

## 3-Phase Brushless DC Sinusoidal Sensorless Fan Motor Driver

#### **Features**

- Position Sensorless BLDC Drivers (No Hall Sensor Required)
- 180° Sinusoidal Drive, for High Efficiency and Low Acoustic Noise
- Support 2V to 14V Power Supplies
- · Speed Control Through PAM and/or PWM
- Built-in Frequency Generator (FG Output Signal)
- Built-in Lock-up Protection and Automatic Recovery Circuit (External Capacitor not Necessary)
- Built-in Over Current Limitation and Short Circuit Protection
- · Built-in Thermal Shutdown Protection
- Thermally Enhanced SOP-8 Package for MTD6501C; MSOP-10L Package for MTD6501D
- · No External Tuning Required
- Boost Mode (Optional BEMF Pre-amplification in MTD6501D)

**Note:** The MTD6501C/MTD6501D devices are formerly products of Advanced Silicon.

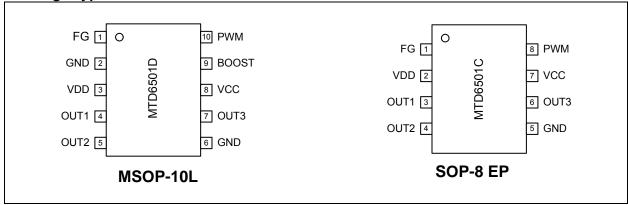
#### Description

The MTD6501C/MTD6501D devices are 3-phase full-wave drivers for brushless sensorless DC motors. They feature 180° sinusoidal drive, high torque output, and silent drive. Due to their adaptive features and wide power-supply range capabilities (2V to 14V) they are intended to cover a wide range of motor characteristics, while requiring no external tuning from the user. Speed control can be achieved through either power supply modulation or pulse-width modulation (using the PWM digital input pin).

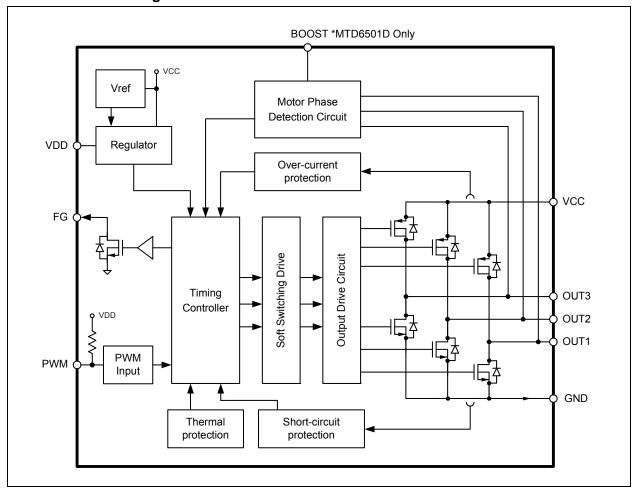
Due to the compact packaging and minimum bill-of-material (power transistors incorporated, no Hall sensor, no external tuning), they are best suited for low-cost fan applications requiring high efficiency and low acoustic noise, such as CPU cooling fans. Frequency generator output enables precision speed control in closed-loop applications. The MTD6501C/MTD6501D drivers include a lock-up protection mode, which turns off the output current when the motor is under lock condition, and an automatic recovery that enables the fan to run when the lock condition is removed. Motor overcurrent limitation, short-circuit protection, and thermal-shutdown protection are also included.

The MTD6501C is available in a compact thermally-enhanced SOP-8 package, while the MTD6501D is available in the MSOP-10L package.

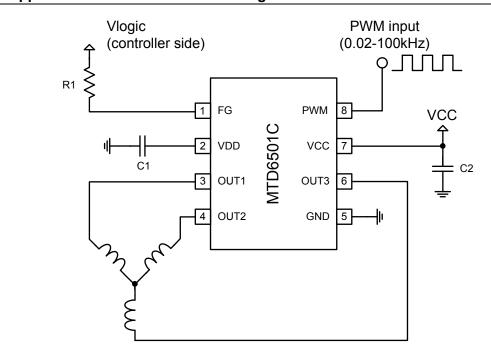
### **Package Types**



## **Functional Block Diagram**



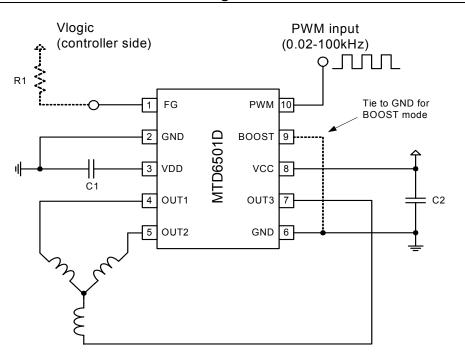
## Typical Application – Fan Motor Driver Using the MTD6501C



