
CDSTEP	33	I	Motor CD step input	Rising edge causes the indexer to move one step.
CDDIR	31	I	Motor CD direction input	Level sets the direction of stepping.
CDUSM0	32	I	Motor CD microstep mode 0	USM0 and USM1 set the step mode - full step, half step, quarter step, or eight microsteps/step.
CDUSM1	29	I	Motor CD microstep mode 1	
CDENBLn	30	I	Motor CD enable input	Logic high to disable motor Boutputs, logic low to enable.
CDRESETn	28	I	Motor CD reset input	Active-low reset input initializes the indexer logic and disables the H-bridge outputs for motor B.
CDDECAY	19	I	Motor CD decay mode	Logic low for slow decay mode, high for mixed decay.
CDREF	18	I	Motor CD current set reference voltage	Sets current trip threshold.
COUT1	27	O	Bridge C output 1	Connect to first coil of bipolar stepper motor 2, or DC motor winding.
COUT2	25	O	Bridge C output 2	
CISEN	26	-	Bridge C current sense	Connect to current sense resistor for bridge C.
DOUT1	22	O	Bridge D output 1	Connect to second coil of bipolar stepper motor 2, or DC motor winding.
DOUT2	20	O	Bridge D output 2	
DISEN	21	-	Bridge D current sense	Connect to current sense resistor for bridge D.

(1) Directions: I = input, O = output, OZ = 3-state output, OD = open-drain output, IO = input/output

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ABSOLUTE MAXIMUM RATINGS(1) (2)

over operating free-air temperature range (unless otherwise noted)

V_M	Power supply voltage range	–0.3 to 34	V
V_I	Logic input voltage range(3)	–0.5 to 5.75	V
$I_{O(peak)}$	Peak motor drive output current, t < 1 µs	Internally limited	
I_O	Motor drive output current(4)	1.5	A
P_D	Continuous total power dissipation	See Dissipation Ratings Table	
T_J	Operating virtual junction temperature range	–40 to 150	°C
T_A	Operating ambient temperature range	–40 to 85	°C
T_{stg}	Storage temperature range	–60 to 150	°C

(1) Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute–maximum–rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to network ground terminal.
(3) Input pins may be driven in this voltage range regardless of presence or absence of V_M.
(4) Power dissipation and thermal limits must be observed.

DISSIPATION RATINGS

BOARD	PACKAGE	$R_{\theta JA}$	DERATING FACTOR ABOVE T_A = 25°C	T_A < 25°C	T_A = 70°C	T_A = 85°C
Low-K(1)	DCA	75.7°C/W	13.2 mW/°C	1.65 W	1.06 W	0.86 W
Low-K(2)		32°C/W	31.3 mW/°C	3.91 W	2.50 W	2.03 W
High-K(3)		30.3°C/W	33 mW/°C	4.13 W	2.48 W	2.15 W
High-K(4)		22.3°C/W	44.8 mW/°C	5.61 W	3.59 W	2.91 W

(1) The JEDEC Low-K board used to derive this data was a 76-mm x 114-mm, 2-layer, 1.6-mm thick PCB with no backside copper.
(2) The JEDEC Low-K board used to derive this data was a 76-mm x 114-mm, 2-layer, 1.6-mm thick PCB with 25-cm^2 2-oz copper on back side.
(3) The JEDEC High-K board used to derive this data was a 76-mm x 114-mm, 4-layer, 1.6-mm thick PCB with no backside copper and solid 1-oz internal ground plane.
(4) The JEDEC High-K board used to derive this data was a 76-mm x 114-mm, 4-layer, 1.6-mm thick PCB with 25-cm^2 1-oz copper on back side and solid 1-oz internal ground plane.

