

TO OUR VALUED CUSTOMERS

It is our intention to provide our valued customers with the best documentation possible to ensure successful use of your Microchip products. To this end, we will continue to improve our publications to better suit your needs. Our publications will be refined and enhanced as new volumes and updates are introduced.

If you have any questions or comments regarding this publication, please contact the Marketing Communications Department via E-mail at docerrors@microchip.com. We welcome your feedback.

Most Current Data Sheet

To obtain the most up-to-date version of this data sheet, please register at our Worldwide Web site at:

<http://www.microchip.com>

You can determine the version of a data sheet by examining its literature number found on the bottom outside corner of any page. The last character of the literature number is the version number, (e.g., DS30000000A is version A of document DS30000000).

Errata

An errata sheet, describing minor operational differences from the data sheet and recommended workarounds, may exist for current devices. As device/documentation issues become known to us, we will publish an errata sheet. The errata will specify the revision of silicon and revision of document to which it applies.

To determine if an errata sheet exists for a particular device, please check with one of the following:

- Microchip's Worldwide Web site; <http://www.microchip.com>
- Your local Microchip sales office (see last page)

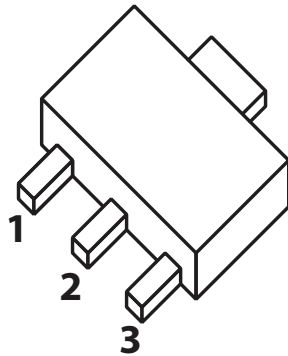
When contacting a sales office, please specify which device, revision of silicon and data sheet (include literature number) you are using.

Customer Notification System

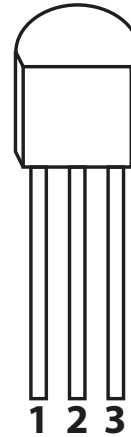
Register on our web site at www.microchip.com to receive the most current information on all of our products.

HV9921/HV9922/HV9923

PIN DIAGRAM



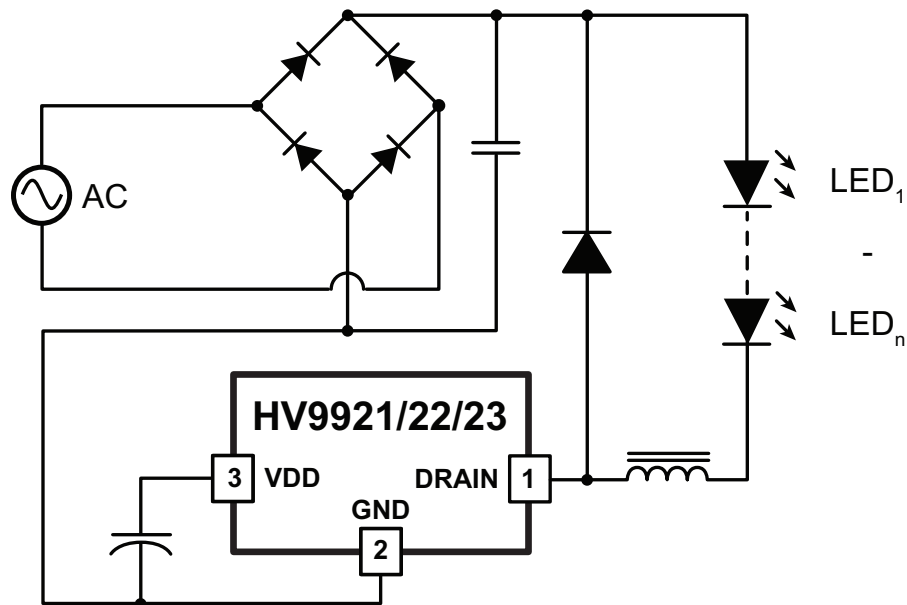
**TO-243AA
(SOT-89)**



TO-92

See [Table 2-1](#) for Pin information.

TYPICAL APPLICATION CIRCUIT



HV9921/HV9922/HV9923

1.0 ELECTRICAL CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS

Supply Voltage V_{DD} -0.3V to +10V
 Supply Current I_{DD} +5mA
 Operating Ambient temperature -40°C to +85°C
 Operating Junction Temperature -40°C to +125°C
 Storage temperature -65°C to +150°C
 Power dissipation @+25°C for TO-92 740 mW
 Power dissipation @+25°C for SOT-89 1600 mW*

* Mounted on FR4 board, 24mmx25mmx1.57mm

Note: Stresses above those listed under “Absolute 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.

