DRV8436E Dual H-Bridge Motor Drivers With Integrated Current Sense and Smart Tune Technology

1 Features

- Dual H-bridge motor driver
  - One bipolar stepper motor
  - Dual brushed-DC motors
- Integrated current sense functionality
  - No sense resistors required
  - ±7.5% Full-scale current accuracy
- 4.5- to 48-V Operating supply voltage range
- Multiple control interface options
  - PHASE/ENABLE
  - PWM
- Smart tune decay technology, fixed slow and mixed decay options
- Low $R_{DS(ON)}$:
  - 900 mΩ HS + LS at 24 V, 25°C (DRV843xx)
  - 1200 mΩ HS + LS at 24 V, 25°C (DRV843xx)
- High Current Capacity Per Bridge
  - DRV843xx: 2.5-A peak, 1.5-A Full-Scale, 1.1-A rms
  - DRV843xx: 1.9-A peak, 1.1-A Full-Scale, 0.8-A rms
- Configurable Off-Time PWM Chopping
  - 7, 16, 24 or 32 µs
- Supports 1.8-V, 3.3-V, 5.0-V logic inputs
- Low-current sleep mode (2 µA)
- Small package and footprint
- Protection features
  - VM undervoltage lockout (UVLO)
  - Charge pump undervoltage (CPUV)
  - Overcurrent protection (OCP)
  - Thermal shutdown (OTSD)
  - Thermal shutdown (OTSD)
  - Fault condition output (nFAULT)

2 Applications

- Printers and scanners
- ATMs, currency counters, and EPOS
- Office and home automation
- Factory automation and robotics
- Major and small home appliances
- Vacuum, humanoid, and toy robotics

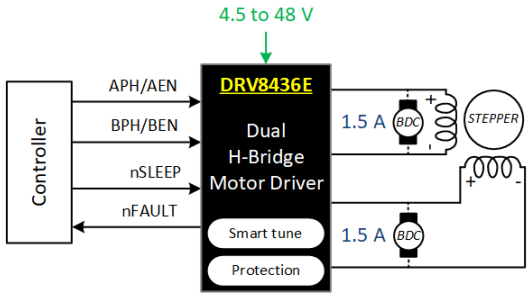
3 Description

The DRV843xx devices are dual H-bridge motor drivers for industrial applications. The devices can be used for driving two DC motors, or a bipolar stepper motor. The output stage of the driver consists of N-channel power MOSFETs configured as two full H-bridges. The DRV843xx is capable of driving up to 1.5-A full scale or 1.1-A rms output current per H-bridge; and the DRV843xx is capable of driving up to 1.1-A full scale or 0.8-A rms output current per H-bridge (dependent on PCB design). For further description see Description Continued.

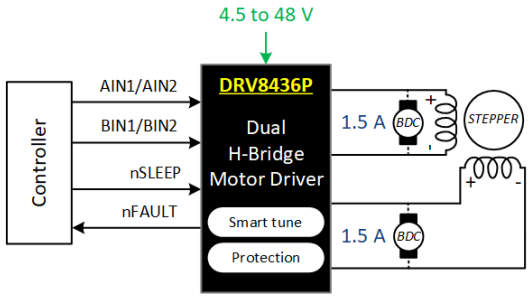
Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
DRV8436EPWPR	HTSSOP (24)	7.7mm x 4.4mm
DRV8436ERGER	VQFN (24)	4.0mm x 4.0mm
DRV8437EPWPR	HTSSOP (24)	7.7mm x 4.4mm
DRV8437ERGER	VQFN (24)	4.0mm x 4.0mm
DRV8436PPWPR	HTSSOP (24)	7.7mm x 4.4mm
DRV8436PRGER	VQFN (24)	4.0mm x 4.0mm
DRV8437PPWPR	HTSSOP (24)	7.7mm x 4.4mm
DRV8437PRGER	VQFN (24)	4.0mm x 4.0mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.



DRV8436E Simplified Schematic



DRV8436P Simplified Schematic

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An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. ADVANCE INFORMATION for pre-production products; subject to change without notice.

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4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
July 2019	*	Initial release.

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5 Description Continued

The devices use an internal current sense architecture to eliminate the need for two external power sense resistors, saving PCB area and system cost. The devices use an internal PWM current regulation scheme selectable between smart tune, fast, slow and mixed decay options. Smart tune decay technology automatically adjusts for optimal current regulation performance and compensates for motor variation and aging effects.

The PH/EN (DRV8436E/DRV8437E) or PWM (DRV8436P/DRV8437P) pins provide a simple control interface. A low-power sleep mode is provided for very-low quiescent current standby using a dedicated nSLEEP pin. Device protection features are provided for supply undervoltage, charge pump faults, overcurrent, short circuits and overtemperature. Fault conditions are indicated by the nFAULT pin.

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6 Device Options

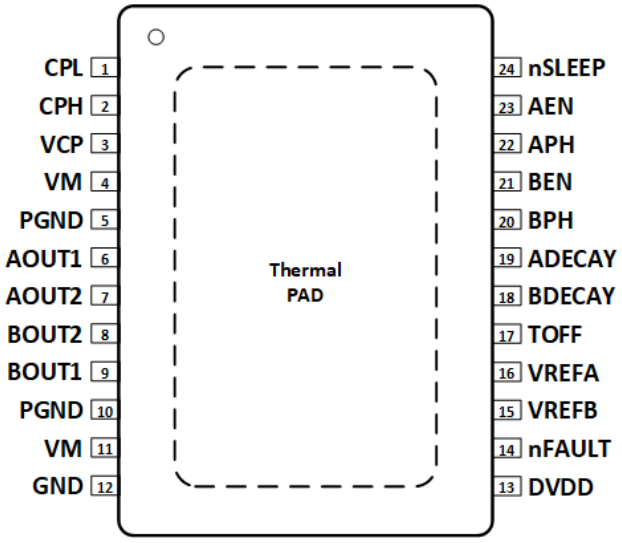
PART NUMBER	CONTROL INTERFACE
DRV8436E	PHASE/ENABLE
DRV8437E	
DRV8436P	PWM
DRV8437P	

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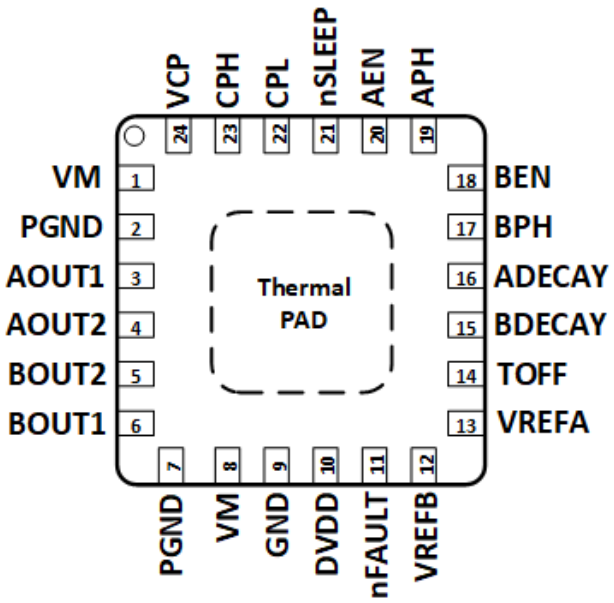
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7 Pin Configuration and Functions

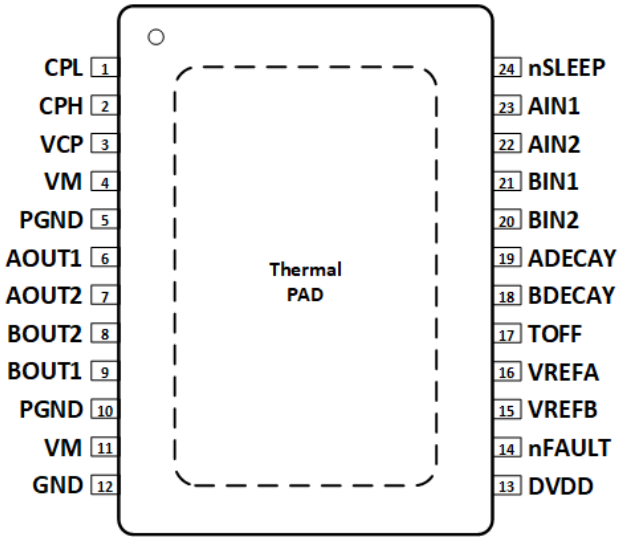
PWP PowerPAD™ Package
24-Pin HTSSOP
Top View DRV8436E, DRV8437E



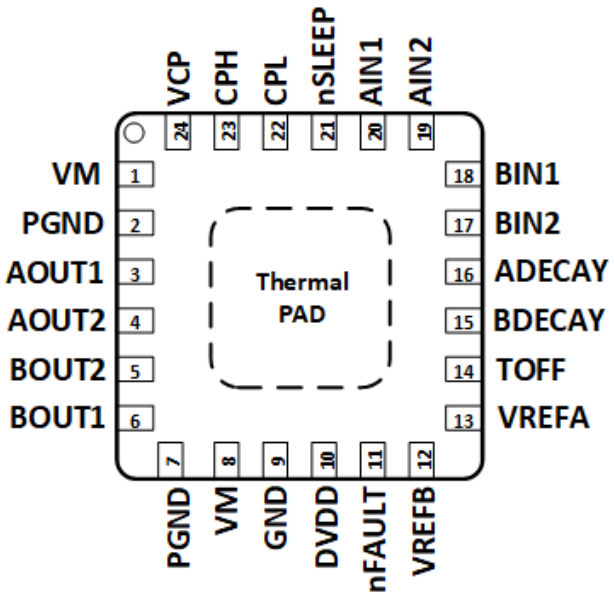
RGE Package
24-Pin VQFN with Exposed Thermal PAD
Top View DRV8436E, DRV8437E



PWP PowerPAD™ Package
24-Pin HTSSOP
Top View DRV8436P, DRV8437P



RGE Package
24-Pin VQFN with Exposed Thermal PAD
Top View DRV8436P, DRV8437P



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Pin Functions

NAME	PIN				TYPE	DESCRIPTION
	PWP		RGE			
	DRV843xE	DRV843xP	DRV843xE	DRV843xP		
ADECAY	19	19	16	16	I	Decay mode setting pins. Set the decay mode for bridge A; see ; quad-level pin.
AEN	23	—	20	—	I	Bridge A enable input. Logic high enables bridge A; logic low disables the bridge Hi-Z.
AIN1	—	23	—	20	I	Bridge A PWM input. Logic controls the state of H-bridge A; internal pulldown.
AIN2	—	22	—	19	I	Bridge A PWM input. Logic controls the state of H-bridge A; internal pulldown.
AOUT1	6	6	3	3	O	Winding A output. Connect to stepper motor winding.
AOUT2	7	7	4	4	O	Winding A output. Connect to stepper motor winding.
APH	22	—	19	—	I	Bridge A phase input. Logic high drives current from AOUT1 to AOUT2.
VREFA	16	16	13	13	I	Reference voltage input. Voltage on this pin sets the full scale chopping current in H-bridge A.
BDECAY	18	18	15	15	I	Decay mode setting pins. Set the decay mode for bridge B; see ; quad-level pin.
BEN	21	—	18	—	I	Bridge B enable input. Logic high enables bridge B; logic low disables the bridge Hi-Z.
BIN1	—	21	—	18	I	Bridge B PWM input. Logic controls the state of H-bridge B; internal pulldown.
BIN2	—	20	—	17	I	Bridge B PWM input. Logic controls the state of H-bridge B; internal pulldown.
BOUT1	9	9	6	6	O	Winding B output. Connect to stepper motor winding.
BOUT2	8	8	5	5	O	Winding B output. Connect to stepper motor winding.
BPH	20	—	17	—	I	Bridge B phase input. Logic high drives current from BOUT1 to BOUT2.
VREFB	15	15	12	12	I	Reference voltage input. Voltage on this pin sets the full scale chopping current in H-bridge B.
CPH	2	2	23	23	PWR	Charge pump switching node. Connect a X7R, 0.022-µF, VM-rated ceramic capacitor from CPH to CPL.
CPL	1	1	22	22		
GND	12	12	9	9	PWR	Device ground. Connect to system ground.
TOFF	17	17	14	14	I	Sets the decay mode off-time during current chopping; quad-level pin.
DVDD	13	13	10	10	PWR	Logic supply voltage. Connect a X7R, 0.47-µF, 6.3-V or 10-V rated ceramic capacitor to GND.
VCP	3	3	24	24	O	Charge pump output. Connect a X7R, 0.22-µF, 16-V ceramic capacitor to VM.
VM	4, 11	4, 11	1, 8	1, 8	PWR	Power supply. Connect to motor supply voltage and bypass to GND with two 0.01-µF ceramic capacitors (one for each pin) plus a bulk capacitor rated for VM.
PGND	5, 10	5, 10	2, 7	2, 7	PWR	Power ground. Both PGND pins are shorted internally. Connect to system ground on PCB.
nFAULT	14	14	11	11	O	Fault indication. Pulled logic low with fault condition; open-drain output requires an external pullup resistor.
nSLEEP	24	24	21	21	I	Sleep mode input. Logic high to enable device; logic low to enter low-power sleep mode; internal pulldown resistor.