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RECOMMENDED OPERATING CONDITIONS

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V_M	Motor power supply voltage range	8		32	V
I_{MOT}	Continuous motor drive output current(1)		1	1.5	A
V_{REF}	VREF input voltage	1		4	V

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

ELECTRICAL CHARACTERISTICS

over operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLIES						
I_{VM}	V_M operating supply current	V_M = 24 V, no loads		5	8	mA
I_{VMSD}	V_M shutdown supply current	V_M = 24 V, ABENBLn = CDENBLn = 1			2.5	μA
V_{UVLO}	V_M undervoltage lockout voltage	V_M rising		6.5	8	V
V_{CP}	Charge pump voltage	Relative to V_M		12		V
V_{V3P3}	V_{V3P3} output voltage		3.20	3.30	3.40	V
LOGIC-LEVEL INPUTS						
V_{IL}	Input low voltage				0.7	V
V_{IH}	Input high voltage		2			V
V_{HYS}	Input hysteresis		0.3	0.45	0.6	V
I_{IN}	Input current (internal pulldown current)	VIN = 3.3 V			100	μA
OVERTEMPERATURE PROTECTION						
t_{TSD}	Thermal shutdown temperature	Die temperature	150			°C
MOTOR DRIVER						
$R_{ds(on)}$	Motor #1 FET on resistance (each individual FET)	V_M = 24 V, I_O = 0.8 A, T_J = 25°C		0.25		Ω
		V_M = 24 V, I_O = 0.8 A, T_J = 85°C		0.31	0.37	
$R_{ds(on)}$	Motor #2 FET on resistance (each individual FET)	V_M = 24 V, I_O = 0.8 A, T_J = 25°C		0.30		Ω
		V_M = 24 V, I_O = 0.8 A, T_J = 85°C		0.38	0.45	
I_{OFF}	Off-state leakage current				±12	μA
f_{PWM}	Motor PWM frequency(1)		45	50	55	kHz
t_{BLANK}	ITRIP blanking time(2)			3.75		μs
t_F	Output fall time		50		300	ns
t_R	Output rise time		50		300	ns
I_{OCP}	Overcurrent protect level		1.5	3	4.5	A
t_{OCP}	Overcurrent protect trip time		2.5			μs
t_{MD}	Mixed decay percentage	Measured from beginning of PWM cycle		75		%
VREF INPUT/CURRENT CONTROL ACCURACY						
I_{REF}	xVREF input current	xVREF = 3.3 V	–3		3	μA
ΔI_{CHOP}	Chopping current accuracy	xVREF = 2.5 V, derived from V3P3; 71% to 100% current	–5		5	%
		xVREF = 2.5 V, derived from V3P3; 20% to 56% current	–10		10	%

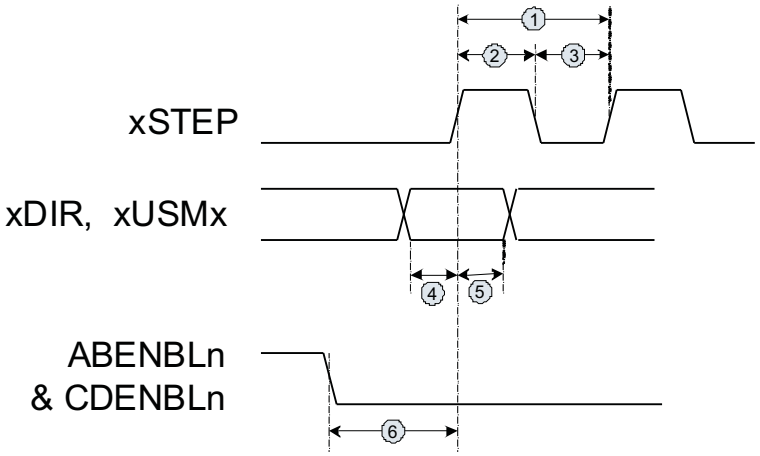
(1) Factory option 100 kHz.
(2) Factory options for 2.5 μs, 5 μs or 6.25 μs.

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TIMING REQUIREMENTS

over operating free-air temperature range (unless otherwise noted)

			MIN	MAX	UNIT
1	f_{STEP}	Step frequency		200	kHz
2	$t_{WH(STEP)}$	Pulse duration, xSTEP high	2.5		µs
3	$t_{WL(STEP)}$	Pulse duration, xSTEP low	2.5		µs
4	$t_{SU(STEP)}$	Setup time, command to xSTEP rising	200		ns
5	$t_{H(STEP)}$	Hold time, command to xSTEP rising	200		ns
6	t_{WAKE}	Wakeup time, SLEEPn inactive to xSTEP	1		ms



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FUNCTIONAL DESCRIPTION

PWM Motor Drivers

The DRV8821 contains four H-bridge motor drivers with current-control PWM circuitry. A block diagram showing drivers A and B of the motor control circuitry (as typically used to drive a bipolar stepper motor) is shown below. Drivers C and D are the same as A and B (though the $R_{ds(on)}$ of the output FETs is different).