1.1 ELECTRICAL SPECIFICATIONS

TABLE 1-1: ELECTRICAL CHARACTERISTICS¹

Symbol	Parameter	Notes	Min	Typ	Max	Units	Conditions
Regulator (V_{DD})							
V_{DD}	V_{DD} Regulator Output	-	-	7.5	-	V	
V_{DRAIN}	V_{DRAIN} Supply Voltage	-	20	-	-	V	
V_{UVLO}	V_{DD} Under-voltage Threshold	-	5.0	-	-	V	
ΔV_{UVLO}	V_{DD} Under-voltage Lockout Hysteresis	-	-	200	-	mV	
I_{DD}	Operating Supply Current	-	-	200	350	μ A	$V_{DD(EXT)} = 8.5V$, $V_{DRAIN} = 40V$
Output (DRAIN)							
V_{BR}	Breakdown Voltage	²	475	-	-	V	
R_{ON}	ON Resistance	-	-	-	210	Ω	$I_{DRAIN} = 20mA$ (HV9921) $I_{DRAIN} = 50mA$ (HV9922) $I_{DRAIN} = 30mA$ (HV9923)
C_{DRAIN}	Output Capacitance	³	-	1	5	pF	$V_{DRAIN} = 400V$
I_{SAT}	MOSFET Saturation Current	³	100	150	-	mA	
Current Sense Comparator							
I_{THL}	Threshold Current - HV9921	²	18.5	-	25.5	mA	
	Threshold Current - HV9922	²	49	-	63	mA	
	Threshold Current - HV9923	²	28.2	-	38.2	mA	
T_{BLANK}	Leading Edge Blanking Delay	^{2, 3}	200	300	400	ns	
$T_{ON(MIN)}$	Minimum ON Time	-	-	-	650	ns	
OFF-Time Generator							
T_{OFF}	OFF Time	-	8	10.5	13	μ S	

¹ Specifications are $T_A = 25^\circ C$, $V_{DRAIN} = 50V$ unless otherwise noted.

² Applies over the full operating ambient temperature range of $-40^\circ C < T_A < +125^\circ C$.

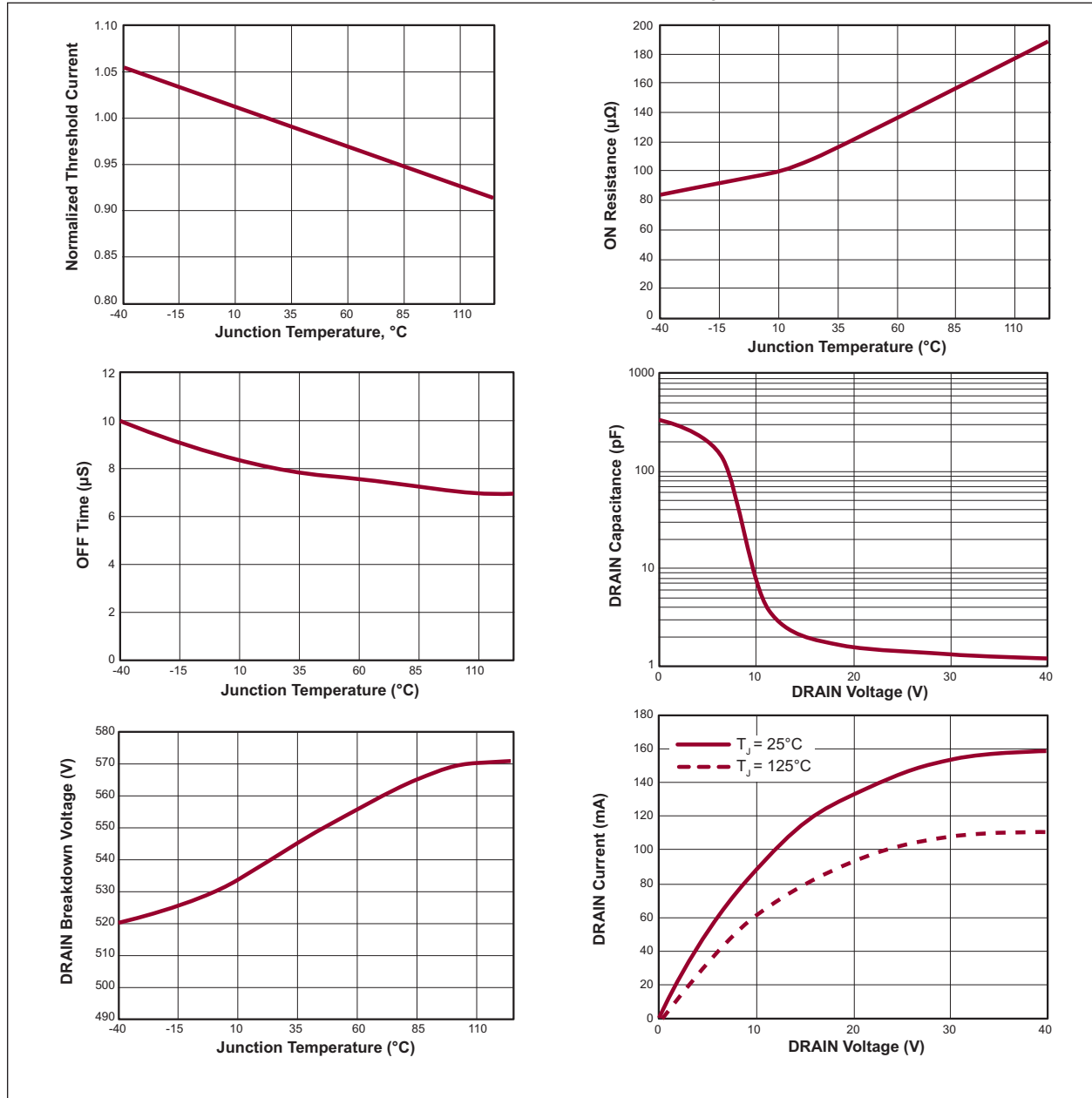
³ For design guidance only

HV9921/HV9922/HV9923

THERMAL RESISTANCE

Package	θ_{ja}
TO-92	132°C/W
TO-243AA(SOT-89)	133°C/W

FIGURE 1-1: TYPICAL PERFORMANCE CHARACTERISTICS ($T_J = 25^\circ\text{C}$ UNLESS OTHERWISE NOTED)



HV9921/HV9922/HV9923

2.0 PIN DESCRIPTION

See [Pin Diagram on page 3](#) for the figures.

