MLX90401

Brushless DC Motor Controller

Features and Benefits

- 12V to 40V Operating Range
- On-Chip "Boost" Voltage Allows Use of All N-Channel Drivers
- Undervoltage Lockout
- On-Chip PWM Oscillator
- PWM Speed Control via Bottom Drivers
- Forward and Reverse Control
- BVDSS > 60V
- Selectable 60° or 120° Sensor Electrical Phasings

Applications

- Brushless DC Motor Control

Ordering Information

Part No.	Temperature Suffix	Package Code
MLX90401	E(-40°C to 85°C)	DF (24 Lead SOIC)

1. Pin connections

1	Supply Voltage	Cap Boost "A"	24
2	V_{REF} Out	Gate Top "A"	23
3	Hall "A" Input	Feedback "A"	22
4	Hall "B" Input	Cap Boost "B"	21
5	Hall "C" Input	Gate Top "B"	20
6	Fwd/Rev Input	Feedback "B"	19
7	Speed Adjust Input / Disable	Cap Boost "C"	18
8	Oscillator R/C	Gate Top "C"	17
9	/Brake Input	Feedback "C"	16
10	Analog Ground	Gate Bottom "A"	15
11	60°/120° Select Input	Gate Bottom "B"	14
12	Power Ground	Gate Bottom "C"	13

2. Description

The MLX90401 is a three-phase brushless DC motor controller, designed to meet the needs of high volume, low cost motors with 60° or 120° electrical sensor phasings which do not require the expensive options needed for servo or other closed loop applications.

The use of CMOS technology offers dense logic as well as high voltage (60V) driver capabilities. The use of discrete low cost N-channel power FETs reduces overall system cost and the device provides all of the logic necessary to interface Hall-effect position sensors to N-channel power FETs. Upper N-channel power FETs require a gate drive in excess of the supply voltage V+, and with the device's on-chip "boost" voltage, the use of all N-Channel power FETs is allowed.

Control inputs are provided for motor speed, forward or reverse direction, disable, and braking. Also 60° or 120° electrical sensor phasings can be set externally.

The device is offered in a 24 Lead "Wide-Body" SOIC package (DF).

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3. MLX90401 Electrical Specifications

DC Operating Parameters T_A = -40°C to 85°C, V_{DD} = 15V (unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Units
Supply Voltage	V_{DD}	Operating	8	24	44	V
Supply Current	I_{DD}	Operating		20	35	mA
Voltage Reference, Undervoltage, Oscillator						
Output Voltage	V_{REF}		8	12	15	V
Output Current	I_{REF}				10	mA
Undervoltage	V_{UV}	Operating		8		V
Oscillator Frequency	f_{OSC}	Operating, R_{OSC}=10k, C_{OSC}=5kΩ	22	25	28	kHz
Frequency Drift	df_{OSC}	Operating		TBD		
Logic Inputs Sensor (Pins 3,4,5), Fwd/Rev (pin 6), /Brake and 60°/120° Select (Pins 9,11) Inputs						
High State	V_{IH}		3.5			V
Low State	V_{IL}				1.5	V
High State Input Current	I_{IH}				1.0	mA
Low State Input Current	I_{IL}				2.0	mA
Disable Input (Pin 7)						
High State	V_{IH}		4.2			V
Low State	V_{IL}				3.5	V
High State Input Current	I_{IH}				1.0	mA
Low State Input Current	I_{IL}				1.0	mA
Debouncing						
Debounce Time (60°/120° Select, Fwd/Rev)[1]	t_{delay1}		18	25	35	ms
Debounce Time (/Brake)[1]	t_{delay2}		2	3.2	4.4	ms
Delay after Start-up[2]	t_{delay3}		18.6	25.6	35.6	ms
Charge Pumps						
Output Current	I_{OCP}				100	µA
Drivers						
Top Output On-Resistance	$R_{ON,T}$	I_{LOAD} = 50mA			50	Ω
Bottom Output On-Resistance	$R_{ON,B}$	I_{LOAD} = 50mA			50	Ω
Rise Time	t_r				150	ns