## **Recommended External Components for Typical Application**

Element	Type/Value	Comment
C1	≥1 µF	Connect as close as possible to IC input pins
C2	<u>≥</u> 1 µF	Connect as close as possible to IC input pins
R1	<u>≥</u> 10 kΩ	Connect to Vlogic on controller side

## Typical Application - Fan Motor Driver Using the MTD6501D



### **Recommended External Components for Typical Application**

Element	Type/Value	Comment
C1	<u>≥</u> 1 µF	Connect as close as possible to IC input pins
C2	<u>≥</u> 1 µF	Connect as close as possible to IC input pins
R1	<u>≥</u> 10 kΩ	Connect to Vlogic on controller side

# 1.0 ELECTRICAL CHARACTERISTICS

### **Absolute Maximum Ratings†**

† Notice: Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

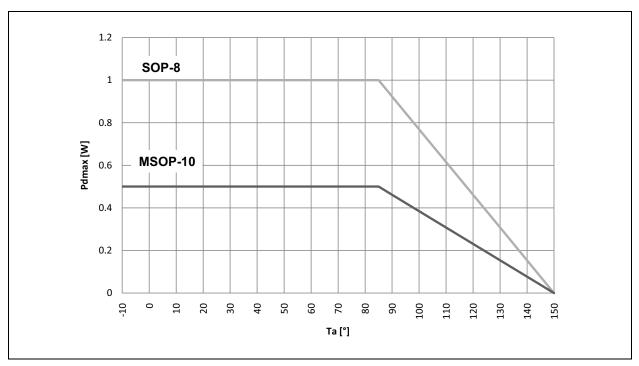
- **Note 1:** Reference PCB, according to JEDEC standard EIA/JESD 51-9.
  - **2:** De-rating applies for ambient temperatures outside the specified operating range (refer to Figure 1-1).
  - **3:** OUT1, OUT2, OUT3 (Continuous, 100% duty cycle).
  - 4: MTD6501C
  - 5: MTD6501D

## **ELECTRICAL CHARACTERISTICS**

Electrical Specifications: Unless otherwise specified, all limits are established for V <sub>CC</sub> = 5.0V, T <sub>A</sub> = 25°C							
Parameters	Sym	Min	Тур	Max	Units	Conditions	
Power Supply Voltage	V <sub>CC</sub>	2	_	14	V		
Power Supply Current	I <sub>VCC</sub>	_	10 5	_	mA mA	Rotation Mode Lock-Protection Mode	
OUTx High Resistance	R <sub>ON(H)</sub>	_	0.75	1	Ω	$I_{OUT} = 0.5A$ , $V_{CC} = 3.3V$ to 14V	
OUTx Low Resistance	R <sub>ON(L)</sub>	_	0.75	1	Ω	$I_{OUT} = -0.5A$ , $V_{CC} = 3.3V$ to 14V	
OUTx Total Resistance	R <sub>ON(H+L)</sub>	_	1.5	2	Ω	$I_{OUT} = 0.5A$ , $V_{CC} = 3.3V$ to 14V	
V <sub>DD</sub> Output Voltage	$V_{DD}$	_	3 V <sub>CC</sub> – 0.2	_	V V	V <sub>CC</sub> = 3.3V to 14V V <sub>CC</sub> < 3.3V	
PWM Input Frequency	f <sub>PWM</sub>	0.02	_	100	kHz		
PWM Input H Level	V <sub>PWM_H</sub>	0.8*V <sub>DD</sub>	_	3.6	V		
PWM Input L Level	$V_{PWM\_L}$	0	_	0.2*V <sub>DD</sub>	V	_	
PWM Internal Pull-Up Current	I <sub>PWM_L</sub>	17 8	34 17	_	μA μA	PWM = GND, $V_{CC}$ = 3.3V to 14V PWM = GND, $V_{CC}$ < 3.3V	
FG Output Pin Low Level Voltage	V <sub>OL_FG</sub>	_	_	0.25	V	I <sub>FG</sub> = -1 mA	
FG Output Pin Leakage Current	I <sub>LH_FG</sub>	_	_	10	μA	V <sub>FG</sub> = 14V	
Lock Protection Operating Time	T <sub>RUN</sub>	ı	0.5	_	S	_	
Lock Protection Waiting Time	T <sub>WAIT</sub>	4.5	5	5.5	S	_	
Thermal Shutdown	T <sub>SD</sub>		170	_	°C		
Thermal Shutdown Hysteresis	T <sub>SD_HYS</sub>	_	25	_	°C	_	

