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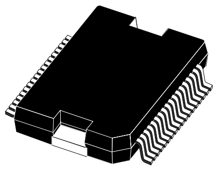
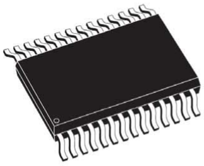
L6470

Fully integrated microstepping motor driver with motion engine and SPI

Datasheet - production data



POWERSO36



HTSSOP28

Features

- Operating voltage: 8 - 45 V
- 7.0 A out peak current (3.0 A $_{r.m.s.}$)
- Low $R_{DS(on)}$ Power MOSFETs
- Programmable speed profile and positioning
- Programmable power MOS slew rate
- Up to 1/128 microstepping
- Sensorless stall detection
- SPI interface
- Low quiescent and standby currents
- Programmable non-dissipative overcurrent protection on high and low-side
- Two-levels of overtemperature protection

Applications

- Bipolar stepper motors

Description

The L6470 device, realized in analog mixed signal technology, is an advanced fully integrated solution suitable for driving two-phase bipolar stepper motors with microstepping. It integrates a dual low $R_{DS(on)}$ DMOS full bridge with all of the power switches equipped with an accurate on-chip current sensing circuitry suitable for non-dissipative current control and overcurrent protection. Thanks to a unique control system, a true 1/128 steps resolution is achieved. The digital control core can generate user defined motion profiles with acceleration, deceleration, speed or target position, easily programmed through a dedicated registers set. All commands and data registers, including those used to set analogue values (i.e. current control value, current protection trip point, deadtime, PWM frequency, etc.) are sent through a standard 5-Mbit/s SPI. A very rich set of protections (thermal, low bus voltage, overcurrent, motor stall) allows the design of a fully protected application, as required by the most demanding motor control applications.

Table 1. Device summary

Order codes	Package	Packaging
L6470H	HTSSOP28	Tube
L6470HTR	HTSSOP28	Tape and reel
L6470PD	POWERSO36	Tube
L6470PDTR	POWERSO36	Tape and reel

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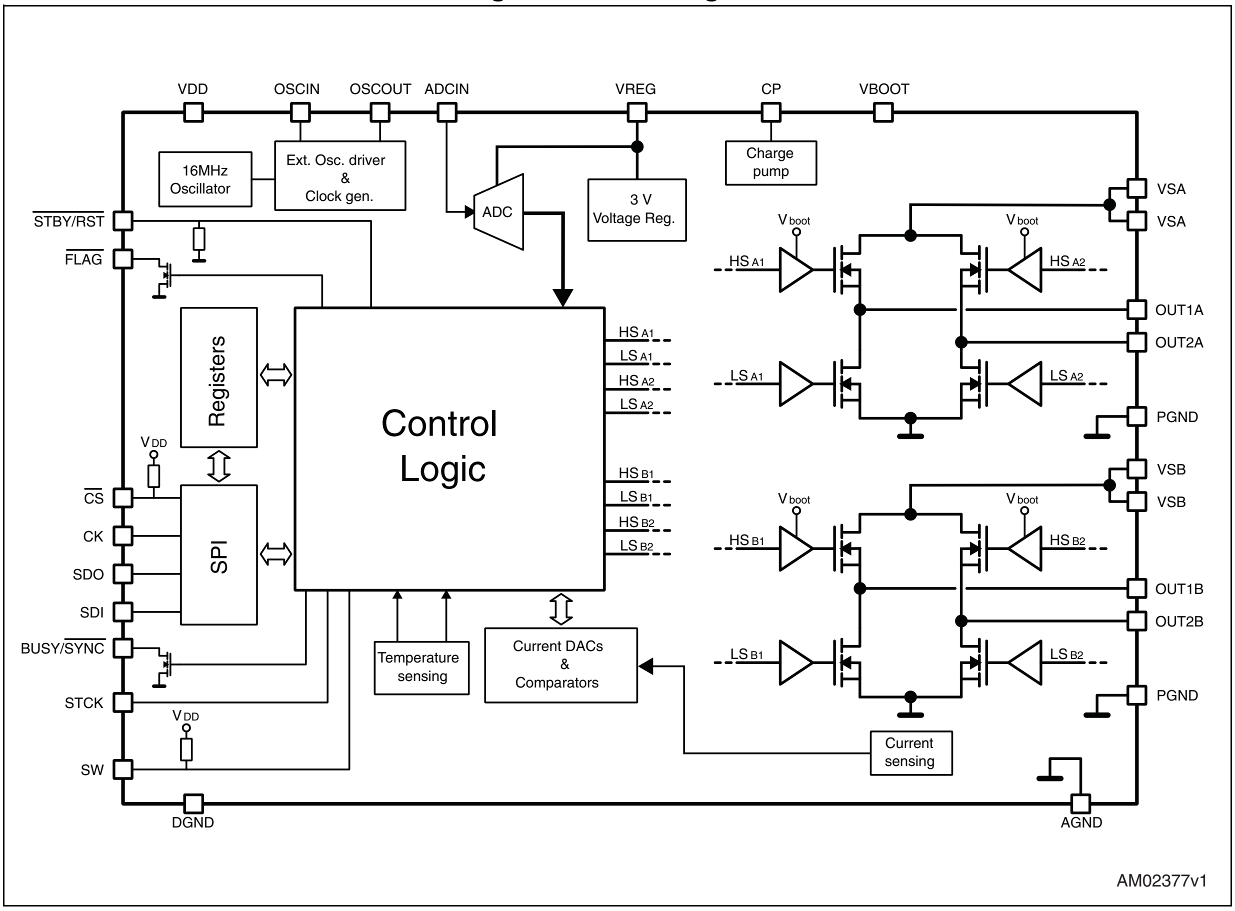
1 Block diagram