Fall Time	t_f					150	ns
Turn-on Propagation Delay	$t_{d,on}$					300	ns
Turn-off Propagation Delay	$t_{d,off}$					300	ns
Top Drivers							
Leakage Current	I_{OFF}	$V_{OUT} = 60V$				-10	µA
Voltage Drop	V_{OL}	$I_{OUT} = 50mA$		1.3	1.6		V
Bottom Drivers							
Voltage Drop High State	V_{OH}	$I_{OUT} = 100mA$		1.3	1.6		V
Voltage Drop Low State	V_{OL}	$I_{OUT} = 100mA$		1.3	1.6		V

Note:

1) t_{delay1} and t_{delay2} depend on f_{osc} and timing of the signals to be debounced. 60°/120° Select and Fwd/Rev are debounced using a clock with a frequency of 256*f_{osc}. /Brake is debounced using a clock with a frequency of 32*f_{osc}. Debouncing takes between 2 and 3 clock cycles. Typical example for, say 60°/120° Select: 2.5*256*1/f_{osc} = 2.5*256*1/25kHz = 25.6 ms.

2) t_{delay3} depends on f_{osc}. Precautions are taken that t_{delay3} is *always* larger than t_{delay1}, so that there are only output signals when the chip is in the correct state.

4. Block Diagram
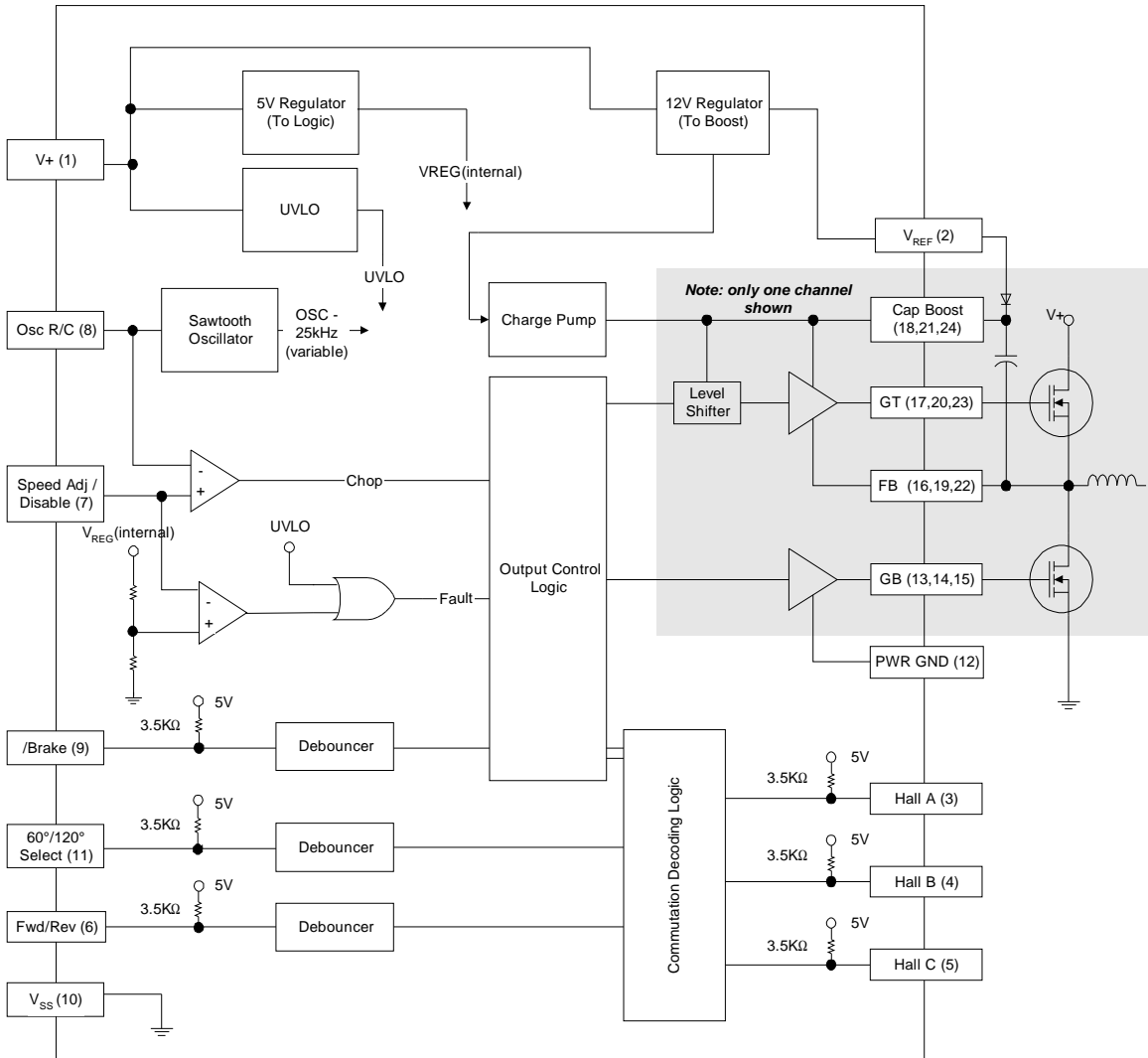
5. Pin function description

Pin	Symbol	Description
1	Supply voltage V+	External power supply voltage.
2	VREF Out	Regulated reference voltage (12V) derived from V+. Used to power external components and Hall-effect sensors, and for boost voltage.
3-5	Hall "A", "B" and "C" Inputs	Hall IC open collect inputs. Pull-up resistance of 3.3k to 5V.
6	Fwd/Rev Input	The Forward/Reverse Input is used to change the direction of motor rotation. A logic high state selects forward direction, a logic low state selects reverse direction. Pull-up resistance of 3.3k to 5V.
7	Speed Adjust Input/Disable	Potentiometer input - adjusts the PWM duty cycle setting current, allowing a manual speed adjustment. Disable input can be used in combination with any type of switch (thermal, Hall, …). A logic low on this pin selects the disable function.