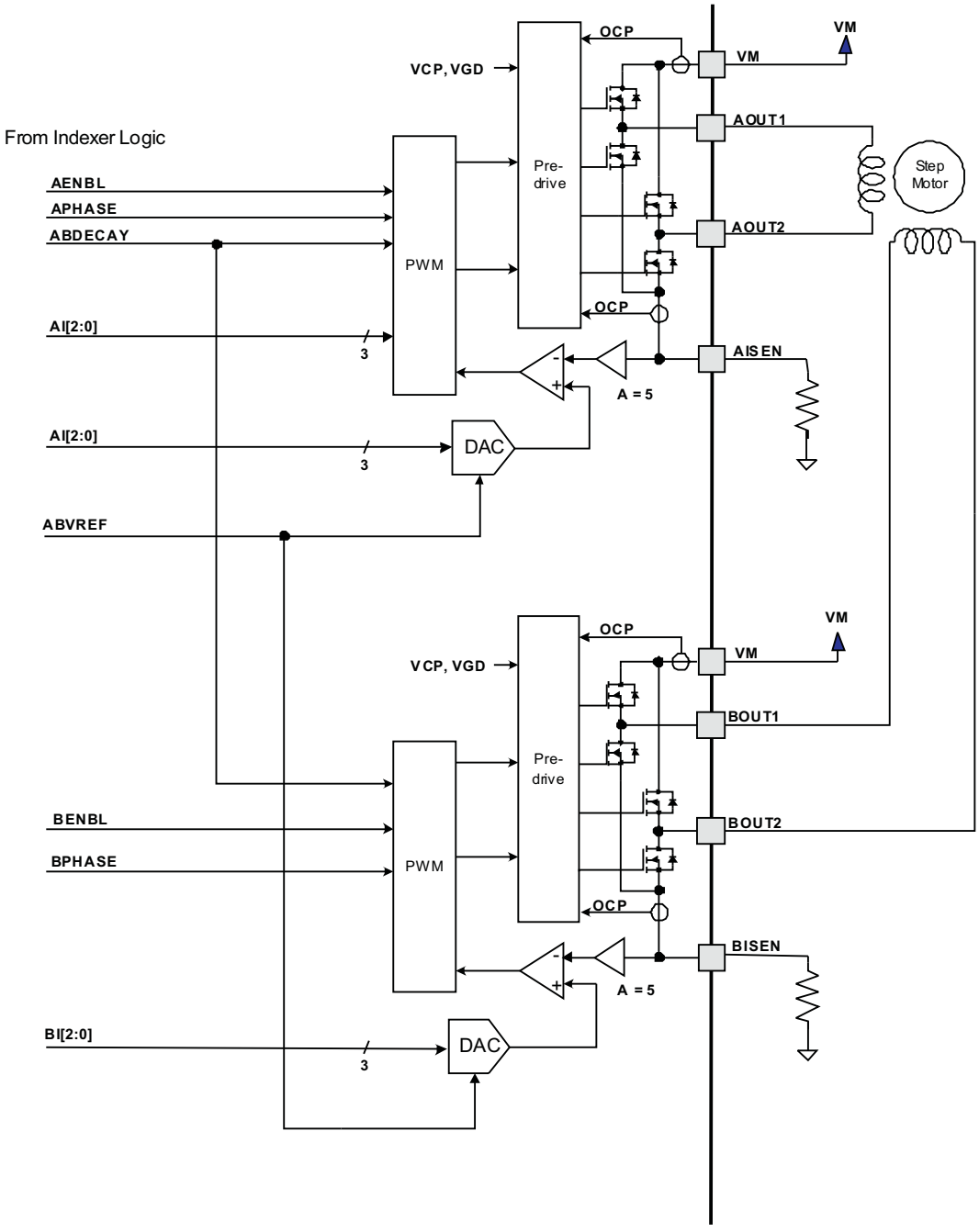


Figure 1. Block Diagram

Note that there are multiple VM motor power supply pins. All VM pins must be connected together to the motor supply voltage.