Figure 1. Block diagram



2 Electrical data

2.1 Absolute maximum ratings

Table 2. Absolute maximum ratings

Symbol	Parameter	Test condition	Value	Unit
V_{DD}	Logic interface supply voltage		5.5	V
V_S	Motor supply voltage	$V_{SA} = V_{SB} = V_S$	48	V
$V_{GND,\ diff}$	Differential voltage between AGND, PGND and DGND		±0.3	V
V_{boot}	Bootstrap peak voltage		55	V
V_{REG}	Internal voltage regulator output pin and logic supply voltage		3.6	V
V_{ADCIN}	Integrated ADC input voltage range (ADCIN pin)		-0.3 to +3.6	V
V_{OSC}	OSCIN and OSCOUT pin voltage range		-0.3 to +3.6	V
V_{out_diff}	Differential voltage between V_{SA}, $OUT1_A$, $OUT2_A$, PGND and V_{SB}, $OUT1_B$, $OUT2_B$, PGND pins	$V_{SA} = V_{SB} = V_S$	48	V
V_{LOGIC}	Logic inputs voltage range		-0.3 to +5.5	V
I_{out}(1)	R.m.s. output current		3	A
I_{out_peak}(1)	Pulsed output current	T_{PULSE} < 1 ms	7	A
T_{OP}	Operating junction temperature		-40 to 150	°C
T_s	Storage temperature range		-55 to 150	°C
P_{tot}	Total power dissipation (T_A = 25 °C)	(2)	5	W

1. Maximum output current limit is related to metal connection and bonding characteristics. Actual limit must satisfy maximum thermal dissipation constraints.
2. HTSSOP28 mounted on EVAL6470H.

2.2 Recommended operating conditions

Table 3. Recommended operating conditions

Symbol	Parameter	Test condition	Value			Unit
V_{DD}	Logic interface supply voltage	3.3 V logic outputs		3.3		V
		5 V logic outputs		5		
V_S	Motor supply voltage	$V_{SA} = V_{SB} = V_S$	8		45	V
V_{out_diff}	Differential voltage between V_{SA}, $OUT1_A$, $OUT2_A$, PGND and V_{SB}, $OUT1_B$, $OUT2_B$, PGND pins	$V_{SA} = V_{SB} = V_S$			45	V
$V_{REG,in}$	Logic supply voltage	V_{REG} voltage imposed by external source	3.2	3.3		V
V_{ADC}	Integrated ADC input voltage (ADCIN pin)		0		V_{REG}	V

2.3 Thermal data

Table 4. Thermal data

Symbol	Parameter	Package	Typ.	Unit
R_{thJA}	Thermal resistance junction ambient	HTSSOP28(1)	22	°C/W
		POWERSO36(2)	12	

1. HTSSOP28 mounted on the EVAL6470H rev 1.0 board: a four-layer FR4 PCB with a dissipating copper surface of about 40 cm^2 on each layer and 15 via holes below the IC.
2. POWERSO36 mounted on the EVAL6470PD rev 1.0 board: a four-layer FR4 PCB with a dissipating copper surface of about 40 cm^2 on each layer and 22 via holes below the IC.

3 Electrical characteristics

V_{SA} = V_{SB} = 36 V; V_{DD} = 3.3 V; internal 3 V regulator; T_J = 25 °C, unless otherwise specified.

Table 5. Electrical characteristics

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
General						
V_{SthOn}	V_S UVLO turn-on threshold		7.5	8.2	8.9	V
V_{SthOff}	V_S UVLO turn-off threshold		6.6	7.2	7.8	V
$V_{SthHyst}$	V_S UVLO threshold hysteresis		0.7	1	1.3	V
I_q	Quiescent motor supply current	Internal oscillator selected; VREG = 3.3 V ext.; CP floating		0.5	0.65	mA
$T_{j(WRN)}$	Thermal warning temperature			130		°C
$T_{j(SD)}$	Thermal shutdown temperature			160		°C
Charge pump						
V_{pump}	Voltage swing for charge pump oscillator			10		V
$f_{pump,min}$	Minimum charge pump oscillator frequency(1)			660		kHz
$f_{pump,max}$	Maximum charge pump oscillator frequency(1)			800		kHz
I_{boot}	Average boot current	$f_{sw,A}$ = $f_{sw,B}$ = 15.6 kHz POW_SR = '10'		1.1	1.4	mA
Output DMOS transistor						
$R_{DS(on)}$	High-side switch on-resistance	T_j = 25 °C, I_{out} = 3 A		0.37		Ω
		T_j = 125 °C, (2) I_{out} = 3 A		0.51		
$R_{DS(on)}$	Low-side switch on-resistance	T_j = 25 °C, I_{out} = 3 A		0.18		
		T_j = 125 °C, (2) I_{out} = 3 A		0.23		
I_{DSS}	Leakage current	OUT = V_S			3.1	mA
		OUT = GND	-0.3			
t_r	Rise time(3)	POW_SR = '00', I_{out} = +1 A		100		ns
		POW_SR = '00', I_{out} = -1 A		80		
		POW_SR = '11', I_{out} = ±1 A		100		
		POW_SR = '10', I_{lout} = ±1 A		200		
		POW_SR = '01', I_{out} = ±1 A		300		

Table 5. Electrical characteristics (continued)