## **TEMPERATURE SPECIFICATIONS**

Electrical Specifications: Unless otherwise specified, all limits are established for V <sub>CC</sub> = 5.0V, T <sub>A</sub> = 25°C						
Parameters	Sym	Min	Тур	Max	Units	Conditions
Temperature Ranges						
Operating Temperature	T <sub>OPR</sub>	-10	_	+85	°C	MTD6501C
Operating Temperature	T <sub>OPR</sub>	-30	_	+95	°C	MTD6501D
Storage Temperature Range	T <sub>STG</sub>	-55	_	+150	°C	



**FIGURE 1-1:** Allowable Power Dissipation ( $P_{D\_MAX}$ ) as a Function of Ambient Temperature ( $T_A$ )

## 2.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 2-1.

TABLE 2-1: MTD6501C/MTD6501D PIN FUNCTION TABLE

Pin Number: MTD6501C	Pin Number: MTD6501D	Туре	Name	Function
7	8	Р	V <sub>CC</sub>	Positive voltage supply for motor driver
5	2, 6	Р	GND	Negative voltage supply (ground)
3	4	0	OUT1	Single phase coil output pin
4	5	0	OUT2	Single phase coil output pin
6	7	0	OUT3	Single phase coil output pin
8	10	I	PWM	PWM input signal for speed control
1	1	0	FG	Motor speed indication output (MTD6501C: FG)
2	3	Р	$V_{DD}$	Internal regulator output (for decoupling only)
N/A	9	I	BOOST	Boost mode selection:
				Pin floating for Normal mode
				Pin tied to GND for Boost mode

**Legend:** I = Input; O = Output; P = Power

#### 3.0 FUNCTIONAL DESCRIPTION

The MTD6501C/MTD6501D devices generate a full-wave signal to drive a 3-phase sensorless BLDC motor. High efficiency and low-power consumption are achieved due to DMOS transistors and synchronous rectification drive type. The current carrying order of the outputs is as follows: OUT1 -> OUT2 -> OUT3.

#### 3.1 Speed Control

The rotational speed of the motor can be controlled either through the PWM digital input signal or by acting directly on the power supply ( $V_{CC}$ ). When the PWM signal is "High" (or left open) the motor rotates at full speed. When the PWM signal is "Low" the motor is stopped (and the IC outputs are set to high-impedance). By changing the PWM duty cycle, the speed can be adjusted. Notice that the PWM frequency has no special meaning for the motor speed and is asynchronous with the activation of the output transistors. Thus the user has maximum freedom to choose the PWM system frequency within a wide range (from 20 Hz to 100 kHz), while the output transistor activation always occurs at a fixed rate (20 kHz, typ.), which is outside of the range of audible frequencies.

### 3.2 Frequency Generator Function

The Frequency Generator output (FG) is a "Hall-sensor equivalent" digital output, giving information to an external controller about the speed and phase of the motor. The FG pin is an open collector output, connecting to a logical voltage level through an external pull-up resistor. When a lock (or out-of-sync) situation is detected by the driver, this output is set to high-impedance until the motor is restarted. Leave the pin open when not used.