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8 Specifications

8.1 Absolute Maximum Ratings

over operating free-air temperature range referenced with respect to GND (unless otherwise noted) (1)

	MIN	MAX	UNIT
Power supply voltage (VM)	–0.3	50	V
Charge pump voltage (VCP, CPH)	–0.3	V_{VM} + 7	V
Charge pump negative switching pin (CPL)	–0.3	V_{VM}	V
nSLEEP pin voltage (nSLEEP)	–0.3	V_{VM}	V
Internal regulator voltage (DVDD)	–0.3	5.5	V
Control pin voltage (APH, AEN, BPH, BEN, AIN1, AIN2, BIN1, BIN2, nFAULT, ADECAY, BDECAY, TOFF)	–0.3	5.5	V
Open drain output current (nFAULT)	0	10	mA
Reference input pin voltage (VREFA, VREFB)	–0.3	5.5	V
Continuous phase node pin voltage (AOUT1, AOUT2, BOUT1, BOUT2)	–1	V_{VM} + 1	V
Transient 100 ns phase node pin voltage (AOUT1, AOUT2, BOUT1, BOUT2)	–3	V_{VM} + 3	V
Peak drive current (AOUT1, AOUT2, BOUT1, BOUT2)	Internally Limited		A
Operating ambient temperature, T_J	–40	125	°C
Operating junction temperature, T_J	–40	150	°C
Storage temperature, T_{stg}	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

8.2 ESD Ratings

				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001		±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101	Corner pins for PWP (1, 12, 13, and 24)	±750	
			Other pins	±500	

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8.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V_{VM}	Supply voltage range for normal (DC) operation	4.5	48	V
V_I	Logic level input voltage	0	5.3	V
VREF	Reference rms voltage range (VREFA, VREFB)	0.05	3.3	V
f_{PWM}	Applied PWM signal (APH, AEN, BPH, BEN, AIN1, AIN2, BIN1, BIN2)	0	100	kHz
I_{FS}	Motor full-scale current (xOUTx) (DRV8436E, DRV8436P)	0	1.5	A
I_{FS}	Motor full-scale current (xOUTx) (DRV8437E, DRV8437P)	0	1.1	A
I_{rms}	Motor RMS current (xOUTx) (DRV8436E, DRV8436P)	0	1.1	A
I_{rms}	Motor RMS current (xOUTx) (DRV8437E, DRV8437P)	0	0.8	A
T_A	Operating ambient temperature	–40	125	°C
T_J	Operating junction temperature	–40	150	°C

8.4 Thermal Information

THERMAL METRIC(1)		DRV8436E/P, DRV8437E/P		UNIT
		PWP (HTSSOP)	RGE (VQFN)	
		24 PINS	24 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	30.9	40.7	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	25.2	31.1	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	11.3	17.9	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.4	0.6	°C/W
ψ_{JB}	Junction-to-board characterization parameter	11.3	17.8	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	3.1	4.3	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

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8.5 Electrical Characteristics

Typical values are at T_A = 25°C and V_{VM} = 24 V. All limits are over recommended operating conditions, unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLIES (VM, DVDD)						
V_{VM}	VM operating voltage	Supply voltage range for normal (DC) operation	4.5		48	V
I_{VM}	VM operating supply current	nSLEEP = 1, No motor load, IC Enabled		5	6.5	mA
I_{VMQ}	VM sleep mode supply current	nSLEEP = 0		2	4	µA
t_{SLEEP}	Sleep time	nSLEEP = 0 to sleep-mode	75			µs
t_{WAKE}	Wake-up time	nSLEEP = 1 to output transition		0.6	0.9	ms
t_{ON}	Turn-on time	VM > UVLO to output transition		0.6	0.9	ms
V_{DVDD}	Internal regulator voltage	No external load	4.5	5	5.5	V
CHARGE PUMP (VCP, CPH, CPL)						
V_{VCP}	VCP operating voltage			V_{VM} + 5		V
$f_{(VCP)}$	Charge pump switching frequency	V_{VM} > UVLO; nSLEEP = 1		400		kHz
LOGIC-LEVEL INPUTS (APH, AEN, BPH, BEN, AIN1, AIN2, BIN1, BIN2, nSLEEP)						
V_{IL}	Input logic-low voltage		0		0.6	V
V_{IH}	Input logic-high voltage		1.5		5.3	V
V_{HYS}	Input logic hysteresis			150		mV
I_{IL}	Input logic-low current	V_{IN} = 0 V	–1		1	µA
I_{IH}	Input logic-high current	V_{IN} = 5 V			100	µA
t_{PD}	Propagation delay	xPH, xEN, xINx input to current change		850		ns
QUAD-LEVEL INPUTS (ADECAY, BDECAY, TOFF)						
V_{I1}	Input logic-low voltage	Tied to GND	0		0.6	V
V_{I2}		330kΩ ± 5% to GND	1	1.25	1.4	V
V_{I3}	Input Hi-Z voltage	Hi-Z (>500kΩ to GND)	1.8	2	2.2	V
V_{I4}	Input logic-high voltage	Tied to DVDD	2.7		5.3	V
I_O	Output pull-up current			10		µA
CONTROL OUTPUTS (nFAULT)						
V_{OL}	Output logic-low voltage	I_O = 5 mA			0.5	V
I_{OH}	Output logic-high leakage	V_{VM} = 24 V	–1		1	µA
MOTOR DRIVER OUTPUTS (AOUT1, AOUT2, BOUT1, BOUT2)						
$R_{DS(ON)}$	High-side FET on resistance (DRV8436E, DRV8436P)	V_{VM} = 24 V, I_O = 0.5A		450	850	mΩ
$R_{DS(ON)}$	Low-side FET on resistance (DRV8436E, DRV8436P)	V_{VM} = 24 V, I_O = 0.5 A		450	850	mΩ
$R_{DS(ON)}$	High-side FET on resistance (DRV8437E, DRV8437P)	V_{VM} = 24 V, I_O = 0.5 A		600	1100	mΩ
$R_{DS(ON)}$	Low-side FET on resistance (DRV8437E, DRV8437P)	V_{VM} = 24 V, I_O = 0.5 A		600	1100	mΩ
t_{SR}	Output rise time	VM = 24V, I_O = 0.5 A, Between 10% and 90%		150		V/µs
PWM CURRENT CONTROL (VREFA, VREFB)						
K_V	Transimpedance gain			2.2		V/A
t_{OFF}	PWM off-time	TOFF = Hi-Z		7		µs
		TOFF = 0		16		
		TOFF = 1		24		
		TOFF = 330 kΩ to GND		32		

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Electrical Characteristics (continued)

Typical values are at T_A = 25°C and V_{VM} = 24 V. All limits are over recommended operating conditions, unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
ΔI_{TRIP}	Current trip accuracy	I_O = 1.5 A, 10% to 20% current setting	–12		12	%
		I_O = 1.5 A, 20% to 100% current setting	–7.5		7.5	
$I_{O,CH}$	AOUT and BOUT current matching	I_O = 1.5 A	–2.5		2.5	%
PROTECTION CIRCUITS						
V_{UVLO}	VM UVLO lockout	VM falling, UVLO falling	4.15	4.25	4.35	V
		VM rising, UVLO rising	4.25	4.35	4.45	
$V_{UVLO,HYS}$	Undervoltage hysteresis	Rising to falling threshold		100		mV
V_{CPUV}	Charge pump undervoltage	VCP falling; CPUV report		V_{VM} + 2		V
I_{OCP}	Overcurrent protection (DRV8436E, DRV8436P)	Current through any FET	2.5			A
I_{OCP}	Overcurrent protection (DRV8437E, DRV8437P)	Current through any FET	1.9			A
t_{OCP}	Overcurrent deglitch time	VM < 37V		3		µs
		VM >= 37V		0.5		
t_{RETRY}	Overcurrent retry time			4		ms
T_{OTSD}	Thermal shutdown	Die temperature T_J	150	165	180	°C
T_{HYS_OTSD}	Thermal shutdown hysteresis	Die temperature T_J		20		°C

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9 Detailed Description

9.1 Overview

The DRV8436E/P, DRV8437E/P are integrated motor driver solutions for bipolar stepper motors or dual brushed-DC motors. The devices integrate two N-channel power MOSFET H-bridges, integrated current sense and regulation circuitry. The DRV8436E/P, DRV8437E/P can be powered with a supply voltage between 4.5 and 48 V. The DRV8436E/P are capable of providing an output current up to 2.5-A peak, 1.5-A full-scale, or 1.1-A root mean square (rms). The DRV8437E/P are capable of providing an output current up to 1.9-A peak, 1.1-A full-scale, or 0.8-A root mean square (rms). The actual full-scale and rms current depends on the ambient temperature, supply voltage, and PCB thermal capability.

The DRV8436E/P, DRV8437E/P devices use an integrated current-sense architecture which eliminates the need for two external power sense resistors. This architecture removes the power dissipated in the sense resistors by using a current mirror approach and using the internal power MOSFETs for current sensing. The current regulation set point is adjusted by the voltage at the VREFA and VREFB pins. These features reduce external component cost, board PCB size, and system power consumption.

A simple PH/**E**N (DRV8436**E** and DRV8437**E**) or **P**WM (DRV8436**P** and DRV8437**P**) interface allows easy interfacing to the controller circuit.

The current regulation is highly configurable, with several decay modes of operation. The decay mode can be selected as a smart tune Dynamic Decay, fixed slow, mixed, or fast decay. The smart tune decay mode automatically adjusts the decay setting to minimize current ripple while still reacting quickly to step changes. This feature greatly simplifies stepper driver integration into a motor drive system. The PWM off-time, t_{OFF}, can be adjusted to 7, 16, 24, or 32 μs.

A low-power sleep mode is included which allows the system to save power when not driving the motor.