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
t_f	Fall time(3)	POW_SR = '00'; I_{out} = +1 A		90		ns
		POW_SR = '00'; I_{out} = -1 A		110		
		POW_SR = '11', I_{out} = ±1 A		110		
		POW_SR = '10', I_{out} = ±1 A		260		
		POW_SR = '01', I_{load}= ±1 A		375		
SR_{out_r}	Output rising slew rate	POW_SR = '00', I_{out} = +1 A		285		V/µs
		POW_SR = '00', I_{out} = -1 A		360		
		POW_SR = '11', I_{out} = ±1 A		285		
		POW_SR = '10', I_{out} = ±1 A		150		
		POW_SR = '01', I_{out} = ±1 A		95		
SR_{out_f}	Output falling slew rate	POW_SR = '00', I_{out} = +1 A		320		V/µs
		POW_SR = '00', I_{out} = -1 A		260		
		POW_SR = '11', I_{out} = ±1 A		260		
		POW_SR = '10', I_{out} = ±1 A		110		
		POW_SR = '01', I_{out} = ±1 A		75		
Deadtime and blanking						
t_{DT}	Deadtime(1)	POW_SR = '00'		250		ns
		POW_SR = '11', f_{OSC} = 16 MHz		375		
		POW_SR = '10', f_{OSC} = 16 MHz		625		
		POW_SR = '01', f_{OSC} = 16 MHz		875		
t_{blank}	Blanking time(1)	POW_SR = '00'		250		ns
		POW_SR = '11', f_{OSC} = 16 MHz		375		
		POW_SR = '10', f_{OSC} = 16 MHz		625		
		POW_SR = '01', f_{OSC} = 16 MHz		875		
Source-drain diodes						
$V_{SD,HS}$	High-side diode forward ON voltage	I_{out} = 1 A		1	1.1	V
$V_{SD,LS}$	Low-side diode forward ON voltage	I_{out} = 1 A		1	1.1	V
t_{rrHS}	High-side diode reverse recovery time	I_{out} = 1 A		30		ns
t_{rrLS}	Low-side diode reverse recovery time	I_{out} = 1 A		100		ns
Logic inputs and outputs						
V_{IL}	Low logic level input voltage				0.8	V
V_{IH}	High logic level input voltage		2			V
I_{IH}	High logic level input current(4)	V_{IN} = 5 V			1	µA
I_{IL}	Low logic level input current(5)	V_{IN} = 0 V	-1			µA

Table 5. Electrical characteristics (continued)

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
V_{OL}	Low logic level output voltage(6)	V_{DD} = 3.3 V, I_{OL} = 4 mA			0.3	V
		V_{DD} = 5 V, I_{OL} = 4 mA			0.3	
V_{OH}	High logic level output voltage	V_{DD} = 3.3 V, I_{OH} = 4 mA	2.4			V
		V_{DD} = 5 V, I_{OH} = 4 mA	4.7			
R_{PU} R_{PD}	CS pull-up and STBY pull-down resistors	$\overline{CS}$ = GND; $\overline{STBY/RST}$ = 5 V	335	430	565	kΩ
I_{logic}	Internal logic supply current	3.3 V V_{REG} externally supplied, internal oscillator		3.7	4.3	mA
$I_{logic,STBY}$	Standby mode internal logic supply current	3.3 V V_{REG} externally supplied		2	2.5	µA
f_{STCK}	Step-clock input frequency				2	MHz
Internal oscillator and external oscillator driver						
$f_{osc,i}$	Internal oscillator frequency	T_j = 25 °C, V_{REG} = 3.3 V	-3%	16	+3%	MHz
$f_{osc,e}$	Programmable external oscillator frequency		8		32	MHz
$V_{OSCOUTH}$	OSCOUT clock source high level voltage	Internal oscillator 3.3 V V_{REG} externally supplied; I_{OSCOUT} = 4 mA	2.4			V
$V_{OSCOUTL}$	OSCOUT clock source low level voltage	Internal oscillator 3.3 V V_{REG} externally supplied; I_{OSCOUT} = 4 mA			0.3	V
$t_{rOSCOUT}$ $t_{fOSCOUT}$	OSCOUT clock source rise and fall time	Internal oscillator			20	ns
t_{extosc}	Internal to external oscillator switching delay			3		ms
t_{intosc}	External to internal oscillator switching delay			1.5		µs
SPI						
$f_{CK,MAX}$	Maximum SPI clock frequency(7)		5			MHz
t_{rCK} t_{fCK}	SPI clock rise and fall time(7)	C_L = 30 pF			25	ns
t_{hCK} t_{lCK}	SPI clock high and low time(7)		75			ns
t_{setCS}	Chip select setup time(7)		350			ns
t_{holCS}	Chip select hold time(7)		10			ns
t_{disCS}	Deselect time(7)		800			ns
t_{setSDI}	Data input setup time(7)		25			ns
t_{holSDI}	Data input hold time(7)		20			ns

Table 5. Electrical characteristics (continued)