TABLE 2-1: PIN DESCRIPTION

Pin #	Name	Description
1	Drain	Drain terminal of the output switching MOSFET and a linear regulator input
2	GND	Common connection for all circuits
3	VDD	Power Supply pin for all control circuits. By pass this pin with a 0.1 μ F low-impedance capacitor

3.0 FUNCTIONAL DESCRIPTION

The HV9921/22/23 are PWM peak current controllers designed to control a buck converter topology in continuous conduction mode (CCM). The output current is internally preset at 20mA for HV9921, 50mA for HV992, and 30mA for HV9923.

When the input voltage of 20 to 400V appears at the DRAIN pin, the internal high-voltage linear regulator seeks to maintain a voltage of 7.5VDC at the VDD pin. Until this voltage exceeds the internally programmed under-voltage threshold, the output switching MOSFET is non-conductive. When the threshold is exceeded, the MOSFET turns on. The input current begins to flow into the DRAIN pin. Hysteresis is provided in the under-voltage comparator to prevent oscillation.

When the input current exceeds the internal preset level, a current sense comparator resets an RS flip-flop, and the MOSFET turns off. At the same time, a one-shot circuit is activated that determines the duration of the off-state (10.5 μ s typical). As soon as this time is over, the flip-flop sets again. The new switching cycle begins.

A “blanking” delay of 300ns is provided that prevents false triggering of the current sense comparator due to the leading edge spike caused by circuit parasitics.

4.0 APPLICATION INFORMATION

HV9921/22/23 are low-cost off-line buck converter ICs specifically designed for driving multi-LED strings. They can be operated from either universal AC line range of 85 to 264VAC, or 20 to 400VDC, and drive up to tens of high-brightness LEDs. All LEDs can be run in series, and the HV9921/22/23 regulate at constant current, yielding uniform illumination. HV9921/22/23 are compatible with triac dimmers. The output current is internally fixed at 20mA for HV9921, 50mA for HV9922, and 30mA for HV9923. These parts are available in space saving TO-92 and SOT-89 packages.

4.1 Selecting L1 and D1

There is a certain trade-off to be considered between optimal sizing of the output inductor L1 and the tolerated output current ripple. The required value of L1 is inversely proportional to the ripple current ΔI_O in it.

$$L1 = \frac{V_O \cdot T_{OFF}}{\Delta I_O}$$

V_O is the forward voltage of the LED string. T_{OFF} is the off-time of HV9921/22/23. The output current in the LED string (I_O) is calculated then as:

$$I_O = I_{TH} - \left(\frac{1}{2} \cdot \Delta I_O\right)$$

where I_{TH} is the current sense comparator threshold. The ripple current introduces a peak-to-average error in the output current setting that needs to be accounted for. Due to the constant off-time control technique used in HV9921/22/23, the ripple current is independent of the input AC or DC line voltage variation. Therefore, the output current will remain unaffected by the varying input voltage.

Adding a filter capacitor across the LED string can reduce the output current ripple even further, thus permitting a reduced value of L1. However, keep in mind that the peak-to-average current error is affected by the variation of T_{OFF} . Therefore, the initial output current accuracy might be sacrificed at large ripple current in L1.

Another important aspect of designing an LED driver with the HV9921/22/23 is related to certain parasitic elements of the circuit, including distributed coil capacitance of L1, junction capacitance and reverse recovery of the rectifier diode D1, capacitance of the printed circuit board traces C_{PCB} and output capacitance C_{DRAIN} of the controller itself. These parasitic elements affect the efficiency of the switching converter and could potentially cause false triggering of the current sense comparator if not properly managed. Minimizing these parasitics is essential for efficient and reliable operation of the HV9921/22/23.

Coil capacitance of inductors is typically provided in the manufacturer's data books either directly or in terms of the self-resonant frequency (SRF).

$$\text{SRF} = 1 / \left(2\pi \sqrt{L \cdot C_L} \right)$$

where L is the inductance value, and C_L is the coil capacitance.) Charging and discharging this capacitance every switching cycle causes high-current spikes in the LED string. Therefore, connecting a small capacitor C_O (~10nF) is recommended to bypass these spikes.

Using an ultra-fast rectifier diode for D1 is recommended to achieve high efficiency and reduce the risk of false triggering of the current sense comparator. Using diodes with shorter reverse recovery time, t_{rr} , and lower junction capacitance, C_J , achieves better performance. The reverse voltage rating, V_R , of the diode must be greater than the maximum input voltage of the LED lamp.

The total parasitic capacitance present at the DRAIN pin of the HV9921/22/23 can be calculated as:

$$C_P = C_{\text{DRAIN}} + C_{\text{PCB}} + C_L + C_J$$

When the switching MOSFET turns on, the capacitance C_P is discharged into the DRAIN pin of the IC. The discharge current is limited to about 150mA typically. However, it may become lower at increased junction temperature. The duration of the leading edge current spike can be estimated as:

$$T_{\text{SPIKE}} = \frac{V_{\text{IN}} \cdot C_P}{I_{\text{SAT}}} + t_{rr}$$

In order to avoid false triggering of the current sense comparator, C_P must be minimized in accordance with the following expression:

$$C_P < \frac{I_{\text{SAT}} \cdot (T_{\text{BLANK(MIN)}} - t_{rr})}{V_{\text{IN(MAX)}}}$$

where $T_{\text{BLANK(MIN)}}$ is the minimum blanking time of 200ns, and $V_{\text{IN(MAX)}}$ is the maximum instantaneous input voltage.