# 3.3 Lockup Protection and Automatic Restart

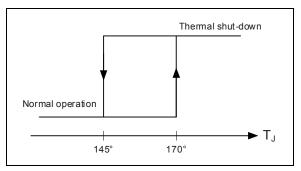
If the motor is stopped (blocked) or if it loses synchronization with the driver, a lock-up protection circuit detects this situation and disables the driver (by setting its outputs to high-impedance) in order to prevent the motor coil from burnout. After a "waiting time" ( $T_{WAIT}$ ), the lock-up protection is released and normal operation resumes for a given time ( $T_{RUN}$ ). In case the motor is still blocked, a new period of waiting time is started.  $T_{WAIT}$  and  $T_{RUN}$  timings are fixed internally, so that no external capacitor is needed.

## 3.4 Overcurrent Protection and Short Circuit Detection

The motor peak current is limited by the driver to a fixed value (defined internally), thus limiting the maximum power dissipation in the coils. The detection of a short-circuit situation immediately sets the driver outputs to high-impedance, in order to avoid permanent damage to the IC.

#### 3.5 Thermal Shutdown

The MTD6501C/MTD6501D have a thermal protection function which detects when the die temperature exceeds  $T_J = 170\,^{\circ}\text{C}$ . When this temperature is reached, the circuit enters the thermal shutdown mode and the outputs OUT1, OUT2 and OUT3 are disabled (high-impedance), avoiding IC destruction and allowing the circuit to cool down. Once the junction temperature  $(T_J)$  has dropped below 145 $^{\circ}\text{C}$ , the normal operation resumes (thermal detection circuit has 25 $^{\circ}\text{C}$  hysteresis function).



**FIGURE 3-1:** Thermal Protection Hysteresis

#### 3.6 Internal Voltage Regulator

 $V_{DD}$  voltage is generated internally and is used to supply internal logical blocks. The  $V_{DD}$  pin is used to connect an external decoupling capacitor (1µF or higher). Notice that this pin is for IC internal use and is not designed to supply DC current to external blocks.

### 3.7 Boost Mode (MTD6501D)

The Boost mode is an optional BEMF pre-amplification by a factor of 3. The interest of the Boost mode is to compensate for motors with a low coupling coefficient (= BEMF coefficient), thus allowing to cover an even wider range of motor characteristics. Notice that the Boost mode impacts the mechanical performance of the motor altogether. In Boost mode, the speed of the motor will adjust faster to variations of the control (V<sub>CC</sub> or PWM) and/or of the load, including at start-up. On the other hand, however, when the BEMF is amplified too much, the mechanical performance (in terms of vibration and acoustic noise) may start degrading. Thus, the Boost mode may be inappropriate, for motors that already have a good coupling coefficient. The optimum choice (between normal mode and Boost mode) depends both on the application requirements and on the motor characteristics.

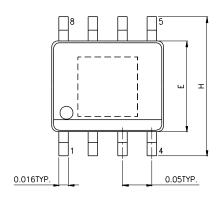
Refer to Table 3-1 for the usage of the "BOOST" pin #9: leaving this pin floating results the normal mode of operation, tying this pin to GND activates the Boost mode.

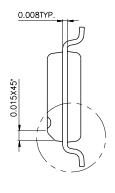
TABLE 3-1: POSSIBLE MODES OF OPERATION BASED ON THE BOOST PIN CONNECTION

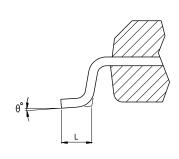
BOOST Pin	Mode of Operation
Floating	Normal
Tied to GND	Boost

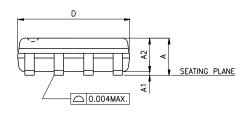
#### 4.0 **PACKAGE OUTLINES**

### **Thermally Enhanced SOP-8 Package**









-	0.0	90		
Ы	А	П	А	
				0.090
				0.0
				<b>—</b>
	Н		H	

SYMBOLS	MIN.	MAX.
Α	0.053	0.069
A1	0.000	0.006
A2	_	0.059
D	0.189	0.196
E	0.150	0.157
Н	0.228	0.244
L	0.016	0.050
θ°	0	8

UNIT: INCH

#### NOTES:

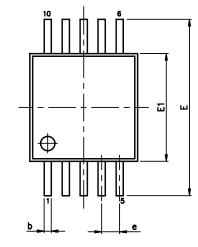
- 1.JEDEC OUTLINE: N/A

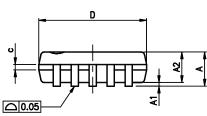
  2.DIMENSIONS "D" DOES NOT INCLUDE MOLD FLASH,
  PROTRUSIONS OR GATE BURRS.MOLD FLASH, PROTRUSIONS
  AND GATE BURRS SHALL NOT EXCEED .15mm (.006in)
- 3.DIMENSIONS "E" DOES NOT INCLUDE INTER-LEAD FLASH, OR PROTRUSIONS. INTER-LEAD FLASH AND PROTRUSIONS SHALL NOT EXCEED .25mm (.010in) PER SIDE.