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
t_{enSDO}	Data output enable time(7)				38	ns
t_{disSDO}	Data output disable time(7)				47	ns
t_{vSDO}	Data output valid time(7)				57	ns
t_{holSDO}	Data output hold time(7)		37			ns
Switch input (SW)						
R_{PUSW}	SW input pull-up resistance	SW = GND	60	85	110	kΩ
PWM modulators						
f_{PWM}	Programmable PWM frequency(1)	f_{osc} = 16 MHz	2.8		62.5	kHz
		f_{osc} = 32 MHz	5.6		125	
N_{PWM}	PWM resolution			8		bit
Stall detection						
$I_{STALL,MAX}$	Maximum programmable stall threshold	STALL_TH = '1111111'		4		A
$I_{STALL,MIN}$	Minimum programmable stall threshold	STALL_TH = '0000000'		31.2 5		mA
$I_{STALL,RES}$	Programmable stall threshold resolution			31.2 5		mA
Overcurrent protection						
$I_{OCD,MAX}$	Maximum programmable overcurrent detection threshold	OCD_TH = '1111'		6		A
$I_{OCD,MIN}$	Minimum programmable overcurrent detection threshold	OCD_TH = '0000'		0.37 5		A
$I_{OCD,RES}$	Programmable overcurrent detection threshold resolution			0.37 5		A
$t_{OCD,Flag}$	OCD to flag signal delay time	dI_{out}/dt = 350 A/μs		650	1000	ns
$t_{OCD,SD}$	OCD to shutdown delay time	dI_{out}/dt = 350 A/μs POW_SR = '10'		600		ns
Standby						
I_{qSTBY}	Quiescent motor supply current in standby conditions	V_S = 8 V		26	34	μA
		V_S = 36 V		30	36	
$t_{STBY,min}$	Minimum standby time			10		μs
$t_{logicwu}$	Logic power-on and wake-up time			38	45	μs
t_{cpwu}	Charge pump power-on and wake-up time	Power bridges disabled, C_p = 10 nF, C_{boot} = 220 nF		650		μs
Internal voltage regulator						
V_{REG}	Voltage regulator output voltage		2.9	3	3.2	V
I_{REG}	Voltage regulator output current				40	mA

Table 5. Electrical characteristics (continued)

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
$V_{REG, drop}$	Voltage regulator output voltage drop	I_{REG} = 40 mA		50		mV
$I_{REG,STBY}$	Voltage regulator standby output current				10	mA
Integrated analog-to-digital converter						
N_{ADC}	Analog-to-digital converter resolution			5		bit
$V_{ADC,ref}$	Analog-to-digital converter reference voltage			V_{REG}		V
f_S	Analog-to-digital converter sampling frequency			f_{PWM}		kHz

1. Accuracy depends on oscillator frequency accuracy.
2. Tested at 25 °C in a restricted range and guaranteed by characterization.
3. Rise and fall time depends on motor supply voltage value. Refer to SR_{out} values in order to evaluate the actual rise and fall time.
4. Not valid for $\overline{\text{STBY/RST}}$ pin which has internal pull-down resistor.
5. Not valid for SW and CS pins which have internal pull-up resistors.
6. $\overline{\text{FLAG}}$, $\overline{\text{BUSY}}$ and SYNC open drain outputs included.
7. See *Figure 17 on page 38* – SPI timings diagram for details.

4 Pin connection

Figure 2. HTSSOP28 pin connection (top view)

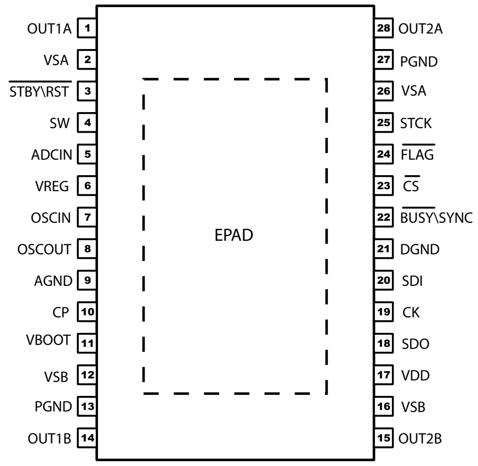
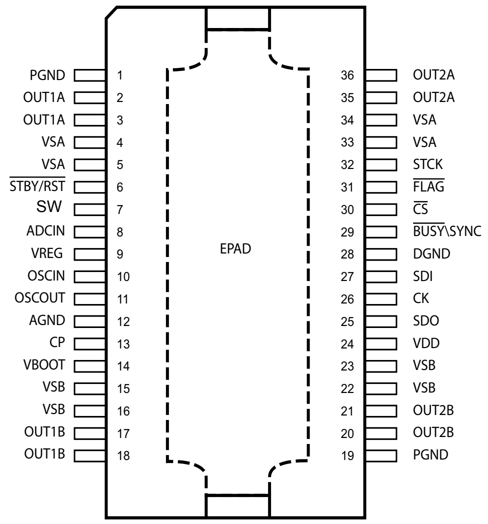


Figure 3. POWERSO36 pin connection (top view)



Pin list

Table 6. Pin description

No.		Name	Type	Function
HTSSOP	POWERSO			
17	24	VDD	Power	Logic outputs supply voltage (pull-up reference)
6	9	VREG	Power	Internal 3 V voltage regulator output and 3.3 V external logic supply
7	10	OSCIN	Analog input	Oscillator pin 1. To connect an external oscillator or clock source. If this pin is unused, it should be left floating.
8	11	OSCOUT	Analog output	Oscillator pin 2. To connect an external oscillator. When the internal oscillator is used this pin can supply 2/4/8/16 MHz. If this pin is unused, it should be left floating.
10	13	CP	Output	Charge pump oscillator output
11	14	VBOOT	Supply voltage	Bootstrap voltage needed for driving the high-side power DMOS of both bridges (A and B)
5	8	ADCIN	Analog input	Internal analog-to-digital converter input
2, 26	4, 5, 33, 34	VSA	Power supply	Full bridge A power supply pin. It must be connected to VSB.
12, 16	15, 16, 22, 23	VSB	Power supply	Full bridge B power supply pin. It must be connected to VSA.
27, 13	1, 19	PGND	Ground	Power ground pin
1	2, 3	OUT1A	Power output	Full bridge A output 1
28	35, 36	OUT2A	Power output	Full bridge A output 2
14	17, 18	OUT1B	Power output	Full bridge B output 1
15	20, 21	OUT2B	Power output	Full bridge B output 2
9	12	AGND	Ground	Analog ground.
4	7	SW	Logical input	External switch input pin. If not used the pin should be connected to VDD.
21	28	DGND	Ground	Digital ground
22	29	$\overline{\text{BUSY}}$\SYNC	Open drain output	By default, this BUSY pin is forced low when the device is performing a command. Otherwise the pin can be configured to generate a synchronization signal.
18	25	SDO	Logic output	Data output pin for serial interface
20	27	SDI	Logic input	Data input pin for serial interface
19	26	CK	Logic input	Serial interface clock
23	30	$\overline{\text{CS}}$	Logic input	Chip select input pin for serial interface