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9.2 Functional Block Diagrams

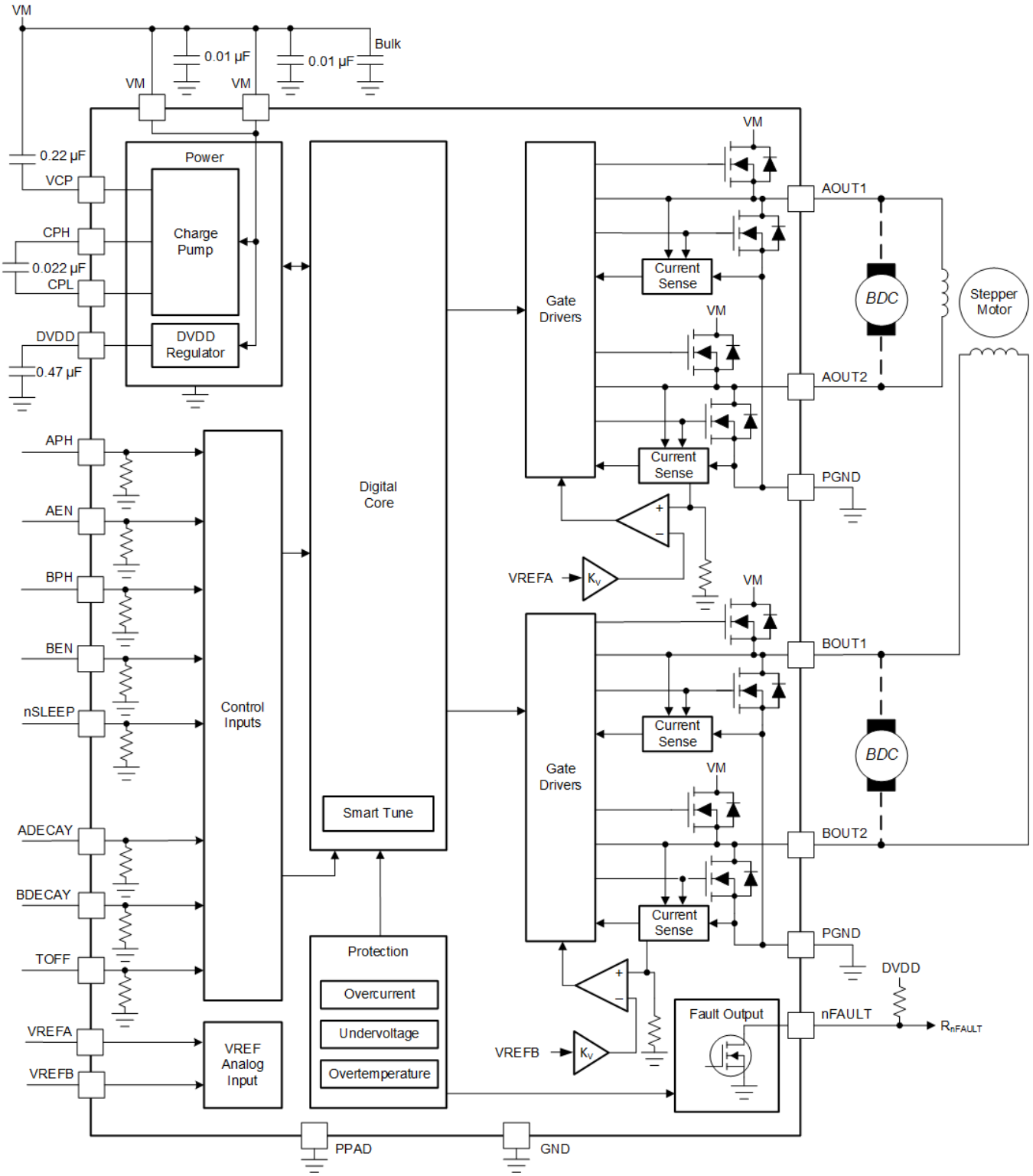


Figure 1. DRV843xE Block Diagram

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Functional Block Diagrams (continued)

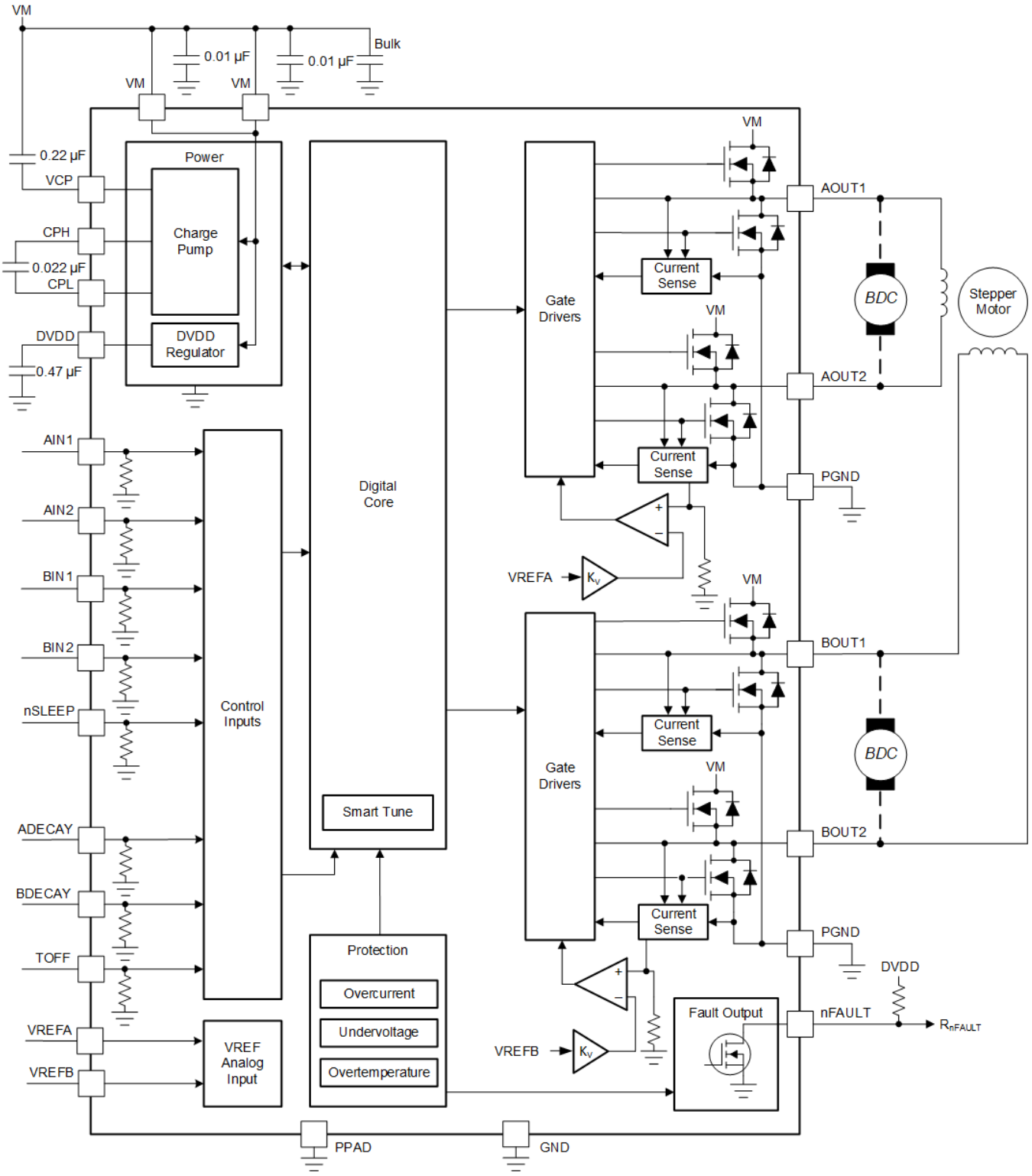


Figure 2. DRV843xP Block Diagram

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9.3 Feature Description

Table 1 shows the recommended values of the external components for the gate driver.

Table 1. External Components

COMPONENT	PIN 1	PIN 2	RECOMMENDED
C_{VM1}	VM	GND	Two X7R, 0.01-µF, VM-rated ceramic capacitors
C_{VM2}	VM	GND	Bulk, VM-rated capacitor
C_{VCP}	VCP	VM	X7R, 0.22-µF, 16-V ceramic capacitor
C_{SW}	CPH	CPL	X7R, 0.022-µF, VM-rated ceramic capacitor
C_{DVDD}	DVDD	GND	X7R, 0.47-µF to 1-µF, 6.3-V or 10-V rated ceramic capacitor
R_{nFAULT}	VCC	nFAULT	>4.7-kΩ resistor
R_{REF1}	VREFxy	VCC	Resistor to limit chopping current. It is recommended that the value of parallel combination of R_{REF1} and R_{REF2} should be less than 50-kΩ.
R_{REF2} (Optional)	VREFxy	GND	

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9.3.1 PWM Motor Drivers

The DRV843xE and DRV843xP contain drivers for two full H-bridges. Figure 3 shows a block diagram of the circuitry.

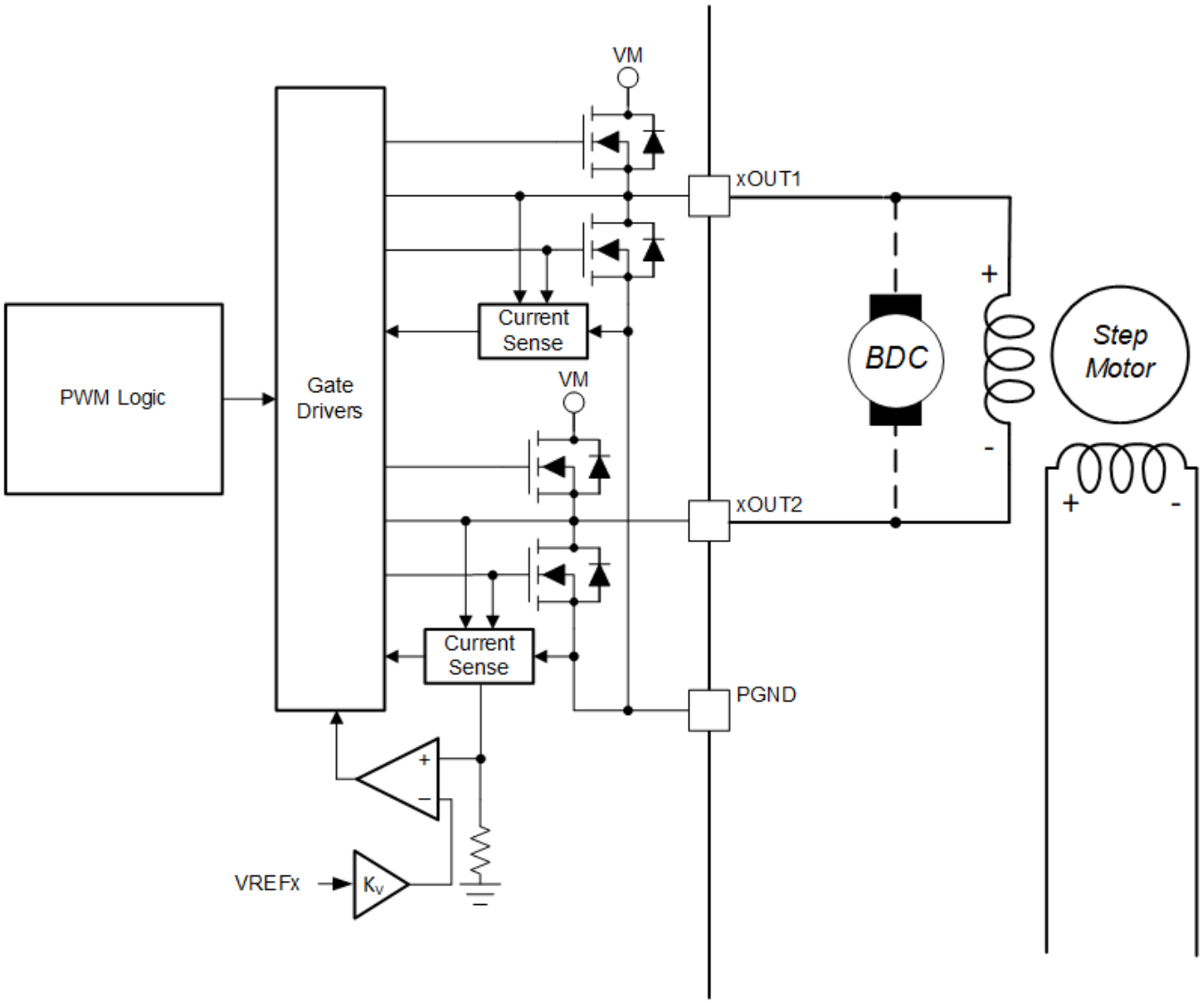


Figure 3. PWM Motor Driver Block Diagram

9.3.2 Bridge Control

The DRV8436E, DRV8437E are controlled using a PH/EN interface. Table 2 gives the full H-bridge state. Note that this table does not take into account the current control built into the DRV8436E, DRV8437E. Positive current is defined in the direction of xOUT1 to xOUT2.

Table 2. DRV8436E, DRV8437E (PH/EN) Control Interface

nSLEEP	ENx	PHx	xOUT1	xOUT2	DESCRIPTION
0	X	X	Hi-Z	Hi-Z	Sleep mode; H-bridge disabled Hi-Z
1	0	X	Hi-Z	Hi-Z	H-bridge disabled Hi-Z
1	1	0	L	H	Reverse (current xOUT2 to xOUT1)
1	1	1	H	L	Forward (current xOUT1 to xOUT2)

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The DRV8436P, DRV8437P is controlled using a PWM interface. Table 3 gives the full H-bridge state. Note that this table does not take into account the current control built into the DRV8436P, DRV8437P. Positive current is defined in the direction of xOUT1 to xOUT2.