8	Oscillator RC	The Oscillator frequency is set with the values selected for the timing components RRC and CRC.
9	/Brake Input	A logic high state at this input allows the motor to run, while a low state causes rapid deceleration. Pull-up resistance of 3.3k to 5V.
10	Analog ground	Ground pin for analog blocks.
11	60°/120° Select Input	A logic high state on this pin selects 60° sensor electrical phasing, a logic low state selects 120°. Pull-up resistance of 3.3k to 5V.
12	Power Ground	Ground pin for digital and output drivers.
13-15	Gate Bottom "A", "B" and "C"	Three push-pull drivers for direct drive of bottom power switch transistors.
16, 19, 22	Feedback "A", "B" and "C"	This pin is negative supply of the top drive circuitry. It is the connection for the negative side of the bootstrap capacitor, the top power FET Source, the bottom power FET Drain, and the Phase C output.
17, 20, 23	Gate Top "A", "B" and "C"	Three push-pull drivers for direct drive of top power switch transistors.
18, 22, 24	Cap Boost "A", "B" and "C"	This pin is the positive supply of the top drive circuitry. The boost capacitor is connected between this pin and Feedback.

6. General Description

The MLX90401 contains all of the functions for controlling three-phase brushless DC motors in open loop applications.

The MLX90401 provides commutation from Hall-effect sensors. The chip contains a rotor position decoder for proper commutation sequencing, a voltage reference that supplies power for the sensors, a pulse width modulator based on a frequency programmable sawtooth oscillator and three top and three bottom drivers. Using a bootstrap/charge pump combination, the MLX90401 also generates a boost voltage to drive the top power FET. In this way the application only uses N-channel power FETS, to reduce overall system cost.

The MLX90401 supports following control functions: speed control, forward or reverse rotation, braking and disable.