Table 6. Pin description (continued)

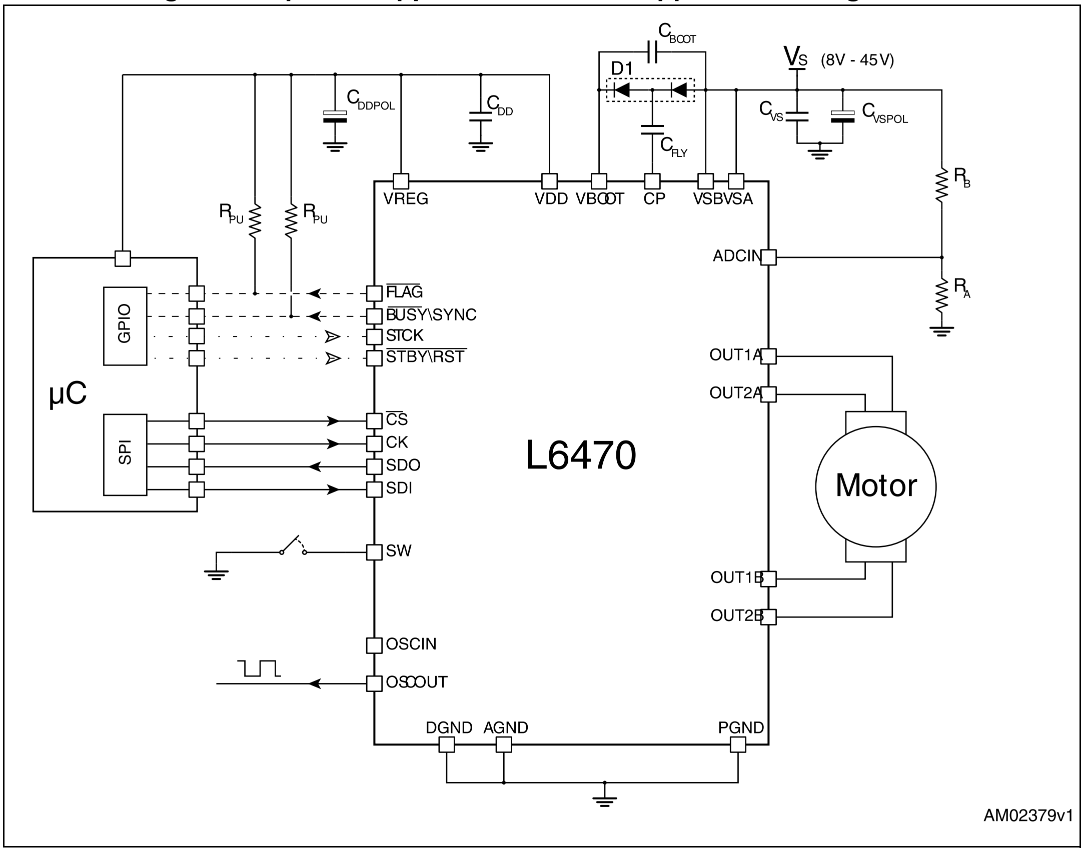
No.		Name	Type	Function
HTSSOP	POWERSO			
24	31	$\overline{FLAG}$	Open drain output	Status flag pin. An internal open drain transistor can pull the pin to GND when a programmed alarm condition occurs (step loss, OCD, thermal pre-warning or shutdown, UVLO, wrong command, non-performable command)
3	6	$\overline{STBY\backslash RST}$	Logic input	Standby and reset pin. LOW logic level resets the logic and puts the device into Standby mode. If not used, it should be connected to VDD.
25	32	STCK	Logic input	Step-clock input
EPAD	EPAD	Exposed pad	Ground	Internally connected to PGND, AGND and DGND pins

5 Typical applications

Table 7. Typical application values

Name	Value
C_{VS}	220 nF
C_{VSPOL}	100 µF
C_{REG}	100 nF
C_{REGPOL}	47 µF
C_{DD}	100 nF
C_{DDPOL}	10 µF
D1	Charge pump diodes
C_{BOOT}	220 nF
C_{FLY}	10 nF
R_{PU}	39 kΩ
R_{SW}	100 Ω
C_{SW}	10 nF
R_A	2.7 kΩ (V_S = 36 V)
R_B	62 kΩ (V_S = 36 V)

Figure 4. Bipolar stepper motor control application using L6470



6 Functional description

6.1 Device power-up

At power-up end, the device state is the following:

- Registers are set to default
- Internal logic is driven by internal oscillator and a 2 MHz clock is provided by the OSCOUT pin
- Bridges are disabled (High Z)
- UVLO bit in the STATUS register is forced low (fail condition)
- FLAG output is forced low.

During power-up, the device is under reset (all logic IOs disabled and power bridges in high impedance state) until the following conditions are satisfied:

- V_S is greater than V_{SthOn}
- V_{REG} is greater than V_{REGth} = 2.8 V typical
- Internal oscillator is operative.