Table 3. DRV843xP (PWM) Control Interface

nSLEEP	xIN1	xIN2	xOUT1	xOUT2	DESCRIPTION
0	X	X	Hi-Z	Hi-Z	Sleep mode; H-bridge disabled Hi-Z
1	0	0	Hi-Z	Hi-Z	Coast; H-bridge disabled Hi-Z
1	0	1	L	H	Reverse (current xOUT2 to xOUT1)
1	1	0	H	L	Forward (current xOUT1 to xOUT2)
1	1	1	L	L	Brake; low-side slow decay

9.3.3 Current Regulation

The current through the motor windings is regulated by an adjustable, off-time PWM current-regulation circuit. When an H-bridge is enabled, current rises through the winding at a rate dependent on the DC voltage, inductance of the winding, and the magnitude of the back EMF present. When the current hits the current regulation threshold, the bridge enters a decay mode for a period of time determined by the TOFF pin setting to decrease the current. After the off-time expires, the bridge is re-enabled, starting another PWM cycle.

Table 4. Off-Time Settings

TOFF	OFF-TIME t_{OFF}
0	7 µs
330kΩ to GND	16 µs
Hi-Z	24 µs
1	32 µs

The PWM chopping current is set by a comparator which monitors the voltage across the current sense MOSFETs in parallel with the low-side power MOSFETs. To generate the reference voltage for the current chopping comparator, the VREFx input is attenuated by a factor of Kv.

The chopping current (I_{FS}) can be calculated as I_{FS} (A) = V_{REFx} (V) / K_V (V/A) = V_{REFx} (V) / 2.2 (V/A).

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9.3.4 Decay Modes

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 4, Item 1.

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. The opposite FETs are turned on; as the winding current approaches zero, the bridge is disabled to prevent any reverse current flow. Fast decay mode is shown in Figure 4, item 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 4, Item 3.

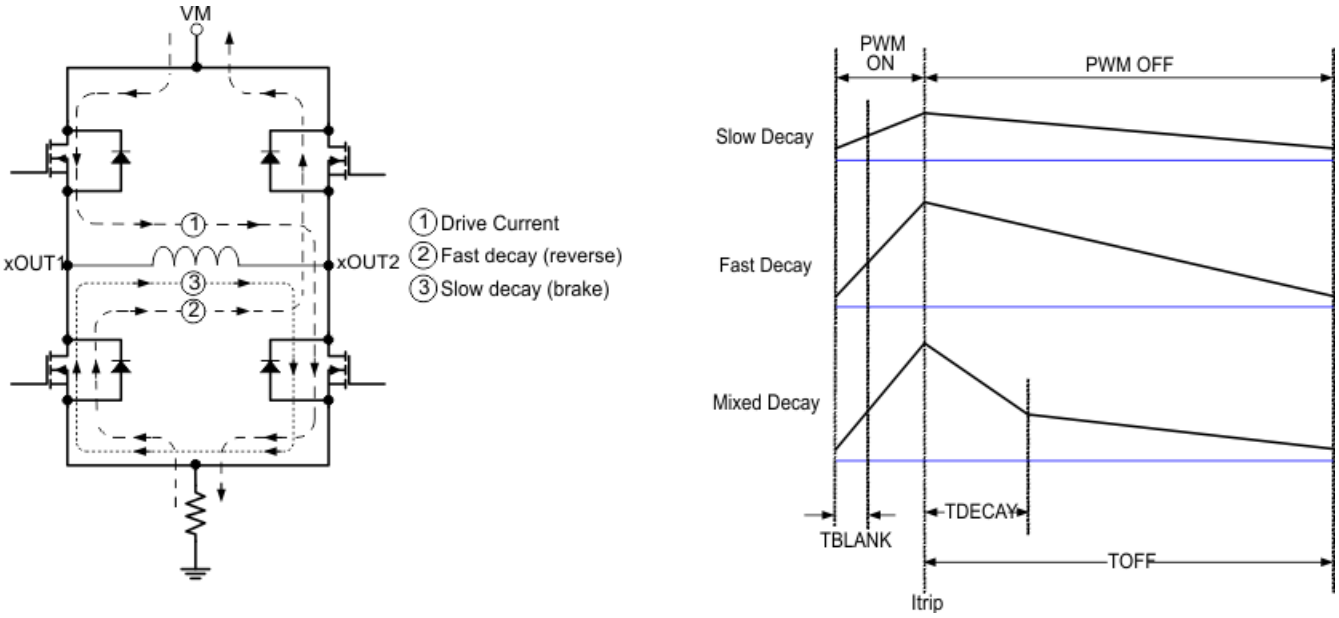


Figure 4. Decay Modes

The decay mode is selected by setting the quad-level ADECAY and BDECAY pins as shown in Table 5.

Table 5. Decay Mode Settings

xDECAY	DECAY MODE
0	Smart tune Dynamic Decay
330k to GND	Slow decay
Hi-Z	Mixed decay: 30% fast
1	Fast decay

The ADECAY pin sets the decay mode for H-bridge A (AOUT1, AOUT2), and the BDECAY pin sets the decay mode for H-bridge B (BOUT1, BOUT2).

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9.3.4.1 Slow Decay

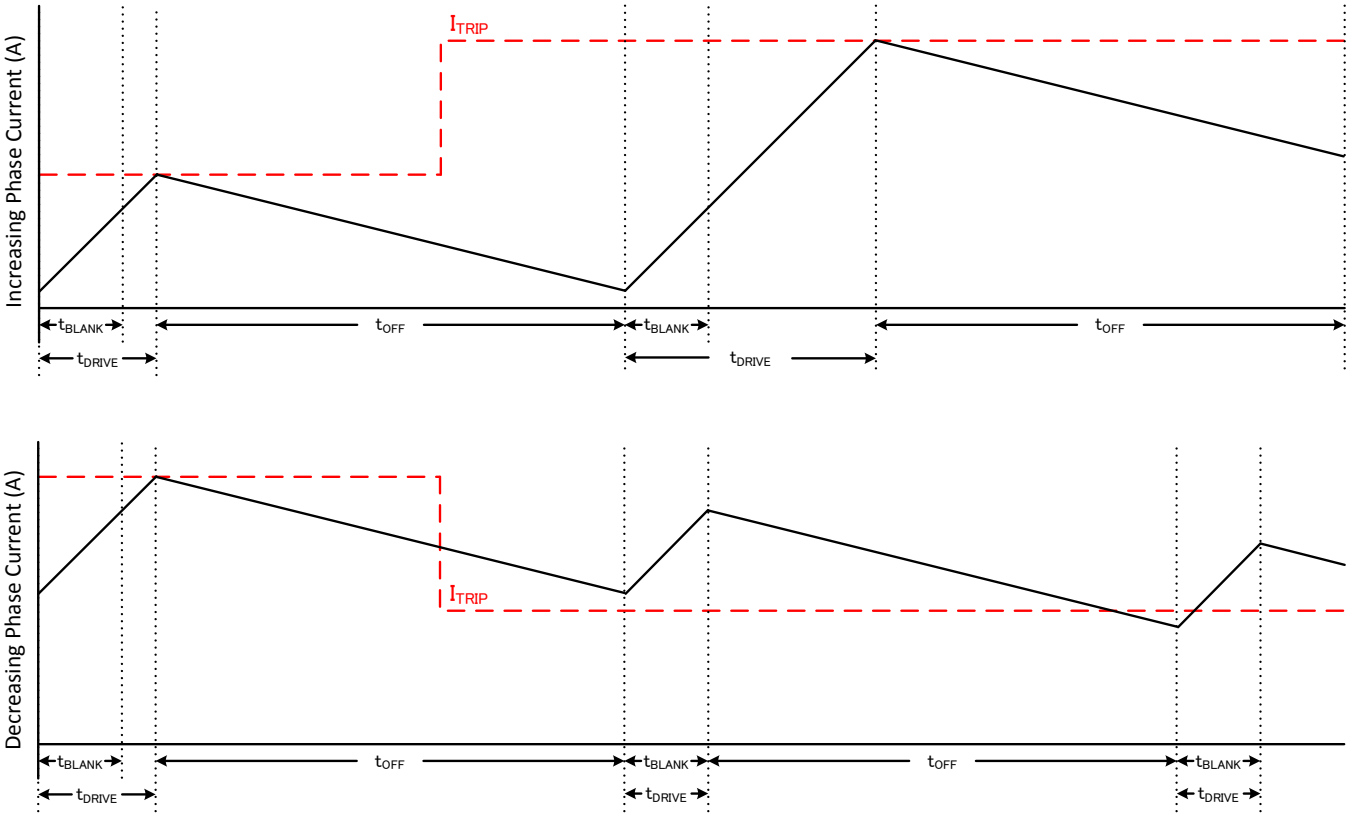


Figure 5. Slow Decay Mode

During slow decay, both of the low-side FETs of the H-bridge are turned on, allowing the current to be recirculated.

Slow decay exhibits the least current ripple of the decay modes for a given t_{OFF}. However on decreasing current steps, slow decay will take a long time to settle to the new ITRIP level because the current decreases very slowly. If the current at the end of the off time is above the ITRIP level, slow decay will be extended for another off time duration and so on, till the current at the end of the off time is below ITRIP level.

In cases where current is held for a long time, slow decay may not properly regulate current because no back-EMF is present across the motor windings. In this state, motor current can rise very quickly, and may require a large off-time. In some cases this may cause a loss of current regulation, and a more aggressive decay mode is recommended.

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9.3.4.2 Mixed Decay

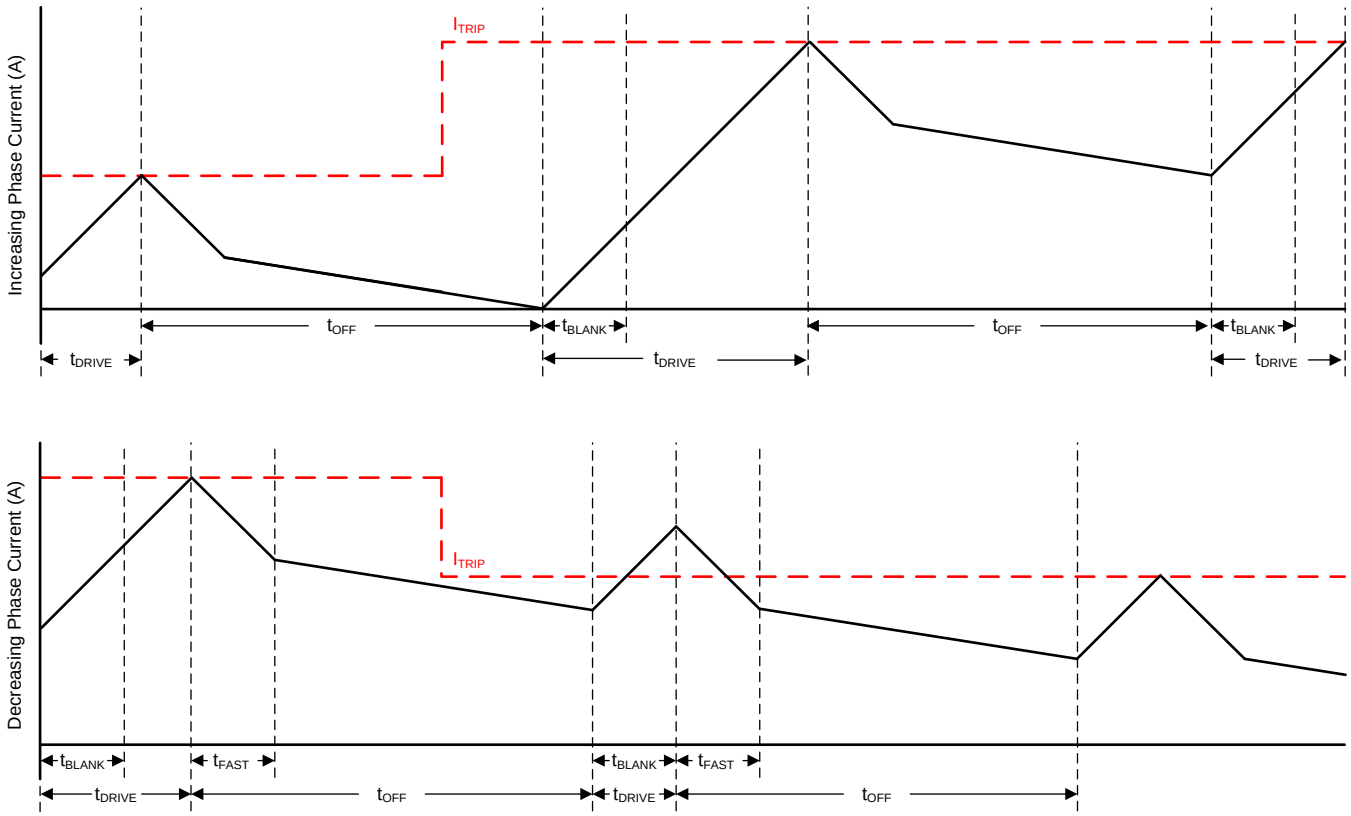


Figure 6. Mixed Decay Mode

Mixed decay begins as fast decay for 30% of t_{OFF}, followed by slow decay for the remainder of t_{OFF}.