Current Regulation

The PWM chopping current is set by a comparator which compares the voltage across a current sense resistor connected to the xISEN pins, multiplied by a factor of 5, with a reference voltage. The reference voltage is input from the xVREF pin.

The full-scale (100%) chopping current is calculated as follows:

$$I_{CHOP} = \frac{V_{REFX}}{5 \bullet R_{ISENSE}} \quad (1)$$

Example:

If a 0.22-Ω sense resistor is used and the VREFx pin is 3.3 V, the full-scale (100%) chopping current is 3.3 V/(5 * 0.22 Ω) = 1.875 A.

The reference voltage is also scaled by an internal DAC that allows torque control for fractional stepping of a bipolar stepper motor, as described in the "microstepping indexer" section below.

Decay Mode

During PWM current chopping, the H-bridge is enabled to drive through the motor winding until the PWM current chopping threshold is reached. This is shown in Figure 2 as case 1. The current flow direction shown indicates positive current flow in the step table below.

Once the chopping current threshold is reached, the H-bridge can operate in two different states, fast decay or slow decay.

In fast decay mode, once the PWM chopping current level has been reached, the H-bridge reverses state to allow winding current to flow in a reverse direction. As the winding current approaches zero, the bridge is disabled to prevent any reverse current flow. Fast-decay mode is shown in Figure 2 as case 2.

In slow-decay mode, winding current is re-circulated by enabling both of the low-side FETs in the bridge. This is shown in Figure 2 as case 3.

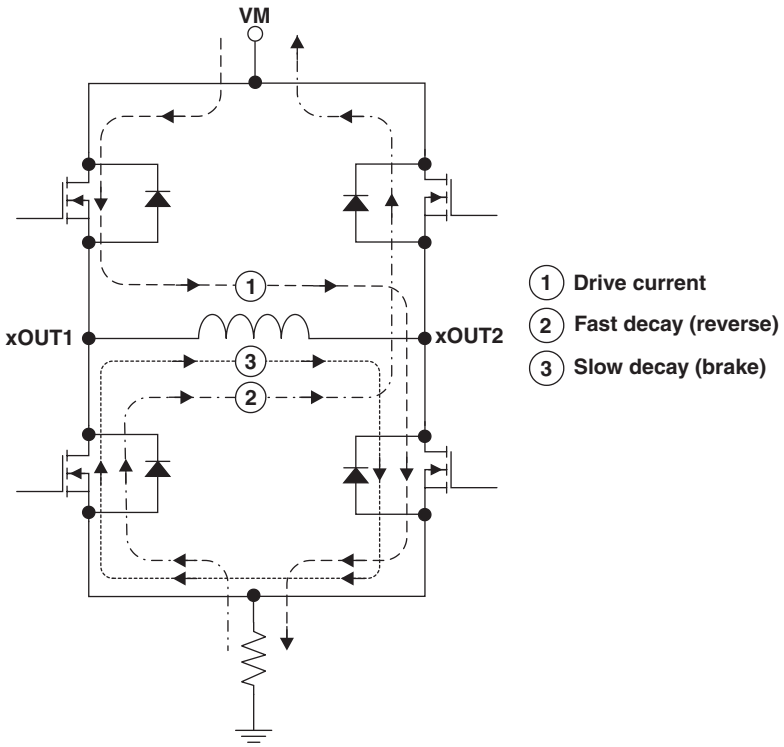


Figure 2. Decay Mode

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The DRV8821 also supports a mixed decay mode. Mixed decay mode begins as fast decay, but after a period of time (75% of the PWM cycle) switches to slow decay mode for the remainder of the fixed PWM period.

Mixed decay mode is only active if the current through the winding is decreasing (per the indexer step table); if the current is increasing, then slow decay is always used.

Slow or mixed decay mode is selected by the state of the xDECAY pins - logic low selects slow decay, and logic high selects mixed decay operation.