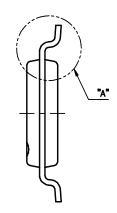
**SOP-8 Package Thermal Information** 

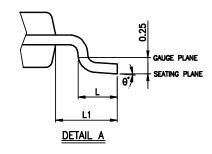
Symbol	Description	Conditions	Value	Unit
Theta_JA	Thermal Resistance Junction to Ambient	Reference PCB, according to JEDEC Standard EIA/JESD 51-9	65	°C/W
Theta_JC	Thermal Resistance Junction to Case		TBD	°C/W

### **MSOP-10L Package**









SYMBOLS	MIN.	NOM.	MAX.		
Α	ı	_	1.10		
A1	0.00	_	0.15		
A2	0.75	0.85	0.95		
b	0.17	_	0.27		
С	80.0	_	0.23		
D	3.00 BSC				
E	4.90 BSC				
E1		3.00 BSC			
е		0.50 BSC			
L	0.40	0.60	0.80		
L1	·	0.95 REF			
θ,	0	_	8		

UNIT : MM

#### NOTES:

- DIMENSION 'D' DOES NOT INCLUDE MOLD FLASH,
   PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS
   OR GATE BURRS SHALL NOT EXCEED 0.15 PER SIDE.
   DIMENSION 'E1' DOES NOT INCLUDE INTERLEAD FLASH OR
   PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL
- NOT EXCEED 0.25 PER SIDE.

  3. DIMENSION '0.22' DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 MM
  TOTAL IN EXCESS OF THE '0.22' DIMENSION AT MAXIMUM
  MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE
  LOWER RADIUS OF THE FOOT. MINIMUM SPAC BETWEEN
  PROTRUSION AND ADJACENT LEAD IS 0.07 MM.
  4. DIMENSIONS 'D' AND 'E1' TO BE DETERMINED AT DATUM
  PLANE 

  ...

#### **SOP-8 Package Thermal Information**

Symbol	Description	Conditions	Value	Unit
Theta_JA	Thermal Resistance Junction to Ambient	Reference PCB, according to JEDEC Standard EIA/JESD 51-9	120	°C/W
Theta_JC	Thermal Resistance Junction to Case		45	°C/W

NOTES:

## **APPENDIX A: REVISION HISTORY**

## **Revision A (September 2010)**

• Original Release of this Document.

NOTES:

#### Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our
  knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data
  Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

#### **Trademarks**

The Microchip name and logo, the Microchip logo, dsPIC, Keeloq, Keeloq logo, MPLAB, PIC, PICmicro, PICSTART, PIC<sup>32</sup> logo, rfPIC and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, Hampshire, HI-TECH C, Linear Active Thermistor, MXDEV, MXLAB, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, Application Maestro, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniscient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICkit, PICtail, REAL ICE, rfLAB, Select Mode, Total Endurance, TSHARC, UniWinDriver, WiperLock and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

All other trademarks mentioned herein are property of their respective companies.

© 2010, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

Printed on recycled paper.

ISBN: 978-1-60932-560-2

QUALITY MANAGEMENT SYSTEM

CERTIFIED BY DNV

ISO/TS 16949:2002

Microchip received ISO/TS-16949:2002 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.