This mode exhibits ripple larger than slow decay, but smaller than fast decay. On decreasing current steps, mixed decay settles to the new I_{TRIP} level faster than slow decay.

ADVANCE INFORMATION

9.3.4.3 Fast Decay

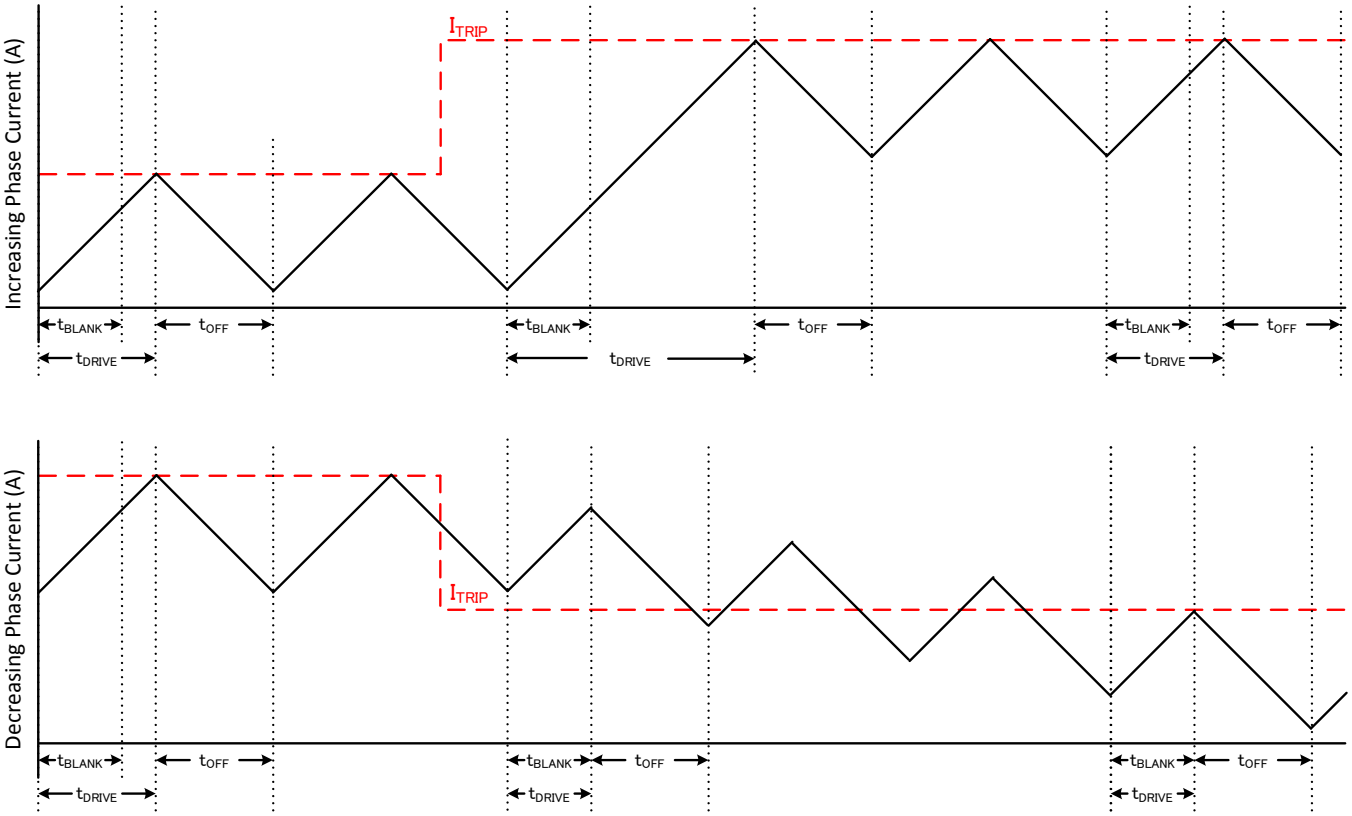


Figure 7. Fast/Fast Decay Mode

During fast decay, the polarity of the H-bridge is reversed. The H-bridge will be turned off as current approaches zero in order to prevent current flow in the reverse direction.

Fast decay exhibits the highest current ripple of the decay modes for a given t_{OFF}. Transition time on decreasing current steps is much faster than slow decay since the current is allowed to decrease much faster.

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9.3.4.4 Smart tune Dynamic Decay

The smart tune current regulation scheme is an advanced current-regulation control method compared to traditional fixed off-time current regulation schemes. Smart tune current regulation scheme helps the stepper motor driver adjust the decay scheme based on operating factors such as the ones listed as follows:

- Motor winding resistance and inductance
- Motor aging effects
- Motor dynamic speed and load
- Motor supply voltage variation
- Low-current versus high-current dI/dt

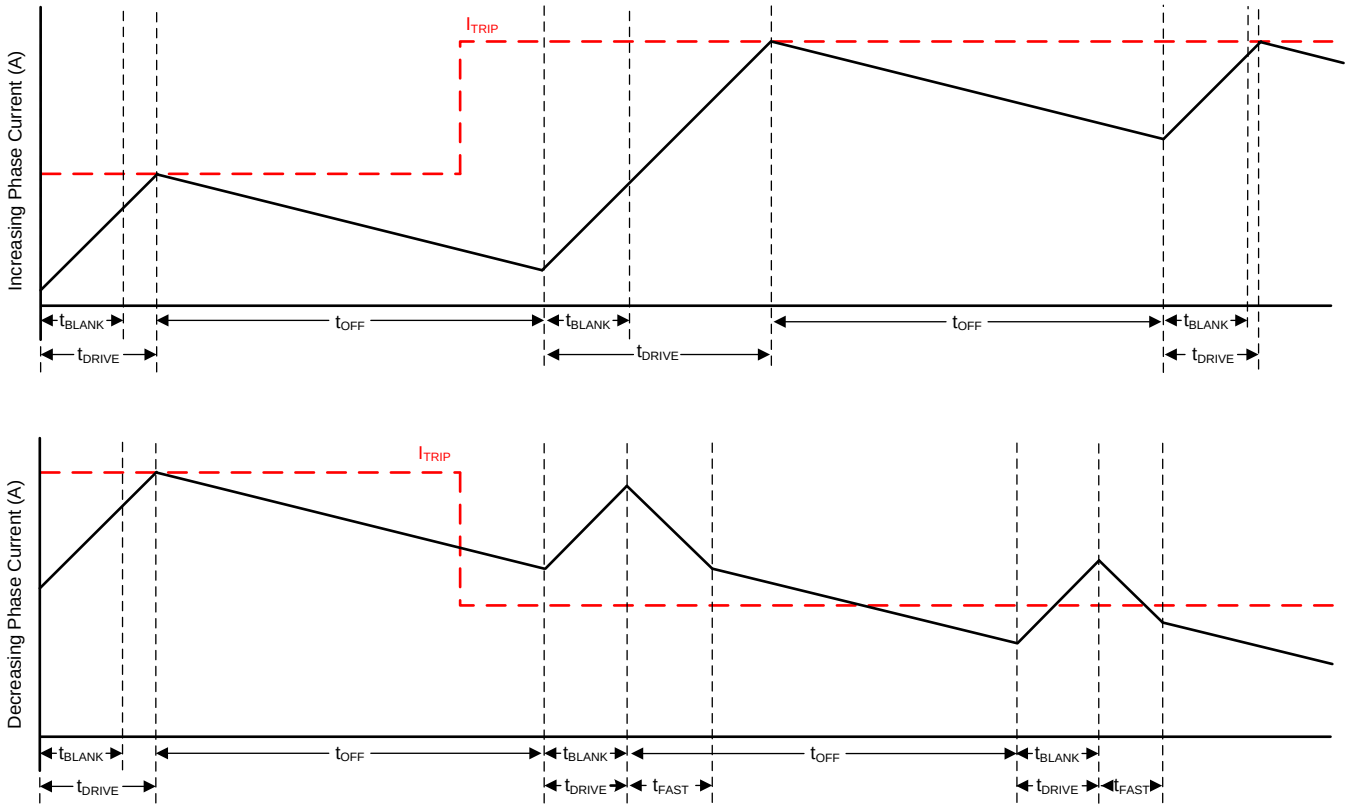


Figure 8. Smart tune Dynamic Decay Mode

Smart tune Dynamic Decay greatly simplifies the decay mode selection by automatically configuring the decay mode between slow, mixed, and fast decay. In mixed decay, smart tune dynamically adjusts the fast decay percentage of the total mixed decay time. This feature eliminates motor tuning by automatically determining the best decay setting that results in the lowest ripple for the motor.

The decay mode setting is optimized iteratively each PWM cycle. If the motor current overshoots the target trip level, then the decay mode becomes more aggressive (add fast decay percentage) on the next cycle to prevent regulation loss. If a long drive time must occur to reach the target trip level, the decay mode becomes less aggressive (remove fast decay percentage) on the next cycle to operate with less ripple and more efficiently. On falling steps, smart tune Dynamic Decay automatically switches to fast decay to reach the next step quickly.

Smart tune Dynamic Decay is optimal for applications that require minimal current ripple but want to maintain a fixed frequency in the current regulation scheme.

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9.3.4.5 Blanking time

After the current is enabled (start of drive phase) in an H-bridge, the current sense comparator is ignored for a period of time (t_{BLANK}) before enabling the current-sense circuitry. The blanking time also sets the minimum drive time of the PWM. When the device goes into a drive phase at the end of a slow-decay phase, the blanking time is approximately 500 ns. If the device goes into drive phase at the end of a fast-decay phase, the blanking time is approximately 860ns.

9.3.5 Charge Pump

A charge pump is integrated to supply a high-side N-channel MOSFET gate-drive voltage. The charge pump requires a capacitor between the VM and VCP pins to act as the storage capacitor. Additionally a ceramic capacitor is required between the CPH and CPL pins to act as the flying capacitor.

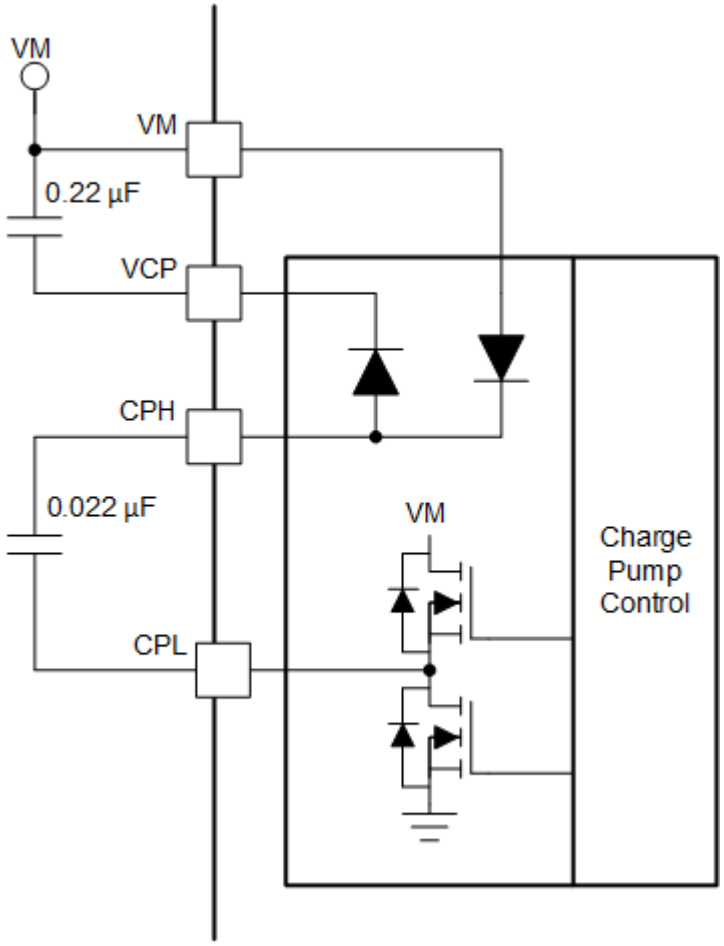


Figure 9. Charge Pump Block Diagram

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9.3.6 Linear Voltage Regulators

A linear voltage regulator is integrated in the device. The DVDD regulator can be used to provide a reference voltage. DVDD can supply a maximum of 2 mA load. For proper operation, bypass the DVDD pin to GND using a ceramic capacitor.