Any motion command makes the device exit from High Z state (HardStop and SoftStop included).

6.2 Logic I/O

Pins $\overline{CS}$, CK, SDI, STCK, SW and $\overline{STBY}\backslash\overline{RST}$ are TTL/CMOS 3.3 V - 5 V compatible logic inputs.

Pin SDO is a TTL/CMOS compatible logic output. VDD pin voltage sets the logic output pin voltage range; when it is connected to VREG or 3.3 V external supply voltage, the output is 3.3 V compatible. When VDD is connected to a 5 V supply voltage, SDO is 5 V compatible.

VDD is not internally connected to V_{REG}, an external connection is always needed.

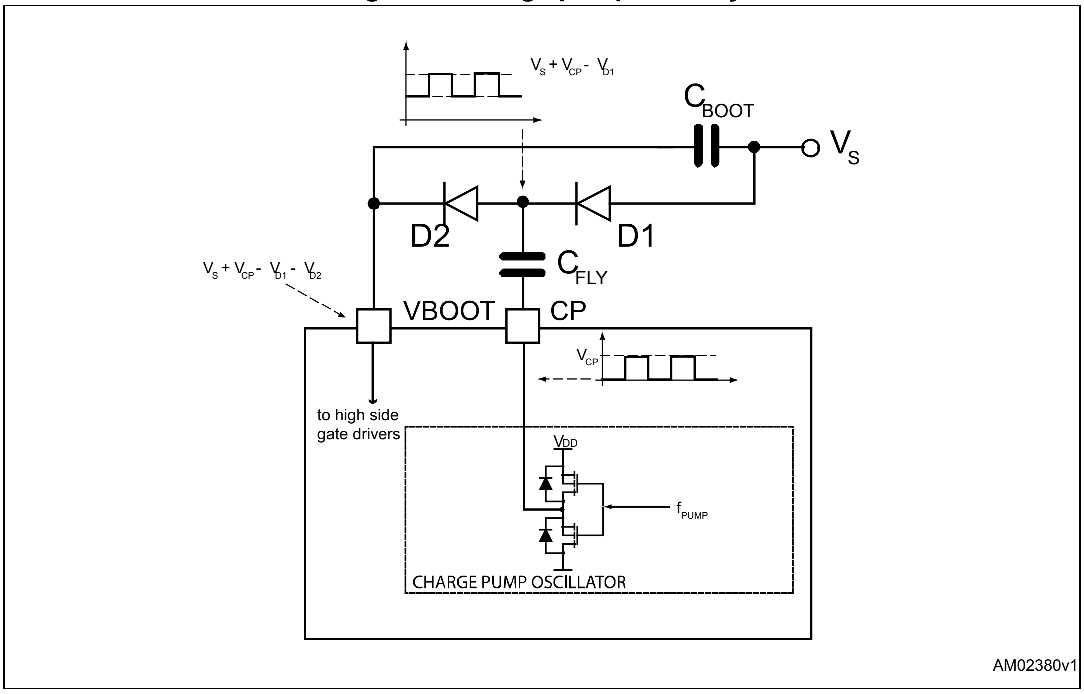
A 10 µF capacitor should be connected to the VDD pin in order to obtain a proper operation.

Pins $\overline{FLAG}$ and $\overline{BUSY}\backslash$SYNC are open drain outputs.

6.3 Charge pump

To ensure the correct driving of the high-side integrated MOSFETs, a voltage higher than the motor power supply voltage needs to be applied to the VBOOT pin. The high-side gate driver supply voltage, V_{boot}, is obtained through an oscillator and a few external components realizing a charge pump (see *Figure 5*).

Figure 5. Charge pump circuitry

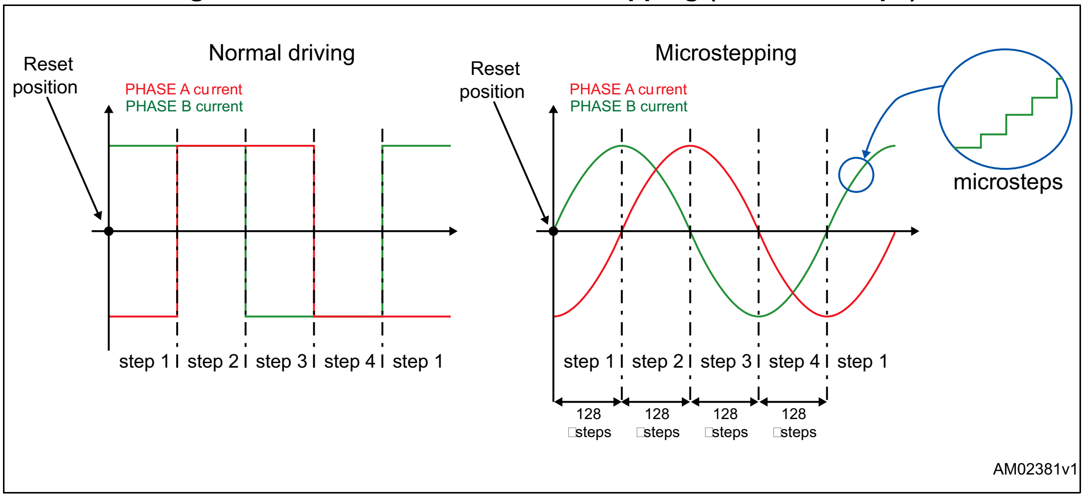


6.4 Microstepping

The driver is able to divide the single step into up to 128 microsteps. Stepping mode can be programmed by the STEP_SEL parameter in the STEP_MODE register (see *Table 18 on page 48*).