Also an undervoltage lockout is provided.

The MLX90401 can be configured for motors with 60° or 120° sensor electrical phasings, using a select pin.

6.1. Commutation decoding and output control logic

An internal digital circuit converts the signals from the Hall-effect position sensors into the proper sequencing of top and bottom drive outputs.

60° or 120° sensor electrical phasing can be selected by an external pin (60°/120° Select, pin 11).

The Forward/Reverse input (pin 6) is used to change the direction of motor rotation.

If the /Brake input (pin 9) is pulled low, bottom drivers are turned on, while top drivers are turned off, thus braking the motor.

These six inputs all have internal pull-up resistors (3.3kΩ to 5V).

Inputs 60°/120° Select, Fwd/Rev and /Brake are debounced to make sure that the device doesn't enter the wrong state, due to noise and/or spikes.

The fact that these signals are debounced, also means that there is a delay in these signals. Whenever one of the external signals that are debounced is changed, it takes time till the outputs change accordingly (ca. 25ms for the 60°/120° Select and Fwd/Rev inputs, ca. 3ms for /Brake).

After start-up, the outputs are disabled for a given time, in order to provide for the time necessary for the debouncing circuits on 60°/120° Select and Fwd/Rev to settle and output the correct signal.

(/Brake is debounced with a shorter time so settles a lot sooner.)

6.2. Oscillator

The frequency of the internal ramp oscillator is set by the values selected for timing components R_T and C_T. Capacitor C_T is charged from the Reference Output (Pin 2) through Resistor R_T and discharged by an internal discharge transistor. The ratio of the ramp peak and valley voltages, referred to the Reference Output voltage are typically 0.65 and 0.3V respectively. To provide a good compromise between audible noise and output switching efficiency, an oscillator frequency in the range of 20 to 30 kHz is recommended.

6.3. Disable

Pin 7, Speed Adjust Input/Disable, is to be connected to an external potentiometer, used to set motor speed.

The input can also be used as a Disable input, turning off all output drivers. This Disable input can be used in many ways. A thermal switch could be used to provide thermal protection. Or a Hall switch could be used to provide protection against overcurrent, etc.

Disable has a higher priority than /Brake. If for instance Disable is active, braking will not have any effect. If /Brake is active at the moment that Disable is made active, all braking will be stopped.

6.4. Pulse width modulation

The use of pulse width modulation provides an energy efficient method of controlling the motor speed by varying the average voltage applied to each stator winding during the commutation sequence. As C_T discharges, the oscillator allows conduction of the top and bottom drive outputs. The PWM comparator terminates the bottom drive output conduction when the positive-going ramp of C_T becomes greater than the Speed Adjust Input. In order to minimize dissipation in the internal diodes of the external top switch transistors, due to free-wheeling currents, the PWM acts also on the top FET, by turning it on when the corresponding bottom FET is off. The pulse width modulator timing diagram is shown below.

(Braking the motor does not depend on the PWM setting. It is always done at 100%.)

PWM Timing Diagram
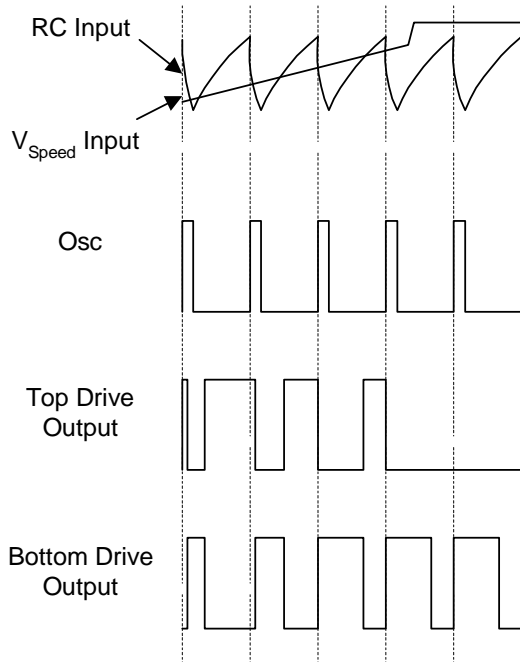
Note
Top and Bottom Drive Output Diagrams assume commutation logic gives 1 for bottom switch and 0 for top switch. In case the commutation logic gives 0 for bottom Switch and 1 for top switch, the PWM does not act on them.