The DVDD output is nominally 5-V. When the DVDD LDO current load exceeds 2 mA, the output voltage drops significantly.

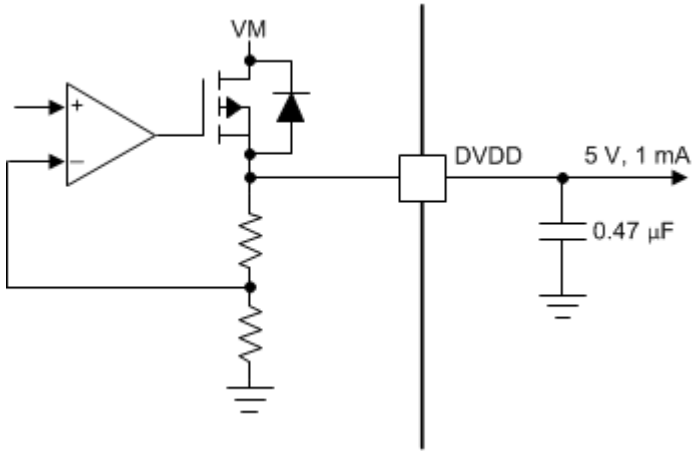


Figure 10. Linear Voltage Regulator Block Diagram

If a digital input must be tied permanently high (that is, ADECAY, BDECAY or TOFF), tying the input to the DVDD pin instead of an external regulator is preferred. This method saves power when the VM pin is not applied or in sleep mode: the DVDD regulator is disabled and current does not flow through the input pulldown resistors. For reference, logic level inputs have a typical pulldown of 200 kΩ.

The nSLEEP pin cannot be tied to DVDD, else the device will never exit sleep mode.

ADVANCE INFORMATION

9.3.7 Logic and Quad-Level Pin Diagrams

Figure 11 gives the input structure for logic-level pins APH, AEN, BPH, BEN, AIN1, AIN2, BIN1, BIN2 and nSLEEP:

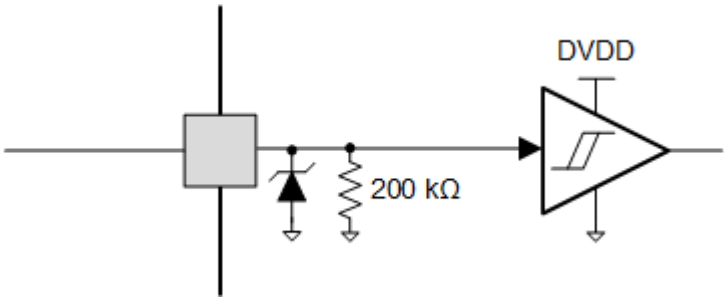


Figure 11. Logic-level Input Pin Diagram

Quad-level logic pins TOFF, ADECAY, and BDECAY have the following structure as shown in Figure 12.

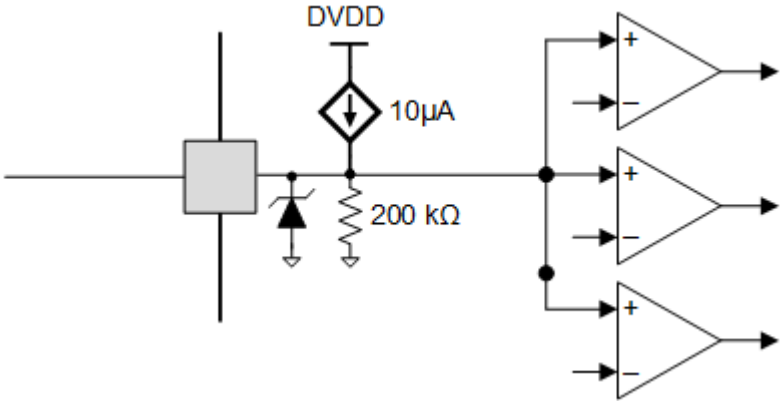


Figure 12. Quad-Level Input Pin Diagram

9.3.7.1 nFAULT Pin

The nFAULT pin has an open-drain output and should be pulled up to a 5-V or 3.3-V supply. When a fault is detected, the nFAULT pin will be logic low. nFAULT pin will be high after power-up. For a 5-V pullup, the nFAULT pin can be tied to the DVDD pin with a resistor. For a 3.3-V pullup, an external 3.3-V supply must be used.

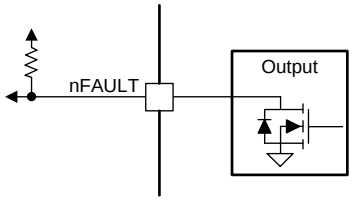


Figure 13. nFAULT Pin

9.3.8 Protection Circuits

The devices are fully protected against supply undervoltage, charge pump undervoltage, output overcurrent, and device overtemperature events.

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9.3.8.1 VM Undervoltage Lockout (UVLO)

If at any time the voltage on the VM pin falls below the UVLO-threshold voltage for the voltage supply, all the outputs are disabled, and the nFAULT pin is driven low. The charge pump is disabled in this condition. Normal operation resumes (motor-driver operation and nFAULT released) when the VM undervoltage condition is removed.

9.3.8.2 CP Undervoltage Lockout (CPUV)

If at any time the voltage on the CP pin falls below the CPUV voltage, all the outputs are disabled, and the nFAULT pin is driven low. The charge pump remains active during this condition. Normal operation resumes (motor-driver operation and nFAULT released) when the CP undervoltage condition is removed.

9.3.8.3 Overcurrent Protection (OCP)

An analog current-limit circuit on each FET limits the current through the FET by removing the gate drive. If this current limit persists for longer than the t_{OCP} time, the FETs in that particular H-bridge are disabled and the nFAULT pin is driven low. The charge pump remains active during this condition. Normal operation resumes automatically (motor-driver operation starts and nFAULT released) after the t_{RETRY} time has elapsed and the fault condition is removed.

9.3.8.4 Thermal Shutdown (OTSD)

If the die temperature exceeds the thermal shutdown limit (T_{OTSD}) all MOSFETs in the H-bridge are disabled, and the nFAULT pin is driven low. The charge pump remains active during this condition. Normal operation resumes (motor-driver operation and the nFAULT line released) when the junction temperature falls below the overtemperature threshold limit minus the hysteresis ($T_{OTSD} – T_{HYS_OTSD}$).

Table 6. Fault Condition Summary

FAULT	CONDITION	ERROR REPORT	H-BRIDGE	CHARGE PUMP	INDEXER	LOGIC	RECOVERY
VM undervoltage (UVLO)	$VM < V_{UVLO}$	nFAULT	Disabled	Disabled	Disabled	Reset (V_{DVDD} < 3.9 V)	Automatic: $VM > V_{UVLO}$
CP undervoltage (CPUV)	$CP < V_{CPUV}$	nFAULT	Disabled	Operating	Operating	Operating	$CP > V_{CPUV}$
Overcurrent (OCP)	$I_{OUT} > I_{OCP}$	nFAULT	Disabled	Operating	Operating	Operating	Automatic retry: t_{RETRY}
Thermal Shutdown (OTSD)	$T_J > T_{TSD}$	nFAULT	Disabled	Disabled	Operating	Operating	Automatic: $T_J < T_{OTSD} - T_{HYS_OTSD}$

9.4 Device Functional Modes

9.4.1 Sleep Mode (nSLEEP = 0)

The state of the device is managed by the nSLEEP pin. When the nSLEEP pin is low, the device enters a low-power sleep mode. In sleep mode, all the internal MOSFETs are disabled and the charge pump is disabled. The t_{SLEEP} time must elapse after a falling edge on the nSLEEP pin before the device enters sleep mode. The device is brought out of sleep automatically if the nSLEEP pin is brought high. The t_{WAKE} time must elapse before the device is ready for inputs.

9.4.2 Operating Mode (nSLEEP = 1)

When the nSLEEP pin is high, and VM > UVLO, the device enters the active mode. The t_{WAKE} time must elapse before the device is ready for inputs.

Table 7 lists a summary of the functional modes.

Table 7. Functional Modes Summary

CONDITION		CONFIGURATION	H-BRIDGE	DVDD Regulator	CHARGE PUMP	Logic
Sleep mode	4.5 V < VM < 45	nSLEEP pin = 0	Disabled	Disbaled	Disabled	Disabled

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Device Functional Modes (continued)

Table 7. Functional Modes Summary (continued)

CONDITION		CONFIGURATION	H-BRIDGE	DVDD Regulator	CHARGE PUMP	Logic
Operating	4.5 V < VM < 45 V	nSLEEP pin = 1	Operating	Operating	Operating	Operating

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10 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

10.1 Application Information

The DRV8436E/P and DRV8437E/P are used in stepper or brushed motor control.

10.2 Typical Application

The following design procedure can be used to configure the DRV843xE/P. In this application, the DRV843xE/P will be used to drive a stepper motor.

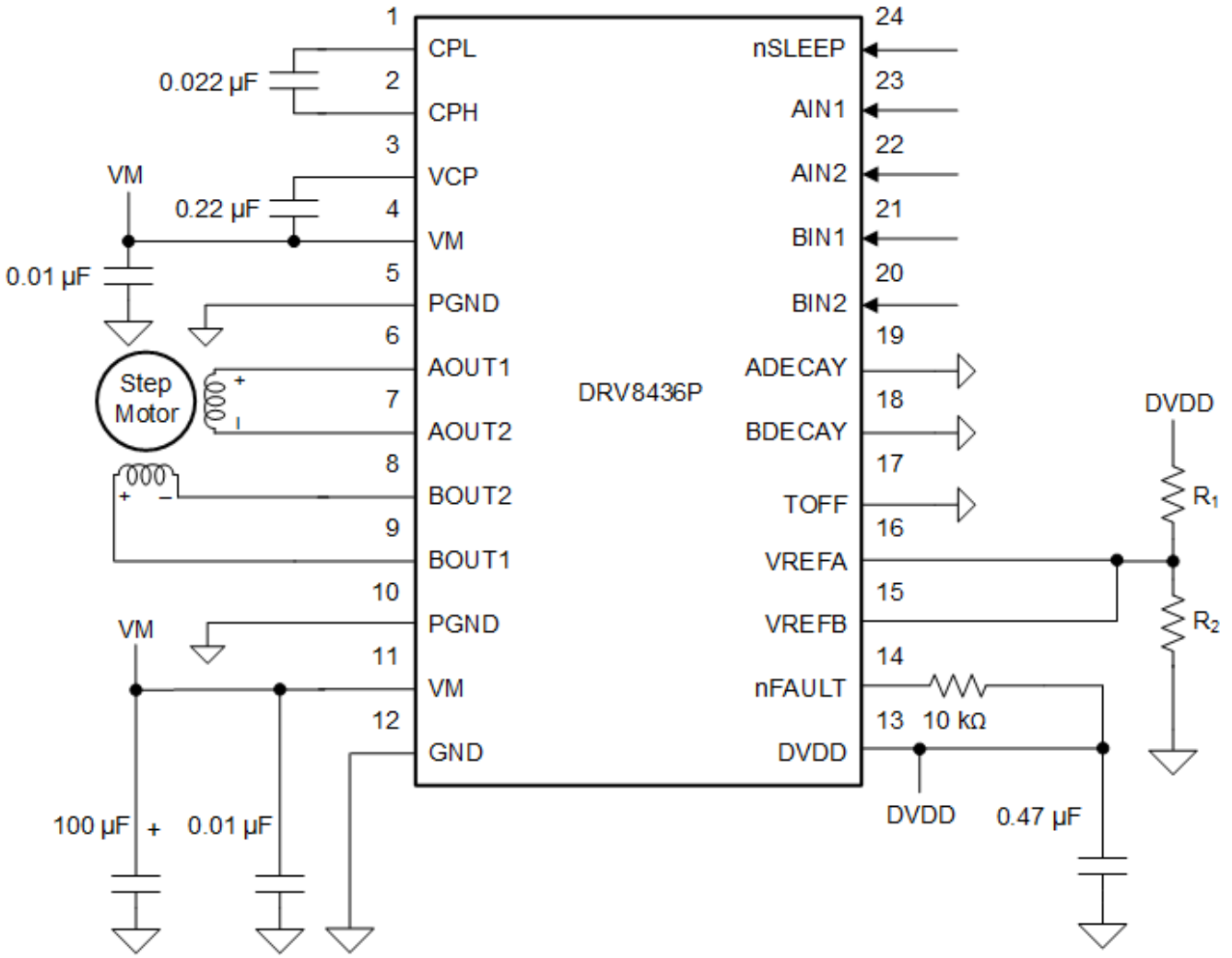


Figure 14. Typical Application Schematic

10.2.1 Design Requirements

Table 8 lists the design input parameters for system design.