4.2 Estimating Power Loss

Discharging the parasitic capacitance C_P into the DRAIN pin of the HV9921/22/23 is responsible for the bulk of the switching power loss. It can be estimated using the following equation:

$$P_{\text{SWITCH}} = \left(\frac{V_{\text{IN}}^2 C_P}{2} + V_{\text{IN}} \cdot I_{\text{SAT}} \cdot t_{rr} \right) \cdot F_S$$

where F_S is the switching frequency, I_{SAT} is the saturated DRAIN current of the HV9921/22/23. The switching loss is the greatest at the maximum input voltage.

The switching frequency is given by the following equation.

$$F_S = \frac{V_{\text{IN}} - V_O}{V_{\text{IN}} \cdot T_{\text{OFF}}}$$

When the HV9921/22/23 LED driver is powered from the full-wave rectified AC input, the switching power loss can be estimated as:

$$P_{\text{SWITCH}} \approx \frac{1}{2 \cdot T_{\text{OFF}}} (V_{\text{AC}} \cdot C_P + 2 \cdot I_{\text{SAT}} \cdot t_{rr}) (V_{\text{AC}} - V_O)$$

V_{AC} is the input AC line voltage.

The switching power loss associated with turn-off transitions of the DRAIN pin can be disregarded. Due to the large amount of parasitic capacitance connected to this switching node, the turn-off transition occurs essentially at zero-voltage.

Conduction power loss in the HV9921/22/23 can be calculated as:

$$P_{\text{COND}} = D \cdot I_O^2 \cdot R_{\text{ON}} + I_{\text{DD}} \cdot V_{\text{IN}} \cdot (1 - D)$$

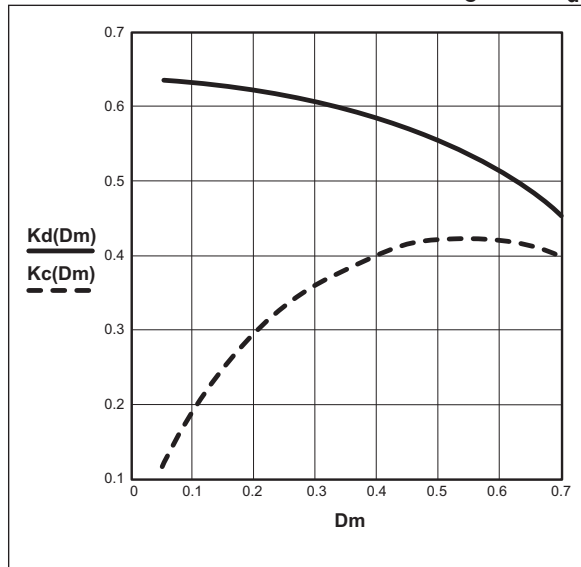
where $D = V_O/V_{\text{IN}}$ is the duty ratio, R_{ON} is the on-resistance, I_{DD} is the internal linear regulator current.

When the LED driver is powered from the full-wave rectified AC line input, the exact equation for calculating the conduction loss is more cumbersome. However, it can be estimated using the following equation:

$$P_{\text{COND}} = K_C \cdot I_O^2 \cdot R_{\text{ON}} + K_d \cdot I_{\text{DD}} \cdot V_{\text{AC}}$$

where V_{AC} is the input AC line voltage. The coefficients K_C and K_d can be determined from the minimum duty ratio of the HV9921/22/23.

FIGURE 4-1: CONDUCTION LOSS COEFFICIENTS K_C AND K_d



4.3 EMI Filter

As with all off-line converters, selecting an input filter is critical to obtaining good EMI. A switching side capacitor, albeit of small value, is necessary in order to ensure low impedance to the high frequency switching currents of the converter. As a rule of thumb, this capacitor should be approximately 0.1-0.2 $\mu\text{F}/\text{W}$ of LED output power. A recommended input filter is shown in [Figure 4-2](#) for the following design example.

4.3.1 DESIGN EXAMPLE

The following example designs a HV9921 LED lamp driver meeting the following specifications:

- **Input:** Universal AC, 85-265VAC
- **Output Current:** 20mA
- **Load:** String of 10 LED (LW541C by OSRAM VF = 4.1V max. each)

4.3.1.1 Step 1. Calculating L1.

The output voltage $V_O = 10 \times V_F \approx 41\text{V}$ (max.). Use this equation assuming a 30% peak-to-peak ripple.

$$L1 = \frac{41\text{V} \cdot 10.5\mu\text{s}}{0.3 \cdot 20\text{mA}} = 72\text{mH}$$

Select L1 68mH, I = 30mA. Typical SRF = 170KHz. Calculate the coil capacitance.

$$C_L = \frac{1}{L1 \cdot (2\pi \cdot \text{SRF})^2} = \frac{1}{68\text{mH} \cdot (2\pi \cdot 170\text{KHz})^2} = 13\text{pF}$$

4.3.1.2 Step 2. Selecting D1

Usually, the reverse recovery characteristics of ultra-fast rectifiers at $I_F = 20 \sim 50\text{mA}$ are not provided in the manufacturer's data books. The designer may want to experiment with different diodes to achieve the best result.