6.5. Drive outputs

The bottom drivers consist of a push-pull driver between the 12V reference voltage and ground. The top drivers use an improved push-pull architecture to guarantee proper drive of the top FETs.

Because the top driver utilizes a bootstrap/charge pump combination, use of only N-channel power FETs for the three-phase bridge is possible. This leads to a reduced system cost.
Internal charge pumps precharge the boost capacitors ensuring full drive of upper power FETs at start-up.
During normal operation, boost is maintained with an external diode and capacitor. The charge pumps compensate for potential leakage currents, in order to ensure that the upper power FETs are driven properly at all time.

6.6. Undervoltage lockout

Should the voltage level on V_{DD} drop below 7V, all gate drives will be turned off until the undervoltage condition is gone. This to prevent improper drive of the power FETs.

7. Logic table

Following logic table shows the output state in function of the inputs. It summarizes the different functions of the MLX90401

Motor position	Inputs						Fwd/ Rev	/Brake	Outputs								
	Sensor Electrical Phasing								Top Drive			Bottom Drive			Motor phases		
	60°			120°													
	SA	SB	SC	SA	SB	SC			TA	TB	TC	BA	BB	BC	PA	PB	PC
0°	0	0	0	1	0	1	1	1	1	0	0	0	1	0	^	v	-
60°	1	0	0	1	0	0	1	1	1	0	0	0	0	1	^	-	v
120°	1	1	0	1	1	0	1	1	0	1	0	0	0	1	-	^	v
180°	1	1	1	0	1	0	1	1	0	1	0	1	0	0	v	^	-
240°	0	1	1	0	1	1	1	1	0	0	1	1	0	0	v	-	^
300°	0	0	1	0	0	1	1	1	0	0	1	0	1	0	-	v	^
0°	0	0	0	1	0	1	0	1	0	1	0	1	0	0	v	^	-
300°	0	0	1	0	0	1	0	1	0	1	0	0	0	1	-	^	v
240°	0	1	1	0	1	1	0	1	1	0	0	0	0	1	^	-	v
180°	1	1	1	0	1	0	0	1	1	0	0	0	1	0	^	v	-
120°	1	1	0	1	1	0	0	1	0	0	1	0	1	0	-	v	^
60°	1	0	0	1	0	0	0	1	0	0	1	1	0	0	v	-	^
	x	x	x	x	x	x	x	0	0	0	0	1	1	1	v	v	v

8. Absolute Maximum Ratings

Supply Voltage, V_{DD} (operating)	-0.3 to 45V
Output Voltage on Pins Gate & Boost	60V
Voltage on Pins 17,18,20,21,23,24	-0.3 to 60V
Power Dissipation, P_D	500mW
Operating Temperature Range, T_A	-40 to 85°C
Storage Temperature Range, T_S	-40 to 125°C