ADVANCE INFORMATION

Table 8. Design Parameters

DESIGN PARAMETER	REFERENCE	EXAMPLE VALUE
Supply voltage	VM	24 V
Motor winding resistance	R_L	4.5 Ω/phase
Motor winding inductance	L_L	10.5 mH/phase
Motor full step angle	θ_{step}	1.8°/step
Target microstepping level	n_m	Non-circular 1/2 step
Target motor speed	v	120 rpm
Target full-scale current	I_{FS}	800 mA

10.2.2 Detailed Design Procedure

10.2.2.1 Current Regulation

In a stepper motor, the full-scale current (I_{FS}) is the maximum current driven through either winding. This quantity depends on the VREFx voltage. The maximum allowable voltage on the VREFx pins is 3.3 V. DVDD can be used to provide VREFx through a resistor divider.

I_{FS} (A) = V_{REF} (V) / 2.2 (V/A)

NOTE

The I_{FS} current must also follow to avoid saturating the motor. VM is the motor supply voltage, and R_L is the motor winding resistance.

$$I_{FS}\ (A) < \frac{VM\ (V)}{R_L\ (\Omega) + 2 \times R_{DS(ON)}\ (\Omega)} \quad (1)$$

10.2.2.2 Stepper Motor Speed

Next, the driving waveform needs to be planned. In order to command the correct speed, determine the frequency of the input waveform.

If the target motor speed is too high, the motor will not spin. Make sure that the motor can support the target speed.

For a desired motor speed (v), microstepping level (n_m), and motor full step angle (θ_{step}),

$$f_{step}\ (steps/s) = \frac{v\ (rpm) \times 360\ (°/rot)}{\theta_{step}\ (°/step) \times n_m\ (steps/microstep) \times 60\ (s/min)} \quad (2)$$

θ_{step} can be found in the stepper motor data sheet or written on the motor itself.

The frequency f_{step} gives the frequency of input change on the DRV843xxP. 1/ f_{step} = t_{STEP} on the diagram below.

$$f_{step}\ (steps/s) = \frac{120\ rpm \times 360°/rot}{1.8°/step \times 1/2\ steps/microstep \times 60\ s/min} = 800\,Hz \quad (3)$$

10.2.2.3 Decay Modes

The DRV843xE/P supports several different decay modes: slow decay, fast decay, mixed decay, and smart tune. The current through the motor windings is regulated using an adjustable fixed-time-off scheme. This means that after any drive phase, when a motor winding current has hit the current chopping threshold (I_{TRIP}), the DRV843xE/P will place the winding in one of the decay modes for TOFF. After TOFF, a new drive phase starts.

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10.3 Alternate Application

In this application, the device is configured to drive bidirectional currents through two external loads (such as two brushed DC motors) using H-bridge configuration. The H-bridge polarity and duty cycle are controlled from the external controller to the xEN/xIN1 and xPH/xIN2 pins.

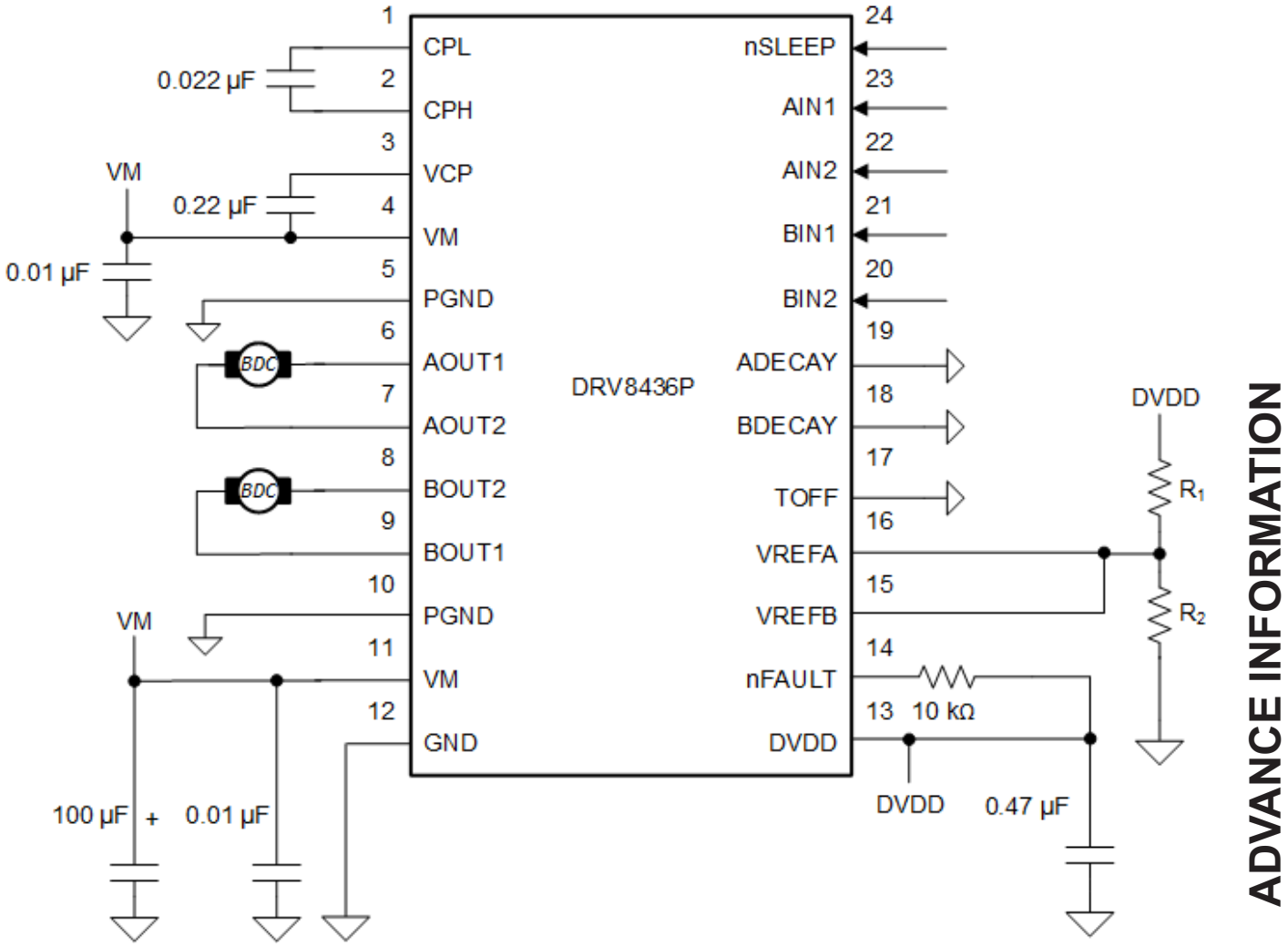


Figure 15. Typical Application Schematic

10.3.1 Design Requirements

Table 9 gives design input parameters for system design.

Table 9. Design Parameters

DESIGN PARAMETER	REFERENCE	EXAMPLE VALUE
Supply voltage	VM	24 V
Motor winding resistance	R_L	6 Ω
Motor winding inductance	L_L	4.1 mH
f_{PWM}	Switching frequency	20 kHz
Target maximum motor current	I_{TRIP}	1 A

ADVANCE INFORMATION

10.3.2 Detailed Design Procedure

10.3.2.1 Current Regulation

The maximum current (I_{TRIP}) is set by the VREFx analog voltage. When starting a brushed-DC motor, a large inrush current may occur because there is no back-EMF. Current regulation will act to limit this inrush current and prevent high current on startup.

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11 Power Supply Recommendations

The device is designed to operate from an input voltage supply (VM) range from 4.5 V to 48 V. A 0.01-µF ceramic capacitor rated for VM must be placed at each VM pin as close to the device as possible. In addition, a bulk capacitor must be included on VM.

11.1 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.

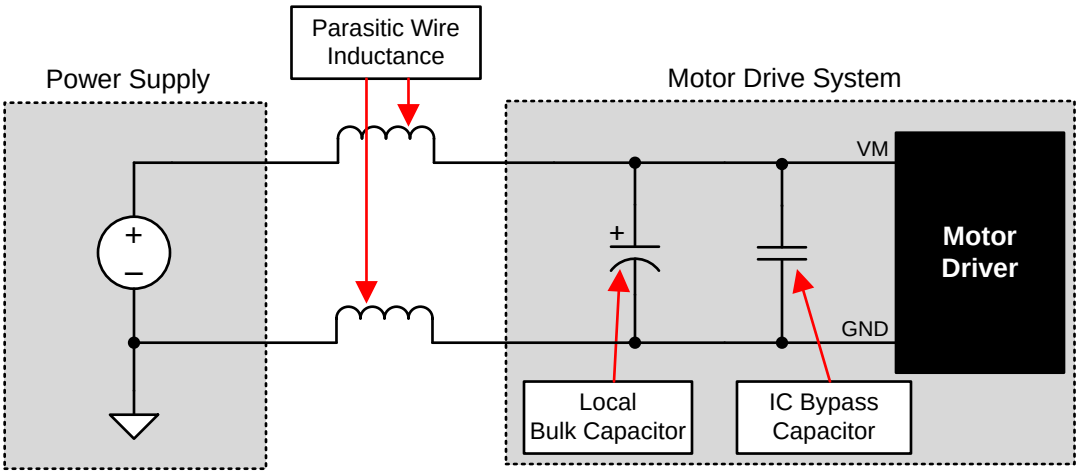
The amount of local capacitance needed depends on a variety of factors, including:

- The highest current required by the motor system
- The power supply's 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 will limit the rate current can change from the power supply. If the local bulk capacitance is too small, the system will respond 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 data sheet generally provides a recommended value, but system-level testing is required to determine the appropriate sized bulk capacitor.

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.



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Figure 16. Example Setup of Motor Drive System With External Power Supply

ADVANCE INFORMATION

12 Layout

12.1 Layout Guidelines

The VM pin should be bypassed to GND using a low-ESR ceramic bypass capacitor with a recommended value of 0.01 µF rated for VM. This capacitor should be placed as close to the VM pin as possible with a thick trace or ground plane connection to the device GND pin.

The VM pin must be bypassed to ground using a bulk capacitor rated for VM. This component can be an electrolytic capacitor.

A low-ESR ceramic capacitor must be placed in between the CPL and CPH pins. A value of 0.022 µF rated for VM is recommended. Place this component as close to the pins as possible.

A low-ESR ceramic capacitor must be placed in between the VM and VCP pins. A value of 0.22 µF rated for 16 V is recommended. Place this component as close to the pins as possible.

Bypass the DVDD pin to ground with a low-ESR ceramic capacitor. A value of 0.47 µF rated for 6.3 V is recommended. Place this bypassing capacitor as close to the pin as possible.