Blanking Time

After the current is enabled in an H-bridge, the voltage on the xISEN pin is ignored for a fixed period of time before enabling the current sense circuitry. This blanking time is fixed at 3.75 μs. Note that the blanking time also sets the minimum on time of the PWM.

Microstepping Indexer

Built-in indexer logic in the DRV8821 allows a number of different stepping configurations. The xUSM1 and xUSM0 pins are used to configure the stepping format as shown in the table below:

xUSM1	xUSM0	STEP MODE
0	0	Full step (2-phase excitation)
0	1	½ step (1-2 phase excitation)
1	0	1/4 step (W1-2 phase excitation)
1	1	Eight microsteps/steps

The following table shows the relative current and step directions for different settings of xUSM1 and xUSM0. At each rising edge of the xSTEP input, the indexer travels to the next state in the table. The direction is shown with the DIR pin high; if the xDIR pin is low the sequence is reversed. Positive current is defined as xOUT1 = positive with respect to xOUT2.

Note that the home state is 45 degrees. This state is entered at power-up or application of xRESETn.

Motor AB and motor CD act independently, and their indexer logic functions identically.

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FULL STEP xUSM = 00	½ STEP xUSM = 01	1/4 STEP xUSM = 10	1/8 STEP xUSM = 11	AOUTx CURRENT (% FULL-SCALE)	BOUTx CURRENT (% FULL-SCALE)	STEP ANGLE (DEGREES)
	1	1	1	100	0	0
			2	98	20	11.25
		2	3	92	38	22.5
			4	83	56	33.75
1	2	3	5	71	71	45 (home state)
			6	56	83	56.25
		4	7	38	92	67.5
			8	20	98	78.75
	3	5	9	0	100	90
			10	–20	98	101.25
		6	11	–38	92	112.5
			12	–56	83	123.75
2	4	7	13	–71	71	135
			14	–83	56	146.25
		8	15	–92	38	157.5
			16	–98	20	168.75
	5	9	17	–100	0	180
			18	–98	–20	191.25
		10	19	–92	–38	202.5
			20	–83	–56	213.75
3	6	11	21	–71	–71	225
			22	–56	–83	236.25
		12	23	–38	–92	247.5
			24	–20	–98	258.75
	7	13	25	0	–100	270
			26	20	–98	281.25
		14	27	38	–92	292.5
			28	56	–83	303.75
4	8	15	29	71	–71	315
			30	83	–56	326.25
		16	31	92	–38	337.5
			32	98	–20	348.75

xRESETn and xENBLn Operation

The xRESETn pin, when driven active low, resets the step table to the home position. It also disables the H-bridge drivers. The xSTEP input is ignored while xRESETn is active. Note that there is a separate xRESETn pin for each motor; each acts only on one of the two motor controllers.

The xENABLEn pin is used to control the output drivers. When xENBLn is low, the output H-bridges are enabled. When xENBLn is high, the H-bridges are disabled and the outputs are in a high-impedance state.. Note that there is a separate xENBLn pin for each motor; each acts only on one of the two motor drivers.

Note that when xENBLn is high, the input pins and control logic, including the indexer (xSTEP and xDIR pins) are still functional.

Driving both ABENBLn and CDENBLn high will put the device into a low power sleep state. In this state, the H-bridges are disabled, the gate drive charge pump is stopped, and all internal clocks are stopped. In this state all inputs are ignored until one or both of the xENBLn pits return active low.

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Protection Circuits

The DRV8821 is fully protected against undervoltage, overcurrent and overtemperature events.

Overcurrent Protection (OCP)

All of the drivers in DRV8821 are protected with an OCP (Over-Current Protection) circuit.

The OCP circuit includes an analog current limit circuit, which acts by removing the gate drive form each output FET if the current through it exceeds a preset level. This circuit will limit the current to a level that is safe to prevent damage to the FET.

A digital circuit monitors the analog current limit circuits. If any analog current limit condition exists for longer than a preset period, all drivers in the device will be disabled.

The device is re-enabled upon the removal and re-application of power at the VM pins.

Thermal Shutdown (TSD)

If the die temperature exceeds safe limits, all drivers in the device will be shut down.