## **Worldwide Sales and Service**

#### **AMERICAS**

**Corporate Office** 2355 West Chandler Blvd. Chandler, AZ 85224-6199

Tel: 480-792-7200 Fax: 480-792-7277 Technical Support:

http://support.microchip.com

Web Address: www.microchip.com

Atlanta

Duluth, GA Tel: 678-957-9614 Fax: 678-957-1455

**Boston** 

Westborough, MA Tel: 774-760-0087 Fax: 774-760-0088

Chicago Itasca, IL

Tel: 630-285-0071 Fax: 630-285-0075

Cleveland

Independence, OH Tel: 216-447-0464 Fax: 216-447-0643

**Dallas** 

Addison, TX Tel: 972-818-7423 Fax: 972-818-2924

Detroit

Farmington Hills, MI Tel: 248-538-2250 Fax: 248-538-2260

Kokomo

Kokomo, IN Tel: 765-864-8360 Fax: 765-864-8387

Los Angeles

Mission Viejo, CA Tel: 949-462-9523 Fax: 949-462-9608

Santa Clara

Santa Clara, CA Tel: 408-961-6444 Fax: 408-961-6445

**Toronto** 

Mississauga, Ontario, Canada

Tel: 905-673-0699 Fax: 905-673-6509

#### ASIA/PACIFIC

**Asia Pacific Office** 

Suites 3707-14, 37th Floor Tower 6, The Gateway Harbour City, Kowloon Hong Kong

Tel: 852-2401-1200 Fax: 852-2401-3431

Australia - Sydney

Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

China - Beijing

Tel: 86-10-8528-2100 Fax: 86-10-8528-2104

China - Chengdu

Tel: 86-28-8665-5511 Fax: 86-28-8665-7889

China - Chongging

Tel: 86-23-8980-9588 Fax: 86-23-8980-9500

China - Hong Kong SAR

Tel: 852-2401-1200 Fax: 852-2401-3431

China - Nanjing

Tel: 86-25-8473-2460 Fax: 86-25-8473-2470

China - Qingdao

Tel: 86-532-8502-7355 Fax: 86-532-8502-7205

China - Shanghai

Tel: 86-21-5407-5533 Fax: 86-21-5407-5066

China - Shenyang

Tel: 86-24-2334-2829 Fax: 86-24-2334-2393

China - Shenzhen

Tel: 86-755-8203-2660 Fax: 86-755-8203-1760

China - Wuhan

Tel: 86-27-5980-5300 Fax: 86-27-5980-5118

China - Xian

Tel: 86-29-8833-7252 Fax: 86-29-8833-7256

China - Xiamen

Tel: 86-592-2388138 Fax: 86-592-2388130

China - Zhuhai Tel: 86-756-3210040

Fax: 86-756-3210049

#### ASIA/PACIFIC

India - Bangalore

Tel: 91-80-3090-4444 Fax: 91-80-3090-4123

India - New Delhi

Tel: 91-11-4160-8631 Fax: 91-11-4160-8632

India - Pune

Tel: 91-20-2566-1512 Fax: 91-20-2566-1513

Japan - Yokohama

Tel: 81-45-471- 6166 Fax: 81-45-471-6122

Korea - Daegu

Tel: 82-53-744-4301 Fax: 82-53-744-4302

Korea - Seoul

Tel: 82-2-554-7200 Fax: 82-2-558-5932 or 82-2-558-5934

Malaysia - Kuala Lumpur

Tel: 60-3-6201-9857 Fax: 60-3-6201-9859

Malaysia - Penang

Tel: 60-4-227-8870 Fax: 60-4-227-4068

Philippines - Manila

Tel: 63-2-634-9065 Fax: 63-2-634-9069

Singapore

Tel: 65-6334-8870 Fax: 65-6334-8850

Taiwan - Hsin Chu

Tel: 886-3-6578-300 Fax: 886-3-6578-370

Taiwan - Kaohsiung Tel: 886-7-213-7830

Fax: 886-7-330-9305

Taiwan - Taipei

Tel: 886-2-2500-6610 Fax: 886-2-2508-0102

Thailand - Bangkok

Tel: 66-2-694-1351 Fax: 66-2-694-1350

#### **EUROPE**

Austria - Wels

Tel: 43-7242-2244-39 Fax: 43-7242-2244-393 Denmark - Copenhagen

Tel: 45-4450-2828

Fax: 45-4485-2829

France - Paris

Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany - Munich

Tel: 49-89-627-144-0 Fax: 49-89-627-144-44

Italy - Milan

Tel: 39-0331-742611 Fax: 39-0331-466781

Netherlands - Drunen

Tel: 31-416-690399 Fax: 31-416-690340

Spain - Madrid

Tel: 34-91-708-08-90 Fax: 34-91-708-08-91

UK - Wokingham Tel: 44-118-921-5869 Fax: 44-118-921-5820

08/04/10