Select D1 MUR160 with $V_R = 600\text{V}$, $t_{rr} \approx 20\text{ns}$ ($I_F = 20\text{mA}$, $I_{RR} = 100\text{mA}$) and $C_J \approx 8\text{pF}$ ($V_F > 50\text{V}$).

4.3.1.3 Step 3. Calculating total parasitic capacitance

$$C_p = 5\text{pF} + 5\text{pF} + 13\text{pF} + 8\text{pF} = 31\text{pF}$$

4.3.1.4 Step 4. Calculating the leading edge spike duration

$$T_{\text{SPIKE}} = \frac{264\text{V} \cdot \sqrt{2} \cdot 31\text{pF}}{100\text{mA}} + 20\text{ns} \approx 136\text{ns} < T_{\text{BLANK(MIN)}}$$

4.3.1.5 Step 5. Estimating power dissipation in HV9921 at 265VAC

Switching power loss:

$$P_{\text{SWITCH}} \approx \frac{1}{2 \cdot 10.5\mu\text{s}} (264\text{V} \cdot 31\text{pF} + 2 \cdot 100\text{mA} \cdot 20\text{ns}) \cdot (264\text{V} - 41\text{V}) \approx 131\text{mW}$$

Minimum duty ratio:

$$D_M = \frac{41\text{V}}{265\text{V} \cdot \sqrt{2}} \approx 0.11$$

Conduction power loss:

$$P_{\text{COND}} = 0.25 \cdot (20\text{mA})^2 \cdot 210\Omega + 0.63 \cdot 200\mu\text{A} \cdot 264\text{V} \approx 55\text{mW}$$

Total power dissipation in HV9921:

$$P_{\text{TOTAL}} = 131\text{mW} + 55\text{mW} = 186\text{mW}$$

4.3.1.6 Step 6. Selecting input capacitor C_{IN}

$$\text{OutputPower} = 41\text{V} \cdot 20\text{mA} = 820\text{mW}$$

Select C_{IN} ECQ-E4104KF by Panasonic® (0.1 μ F, 400V, Metalized Polyester Film).

FIGURE 4-2: UNIVERSAL 85-264VAC LED LAMP DRIVER

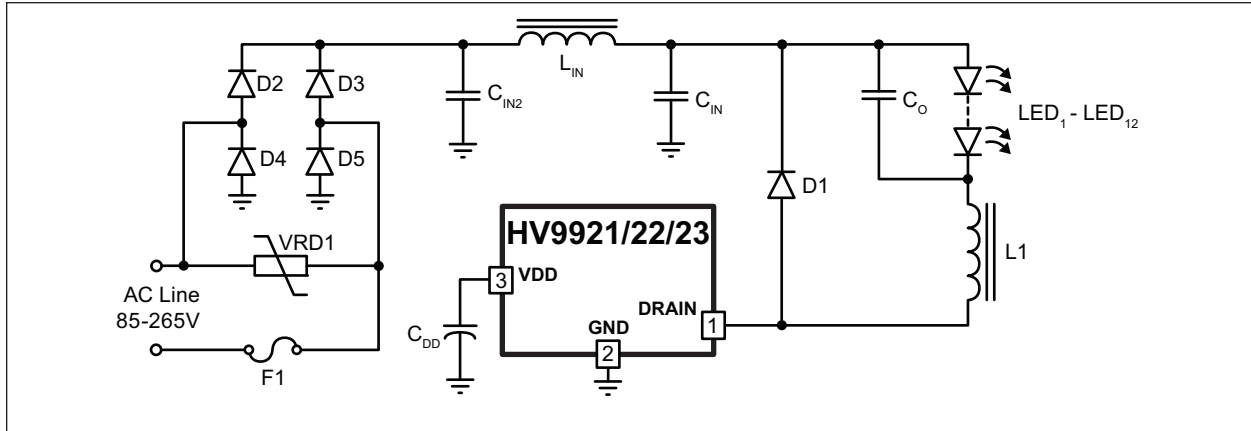


FIGURE 4-3: TYPICAL EFFICIENCY

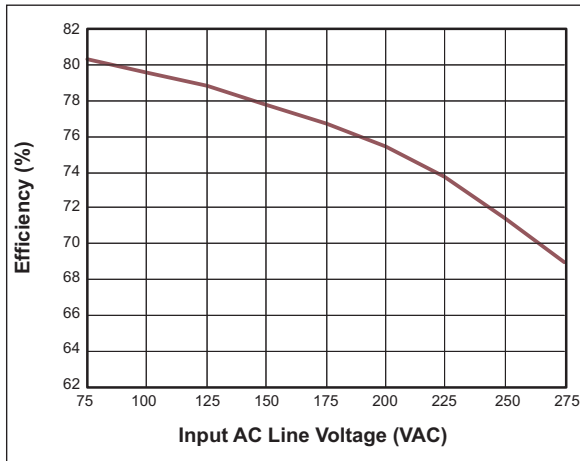
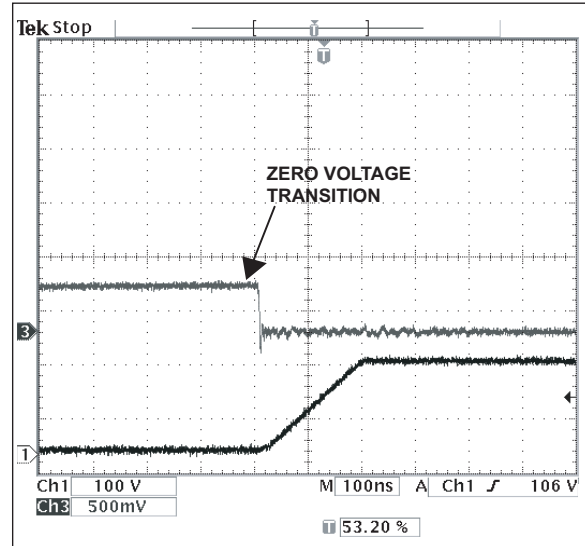