Step mode can only be changed when bridges are disabled. Every time the step mode is changed the electrical position (i.e. the point of microstepping sinewave that is generated) is reset to zero and the absolute position counter value (see *Section 6.5*) becomes meaningless.

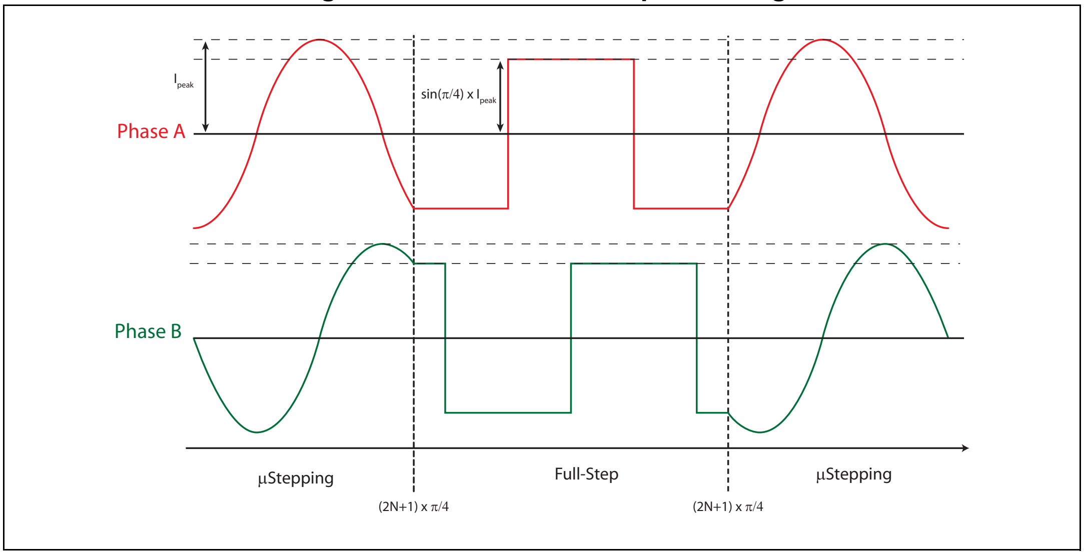
Figure 6. Normal mode and microstepping (128 microsteps)



Automatic full-step mode

When motor speed is greater than a programmable full-step speed threshold, the L6470 device switches automatically to Full-step mode (see *Figure 7*); the driving mode returns to microstepping when motor speed decreases below the full-step speed threshold. The full-step speed threshold is set through the FS_SPD register (see *Section 9.1.9 on page 44*).

Figure 7. Automatic full-step switching



6.5 Absolute position counter

An internal 22-bit register (ABS_POS) records the motor motion according to the selected step mode; the stored value unit is equal to the selected step mode (full, half, quarter, etc.). The position range is from $-2^{21}$to $+2^{21}-1$ (µ)steps (see *Section 9.1.1 on page 41*).

6.6 Programmable speed profiles

The user can easily program a customized speed profile defining independently acceleration, deceleration, maximum and minimum speed values by the ACC, DEC, MAX_SPEED and MIN_SPEED registers respectively (see *Section 9.1.5 on page 42*, *Section 9.1.6 on page 43*, *Section 9.1.7 on page 43* and *Section 9.1.8 on page 43*).

When a command is sent to the device, the integrated logic generates the microstep frequency profile that performs a motor motion compliant to speed profile boundaries.

All acceleration parameters are expressed in step/tick^2 and all speed parameters are expressed in step/tick; the unit of measurement does not depend on the selected step mode. Acceleration and deceleration parameters range from 2^{-40} to $(2^{12} - 2) \cdot 2^{-40}$ step/tick^2 (equivalent to 14.55 to 59590 step/s^2).

The minimum speed parameter ranges from 0 to $(2^{12}-1) \cdot 2^{-24}$ step/tick (equivalent to 0 to 976.3 step/s).

The maximum speed parameter ranges from 2^{-18} to $(2^{10} - 1) \cdot 2^{-18}$ step/tick (equivalent to 15.25 to 15610 step/s).

6.7 Motor control commands

The L6470 device can accept different types of commands:

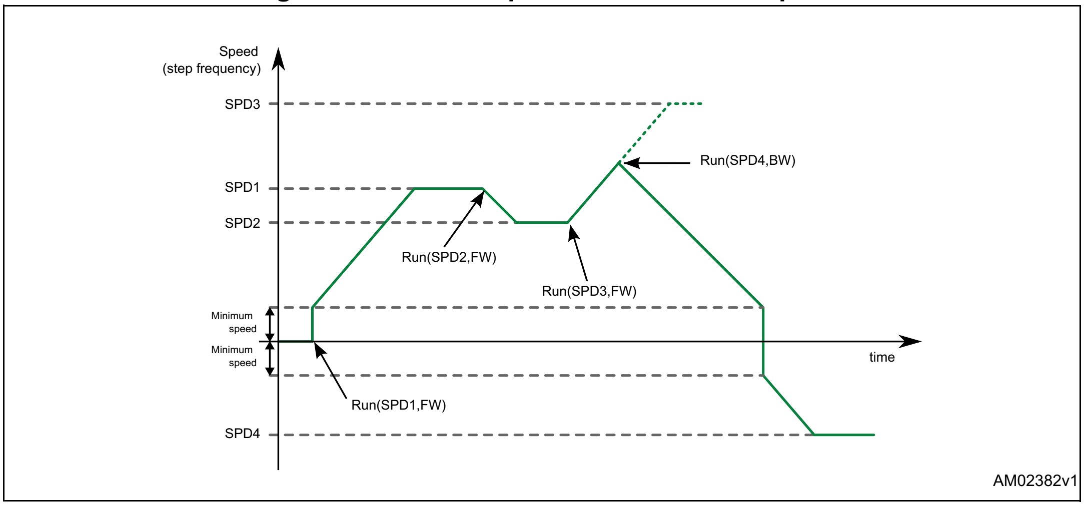
- constant speed commands (Run, GoUntil, ReleaseSW)
- absolute positioning commands (GoTo, GoTo_DIR, GoHome, GoMark)
- motion commands (Move)
- stop commands (SoftStop, HardStop, SoftHiz, HardHiz).