9. Typical Application
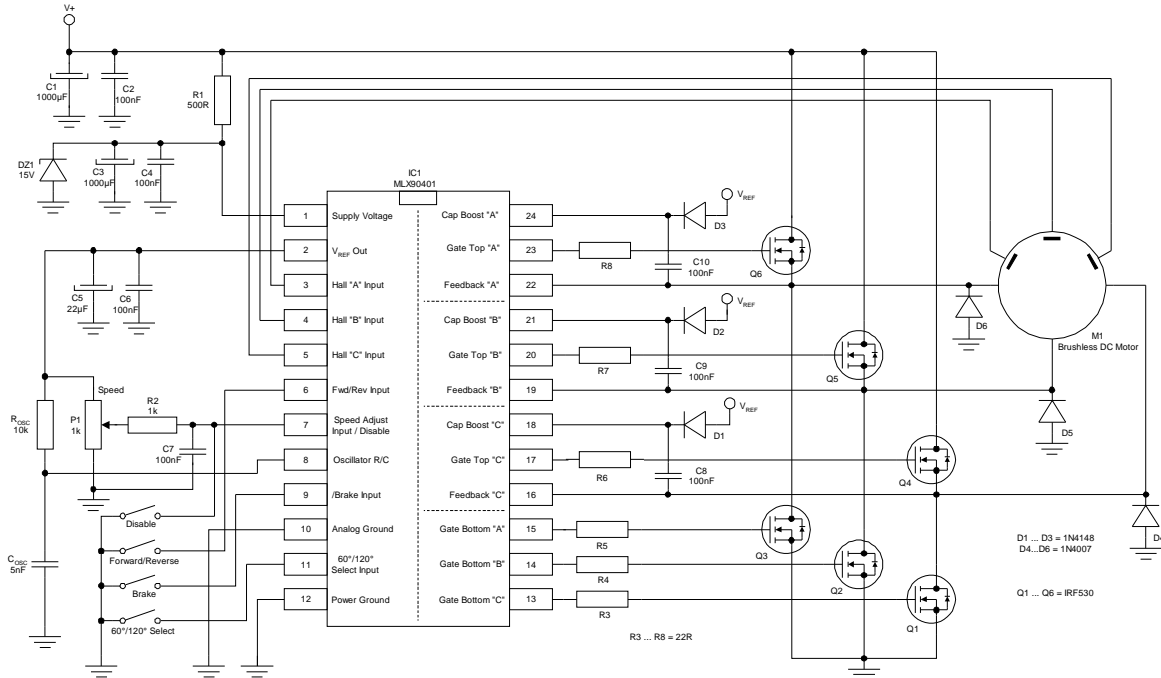
10. Application Comments

10.1. Demo board

A Demo board was designed to facilitate the evaluation of the MLX90401 and the design of new applications. A description of the Demo board can be found on the Melexis website at www.melexis.com. The Demo board can be ordered online.

11. Reliability Information

Melexis devices are classified and qualified regarding suitability for infrared, vapor phase and wave soldering with usual (63/37 SnPb-) solder (melting point at 183degC).
The following test methods are applied:

IPC/JEDEC J-STD-020A (issue April 1999)
Moisture/Reflow Sensitivity Classification For Nonhermetic Solid State Surface Mount Devices
CECC00802 (issue 1994)
Standard Method For The Specification of Surface Mounting Components (SMDs) of Assessed Quality
MIL 883 Method 2003 / JEDEC-STD-22 Test Method B102
Solderability

For all soldering technologies deviating from above mentioned standard conditions (regarding peak temperature, temperature gradient, temperature profile etc) additional classification and qualification tests have to be agreed upon with Melexis.

The application of Wave Soldering for SMD's is allowed only after consulting Melexis regarding assurance of adhesive strength between device and board.

For more information on manufacturability/solderability see quality page at our website:
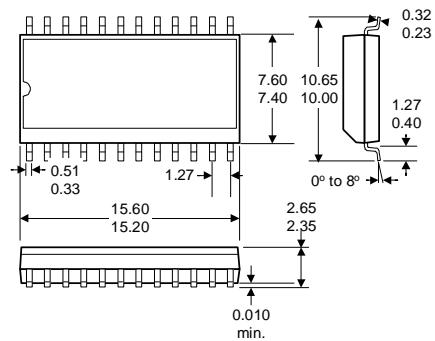http://www.melexis.com/

12. ESD Precautions

Electronic semiconductor products are sensitive to Electro Static Discharge (ESD).
Always observe Electro Static Discharge control procedures whenever handling semiconductor products.

13. Package Information

DF - 24 Lead Wide Body SOIC

All dimensions in millimeters

14. Disclaimer

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