FIGURE 4-4: SWITCH-OFF TRANSITION
Ch1: V_{DRAIN} , Ch3: I_{DRAIN}



HV9921/HV9922/HV9923

FIGURE 4-5: TYPICAL EFFICIENCY

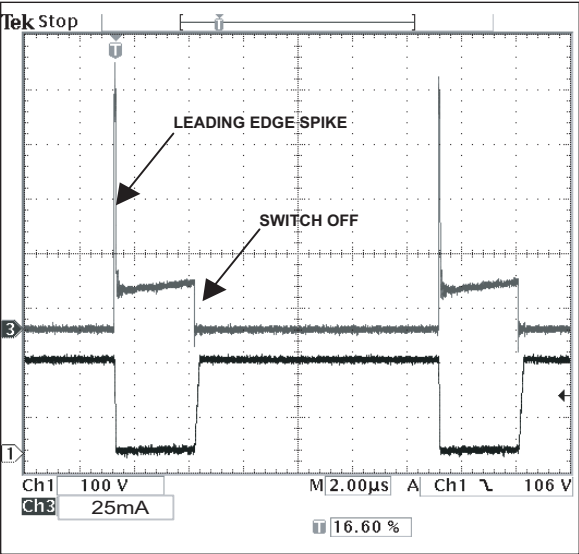


FIGURE 4-6: SWITCH-OFF TRANSITION
Ch1:V_{DRAIN}, Ch3: I_{DRAIN}

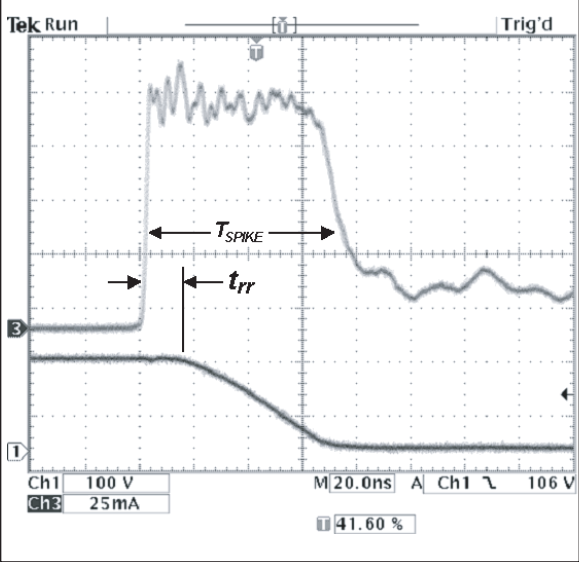
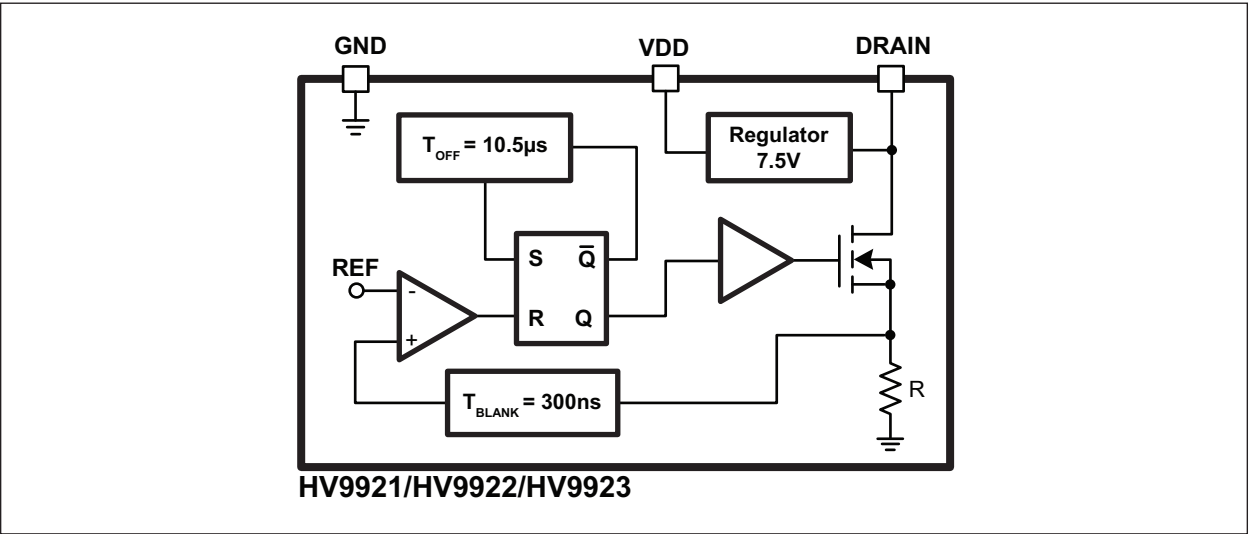


FIGURE 4-7: FUNCTIONAL BLOCK DIAGRAM



5.0 LAYOUT CONSIDERATIONS

For a recommended circuit board layout for the HV9921/22/23, see [Figure 5-1](#).