The thermal PAD must be connected to system ground.

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12.2 Layout Example

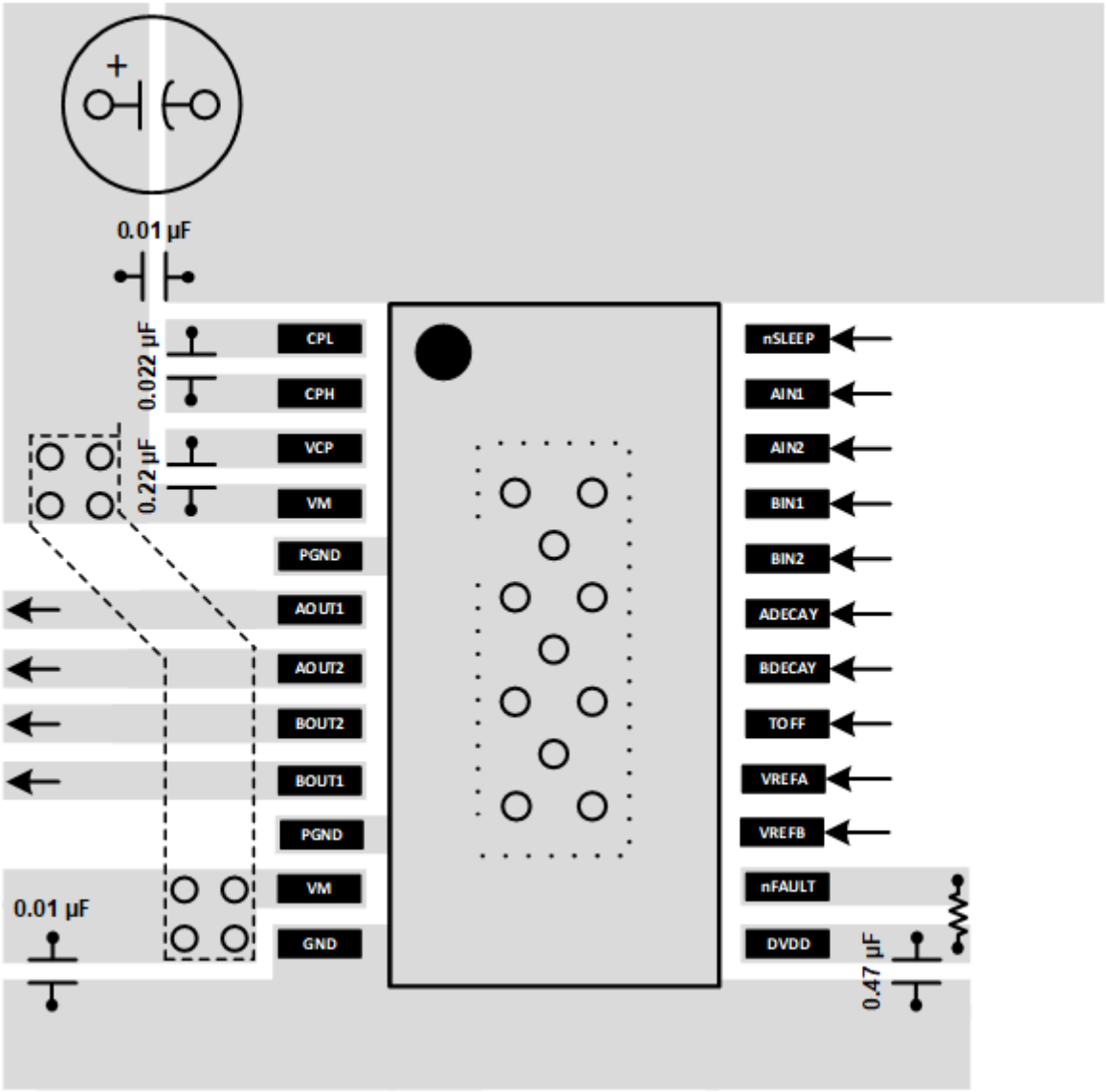


Figure 17. HTSSOP Layout Recommendation

ADVANCE INFORMATION

Layout Example (continued)

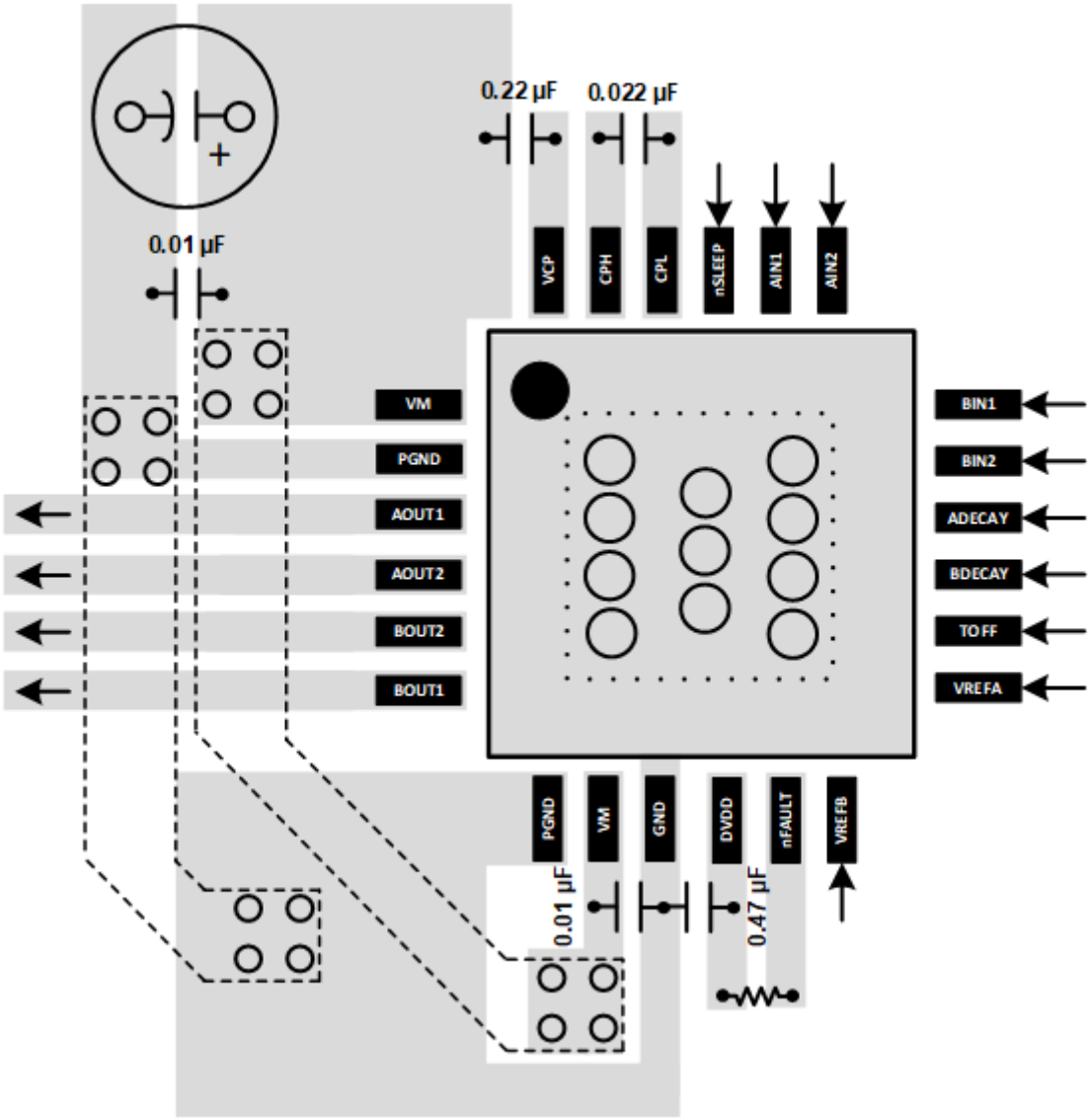


Figure 18. QFN Layout Recommendation

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13 Device and Documentation Support

13.1 Documentation Support

13.1.1 Related Documentation

For related documentation see the following:

- Texas Instruments, *PowerPAD™ Thermally Enhanced Package* application report
- Texas Instruments, *PowerPAD™ Made Easy* application report
- Texas Instruments, *Current Recirculation and Decay Modes* application report
- Texas Instruments, *Calculating Motor Driver Power Dissipation* application report
- Texas Instruments, *Understanding Motor Driver Current Ratings* application report
- Texas Instruments, *High Resolution Microstepping Driver With the DRV88xx Series* application report

13.2 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to order now.

13.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

13.4 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

13.5 Trademarks

E2E is a trademark of Texas Instruments.

13.6 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

13.7 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

ADVANCE INFORMATION

14 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
DRV8436EPWPR	PREVIEW	HTSSOP	PWP	24	1	TBD	Call TI	Call TI	-40 to 125		
DRV8436PPWPR	PREVIEW	HTSSOP	PWP	24	1	TBD	Call TI	Call TI	-40 to 125		
PDRV8436EPWPR	ACTIVE	HTSSOP	PWP	24	1	TBD	Call TI	Call TI	-40 to 125		Samples
PDRV8436PPWPR	ACTIVE	HTSSOP	PWP	24	1	TBD	Call TI	Call TI	-40 to 125		Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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GENERIC PACKAGE VIEW

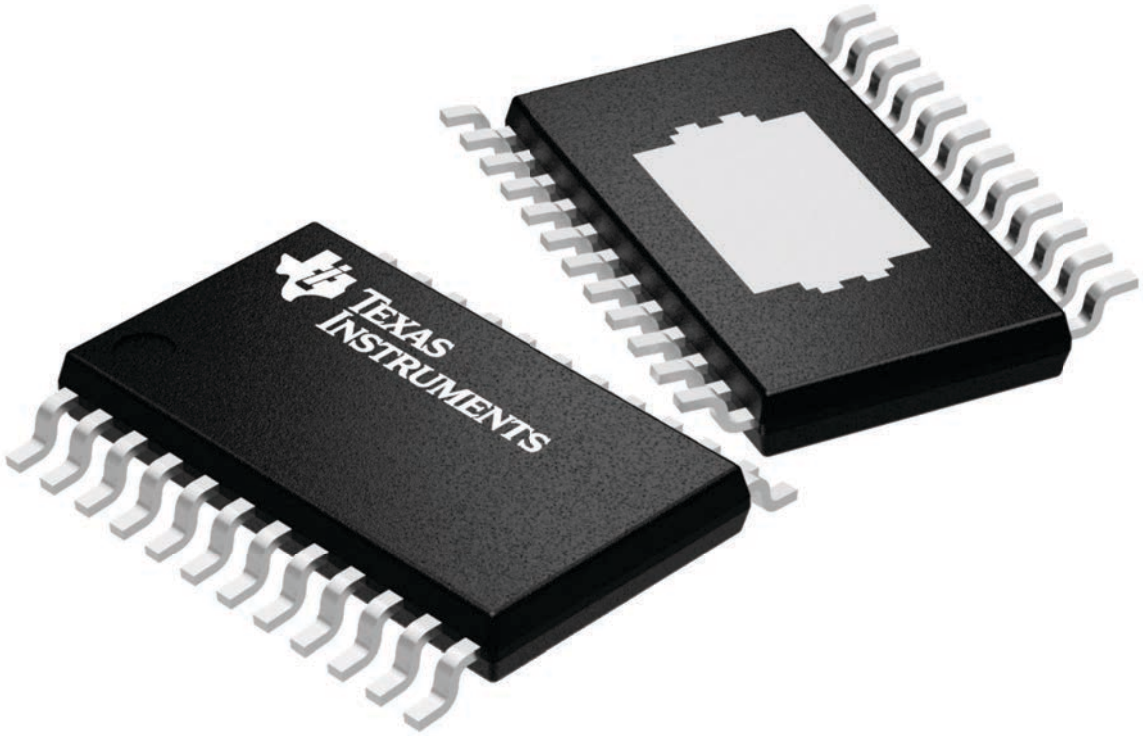
PWP 24

PowerPAD™ TSSOP - 1.2 mm max height

4.4 x 7.6, 0.65 mm pitch

PLASTIC SMALL OUTLINE

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



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Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
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