For detailed command descriptions refer to *Section 9.2 on page 56*.

6.7.1 Constant speed commands

A constant speed command produces a motion in order to reach and maintain a user-defined target speed starting from the programmed minimum speed (set in the MIN_SPEED register) and with the programmed acceleration/deceleration value (set in the ACC and DEC registers). A new constant speed command can be requested anytime.

Figure 8. Constant speed command examples



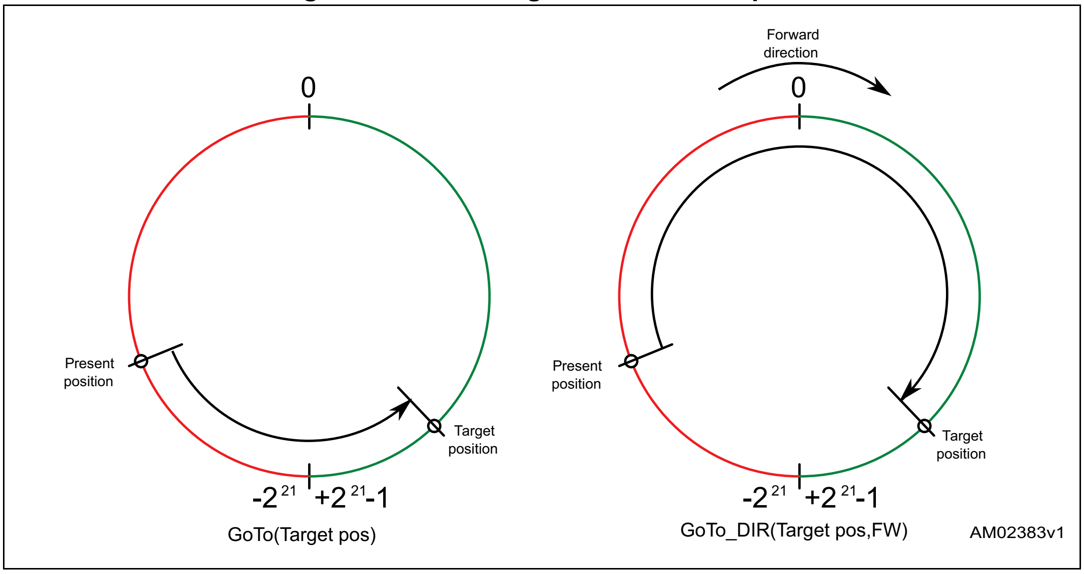
6.7.2 Positioning commands

An absolute positioning command produces a motion in order to reach a user-defined position that is sent to the device together with the command. The position can be reached performing the minimum path (minimum physical distance) or forcing a direction (see *Figure 9*).

The performed motor motion is compliant to programmed speed profile boundaries (acceleration, deceleration, minimum and maximum speed).

Note that with some speed profiles or positioning commands, the deceleration phase can start before the maximum speed is reached.

Figure 9. Positioning command examples



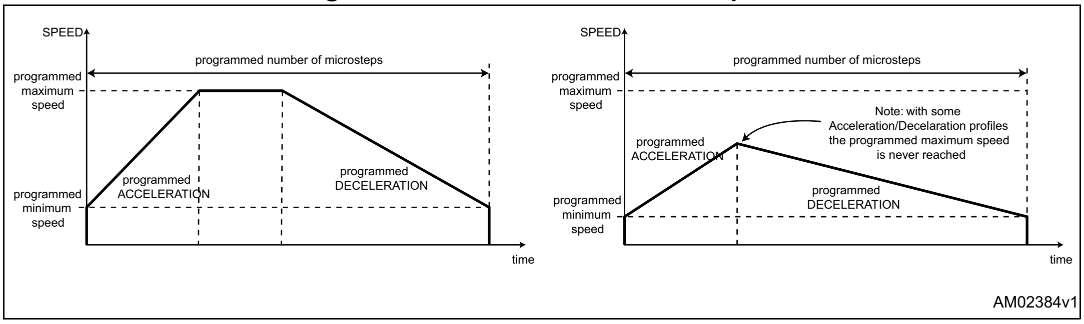
6.7.3 Motion commands

Motion commands produce a motion in order to perform a user-defined number of microsteps in a user-defined direction that are sent to the device together with the command (see *Figure 10*).

The performed motor motion is compliant to programmed speed profile boundaries (acceleration, deceleration, minimum and maximum speed).

Note that with some speed profiles or motion commands, the deceleration phase can start before the maximum speed is reached.

Figure 10. Motion command examples



6.7.4 Stop commands

A stop command forces the motor to stop. Stop commands can be sent anytime.

The SoftStop command causes the motor to decelerate with programmed deceleration value until the MIN_SPEED value is reached and then stops the motor keeping the rotor position (a holding torque is applied).

The HardStop command stops the motor instantly, ignoring deceleration constraints and keeping the rotor position (a holding torque is applied).