5.1 Single Point Grounding

Use a single point ground connection from the input filter capacitor to the area of copper connected to the GND pin.

5.2 Bypass Capacitor (C_{DD})

The V_{DD} pin bypass capacitor C_{DD} should be located as near as possible to the V_{DD} and GND pins.

5.3 Switching Loop Areas

The area of the switching loop connecting the input filter capacitor C_{IN} , the diode D1 and the HV9921/22/23 together should be kept as small as possible.

The switching loop area connecting the output filter capacitor C_O , the inductor L1 and the diode D1 together should be kept as small as possible.

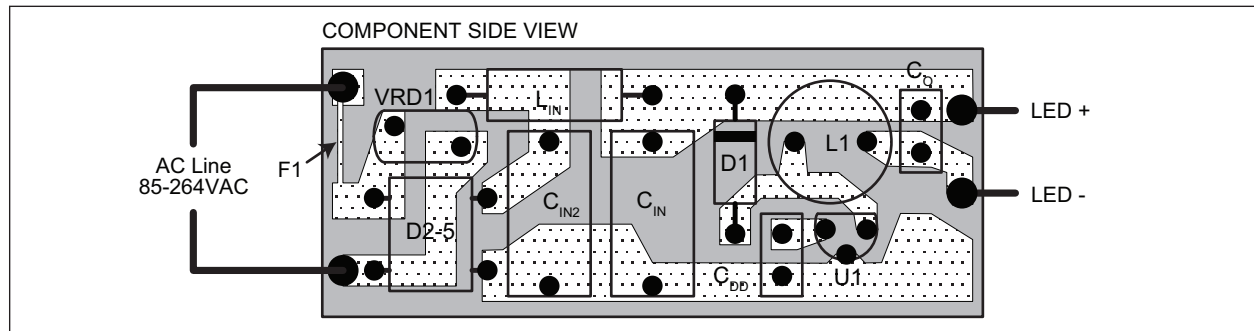
5.4 Thermal Considerations vs. Radiated EMI

The copper area where GND pin is connected acts not only as a single point ground, but also as a heat sink. This area should be maximized for good heat sinking, especially when the SOT-89 package is used. The same applies to the cathode of the free-wheeling diode D1. Both nodes are quiet; therefore, they will not cause radiated RF emission. The switching node copper area connected to the DRAIN pin of the HV9921/22/23, the anode of D1 and the inductor L1 needs to be minimized. A large switching node area can increase high frequency radiated EMI.

5.5 Input Filter Layout Considerations

The input circuits of the EMI filter must not be placed in the direct proximity to the inductor L1 in order to avoid magnetic coupling of its leakage fields. This consideration is especially important when unshielded construction of L1 is used. When an axial input EMI filter inductor L_{IN} is selected, it must be positioned orthogonal with respect to L1. The loop area formed by C_{IN2} , L_{IN} and C_{IN} should be minimized. The input lead wires must be twisted together.

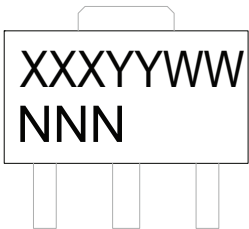
FIGURE 5-1: RECOMMENDED CIRCUIT BOARD LAYOUT WITH HV9921/22/23



6.0 PACKAGING INFORMATION

6.1 Package Marking Information

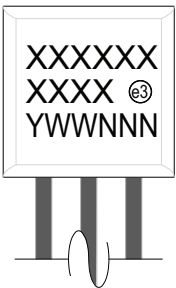
3-lead TO-243AA*
(SOT-89)



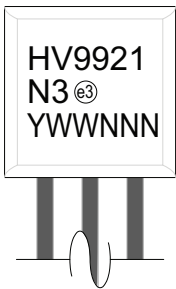
Example



3-lead TO-92



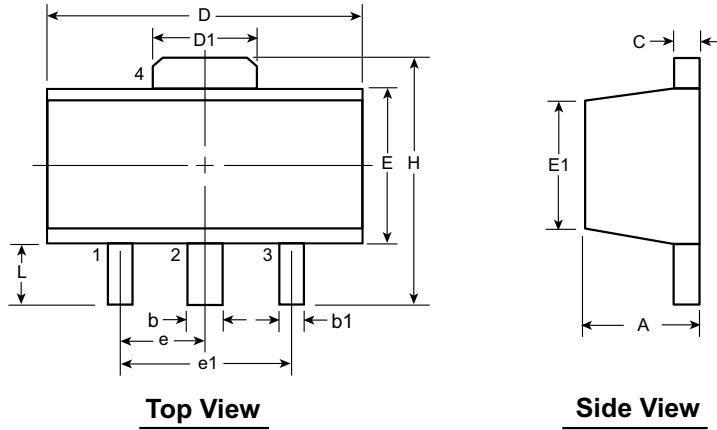
Example



Legend:	XX...X	Product Code or Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for product code or customer-specific information. Package may or may not include the corporate logo.

3-Lead TO-243AA (SOT-89) Package Outline (N8)



Note: For the most current package drawings, see the Microchip Packaging Specification at www.microchip.com/packaging.