The device will remain disabled until the die temperature has fallen to a safe level. After the temperature has fallen, the device may be re-enabled upon the removal and re-application of power at the VM pin.

Undervoltage Lockout (UVLO)

If at any time the voltage on the VM pins falls below the undervoltage lockout threshold voltage, all circuitry in the device will be disabled. Operation will resume when VM rises above the UVLO threshold. The indexer logic will be reset to its initial condition in the event of an undervoltage lockout.

Shoot-Through Current Prevention

The gate drive to each FET in the H-bridge is controlled to prevent any cross-conduction (shoot through current) during transitions.

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THERMAL INFORMATION

Thermal Protection

The DRV8821 has thermal shutdown (TSD) as described above. If the die temperature exceeds approximately 150°C, the device will be disabled until the temperature drops to a safe level.

Any tendency of the device to enter thermal shutdown is an indication of either excessive power dissipation, insufficient heatsinking, or too high an ambient temperature.

Power Dissipation

Power dissipation in the DRV8821 is dominated by the power dissipated in the output FET resistance, or $R_{DS(ON)}$. Average power dissipation when running a stepper motor can be roughly estimated by Equation 2.

$$P_{TOT} = 4 \bullet R_{DS(ON)} \bullet (I_{OUT(RMS)})^2 \quad (2)$$

where P_{TOT} is the total power dissipation, $R_{DS(ON)}$ is the resistance of each FET, and $I_{OUT(RMS)}$ is the RMS output current being applied to each winding. $I_{OUT(RMS)}$ is equal to the approximately 0.7x the full-scale output current setting. The factor of 4 comes from the fact that there are two motor windings, and at any instant two FETs are conducting winding current for each winding (one high-side and one low-side). Remember that the DRV8821 has two stepper motor drivers, so the power dissipation of each must be added together to determine the total device power dissipation.

The maximum amount of power that can be dissipated in the DRV8821 is dependent on ambient temperature and heatsinking. The thermal dissipation ratings table in the datasheet can be used to estimate the temperature rise for typical PCB constructions.

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

Heatsinking

The PowerPAD™ 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 can be accomplished by adding a number of vias to connect the thermal pad to the ground plane. On PCBs without internal planes, 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.

For details about how to design the PCB, refer to TI application report SLMA002, " PowerPAD™ Thermally Enhanced Package" and TI application brief SLMA004, " PowerPAD™ Made Easy", available at www.ti.com.

In general, the more copper area that can be provided, the more power can be dissipated. Figure 3 shows thermal resistance vs. copper plane area for both a single-sided PCB with 2-oz copper heatsink area, and a 4-layer PCB with 1-oz copper and a solid ground plane. Both PCBs are 76 mm x 114 mm, and 1.6 mm thick. It can be seen that the heatsink effectiveness increases rapidly to about 20 cm^2, then levels off somewhat for larger areas.

Six pins on the center of each side of the package are also connected to the device ground. A copper area can be used on the PCB that connects to the PowerPAD™ as well as to all the ground pins on each side of the device. This is especially useful for single-layer PCB designs.