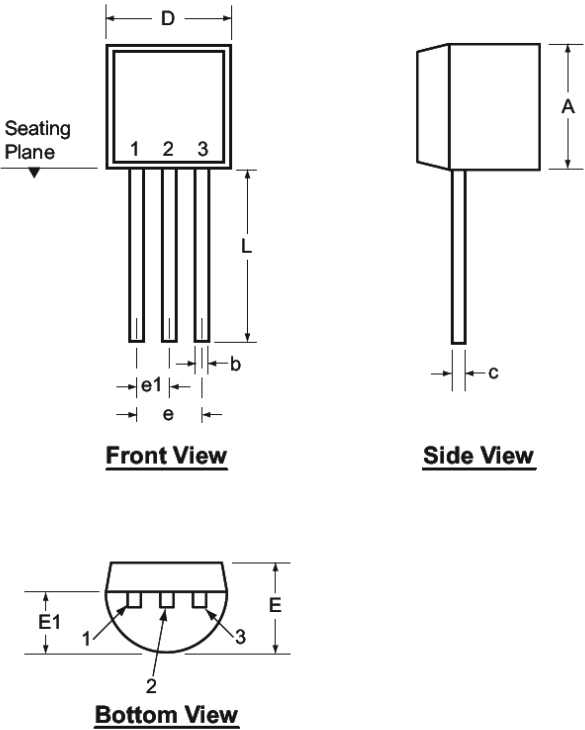
Symbol		A	b	b1	C	D	D1	E	E1	e	e1	H	L
Dimensions (mm)	MIN	1.40	0.44	0.36	0.35	4.40	1.62	2.29	2.00†	1.50 BSC	3.00 BSC	3.94	0.73†
	NOM	-	-	-	-	-	-	-	-			-	-
	MAX	1.60	0.56	0.48	0.44	4.60	1.83	2.60	2.29			4.25	1.20

JEDEC Registration TO-243, Variation AA, Issue C, July 1986.

† This dimension differs from the JEDEC drawing

Drawings not to scale.

3-Lead TO-92 Package Outline (L/LL/N3)



Note: For the most current package drawings, see the Microchip Packaging Specification at www.microchip.com/packaging.

Symbol		A	b	c	D	E	E1	e	e1	L
Dimensions (inches)	MIN	.170	.014†	.014†	.175	.125	.080	.095	.045	.500
	NOM	-	-	-	-	-	-	-	-	-
	MAX	.210	.022†	.022†	.205	.165	.105	.105	.055	.610*

JEDEC Registration TO-92.
* This dimension is not specified in the JEDEC drawing.
† This dimension differs from the JEDEC drawing.
Drawings not to scale.

APPENDIX A: REVISION HISTORY

Revision A (October 2014)

- Original Release of this Document.

THE MICROCHIP WEB SITE

Microchip provides online support via our WWW site at www.microchip.com. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQ), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip web site at www.microchip.com. Under "Support", click on "Customer Change Notification" and follow the registration instructions.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or Field Application Engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: <http://microchip.com/support>

HV9921/HV9922/HV9923

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

<u>PART NO.</u>	<u>XX</u>	-	<u>X</u>	-	<u>X</u>
Device	Package Options		Environmental		Reel
Device:	HV9921 = 3-Pin Switch-Mode LED Lamp Driver IC, 20 mA output current HV9922 = 3-Pin Switch-Mode LED Lamp Driver IC, 50 mA output current HV9923 = 3-Pin Switch-Mode LED Lamp Driver IC, 30 mA output current				
Package:	N3 = TO-92 N8 = TO-243AA (SOT-89)				
Environmental	G = Lead (Pb)-free/ROHS-compliant package				
Reel:	(nothing) = 1000/bag for N3 package, 2000/reel for N8 package				

Examples:
a) HV9921N3-G: 20 mA output current, TO-92 package, 1000/bag
b) HV9923N8-G: 30 mA output current, TO-243AA(SOT-89) package, 2000/reel

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, FlashFlex, KEELOQ, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC³² logo, rPIC, SST, SST Logo, SuperFlash 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, MTP, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

Analog-for-the-Digital Age, Application Maestro, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniscient Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICkit, PICTail, REAL ICE, rLAB, Select Mode, SQI, Serial Quad I/O, Total Endurance, TSHARC, UniWinDriver, WiperLock, ZENA and Z-Scale 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.

GestIC and ULPP are registered trademarks of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

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

© 2014, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.

ISBN: 978-1-63276-708-0

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
= ISO/TS 16949 =

Microchip received ISO/TS-16949:2009 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://www.microchip.com/support>
Web Address:
www.microchip.com

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

Austin, TX
Tel: 512-257-3370

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
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453

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

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110

Canada - Toronto
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: 852-2943-5100
Fax: 852-2401-3431

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

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

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

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

China - Hangzhou
Tel: 86-571-8792-8115
Fax: 86-571-8792-8116

China - Hong Kong SAR
Tel: 852-2943-5100
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: 86-755-8864-2200
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: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880-3770
Fax: 81-3-6880-3771

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: 886-3-5778-366
Fax: 886-3-5770-955

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

Taiwan - Taipei
Tel: 886-2-2508-8600
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 - Dusseldorf
Tel: 49-2129-3766400

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

Germany - Pforzheim
Tel: 49-7231-424750

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

Italy - Venice
Tel: 39-049-7625286

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

Poland - Warsaw
Tel: 48-22-3325737

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

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820

03/25/14