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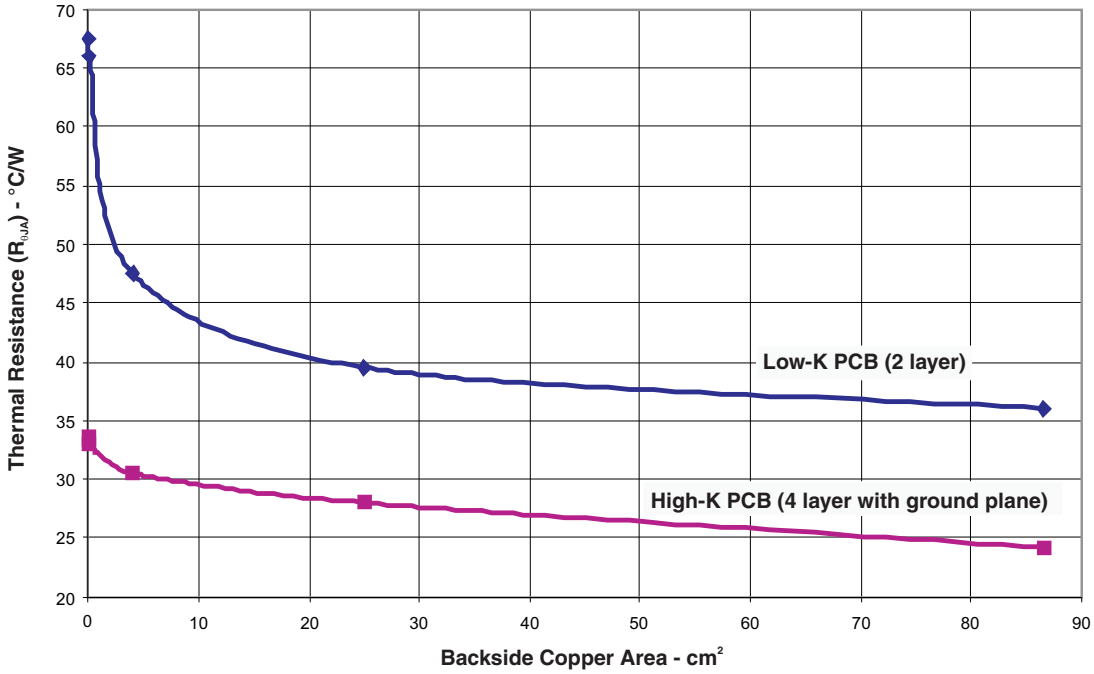
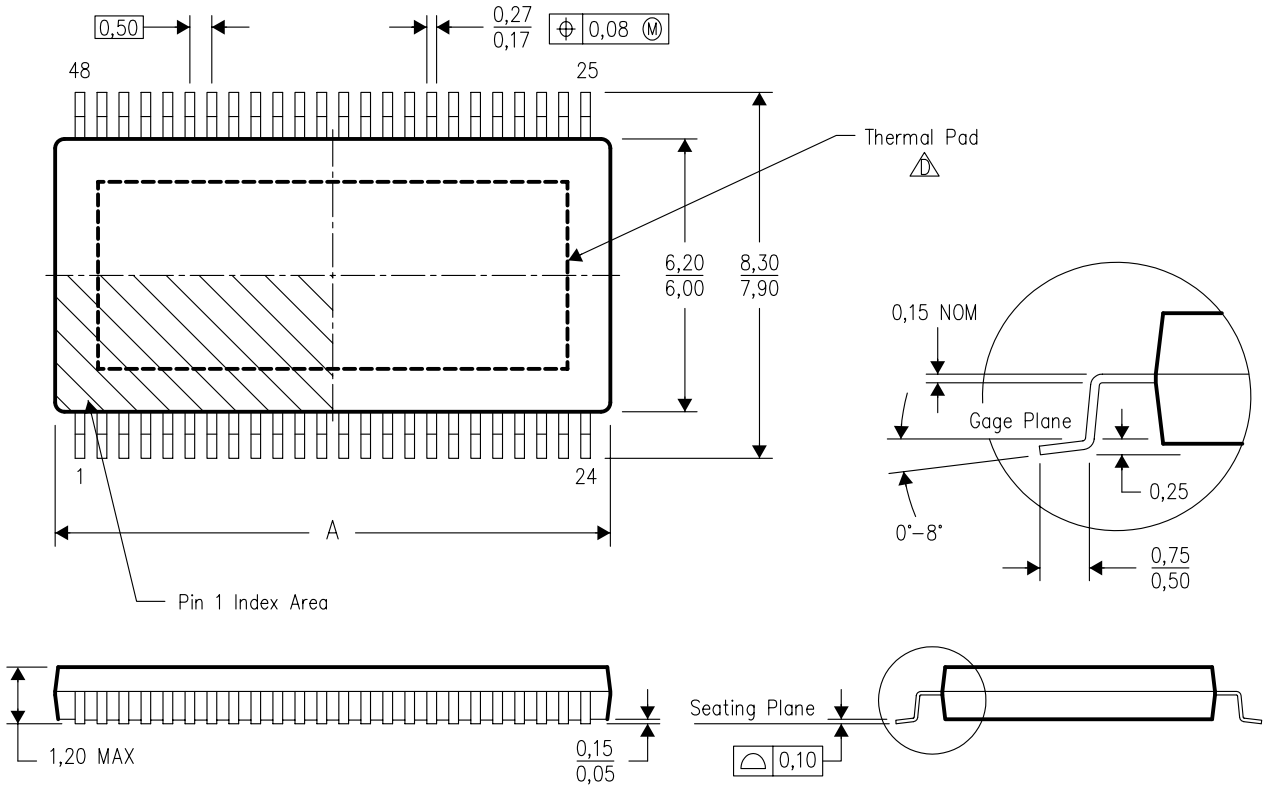


Figure 3. Thermal Resistance vs. Copper Plane Area

DCA (R–PDSO–G**) PowerPAD™ PLASTIC SMALL–OUTLINE PACKAGE

48 PIN SHOWN



DIM \ PINS **	48	56	64
A MAX	12,60	14,10	17,10
A MIN	12,40	13,90	16,90

4073259/C 04/05

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at www.ti.com <http://www.ti.com>.
E. Falls within JEDEC MO–153

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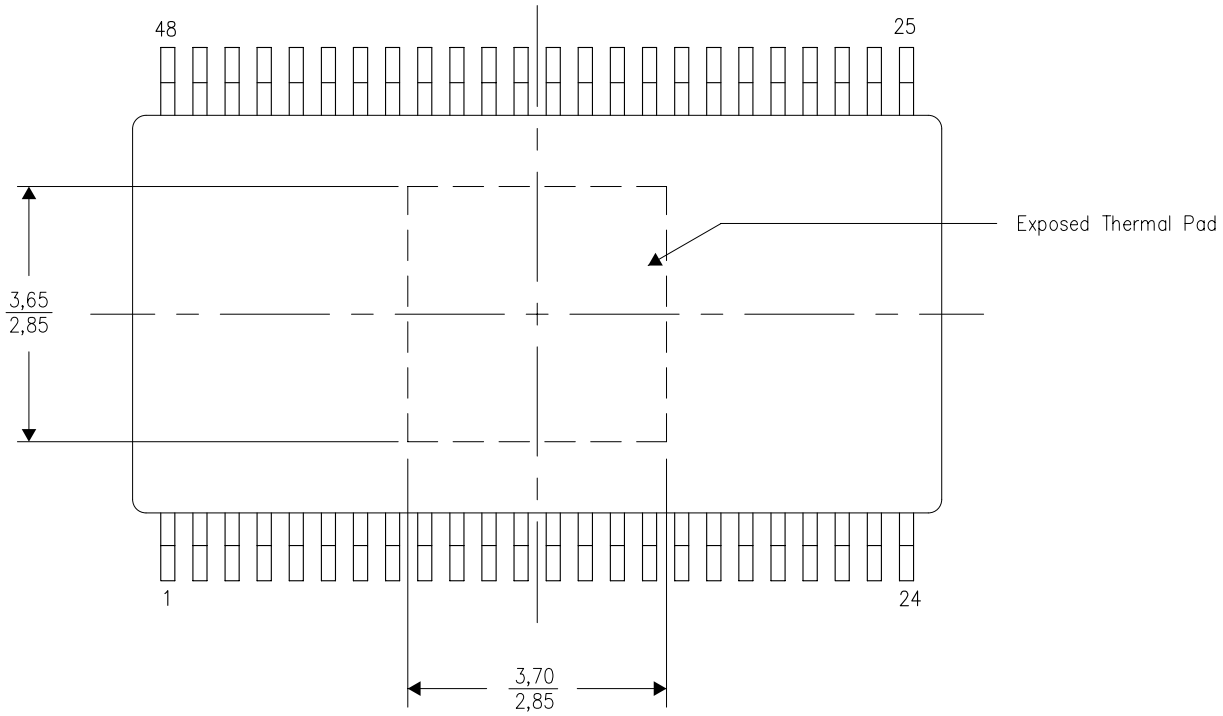
DCA (R–PDSO–G48) PowerPAD™ PLASTIC SMALL OUTLINE

THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Top View

NOTE: All linear dimensions are in millimeters

Exposed Thermal Pad Dimensions

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