Current Mode PWM Controller

SG1842/SG1843

Product Overview

Description

The SG1842/43 family of control IC's provides all the necessary features to implement off-line fixed frequency, current-mode switching power supplies with a minimum number of external components.

Current-mode architecture demonstrates improved line regulation, improved load regulation, pulse-by-pulse current limiting and inherent protection of the power supply output switch. The bandgap reference is trimmed to ±1% over temperature.

Oscillator discharge current is trimmed to less than ±10%. The SG1842/43 has under-voltage lockout, current limiting circuitry and start-up current of less than 1 mA. The totem-pole output is optimized to drive the gate of a power MOSFET. The output is low in the off state to provide direct interface to an N-channel device. The SG1842/43 is specified for operation over the full military ambient temperature range of -55 °C to 125 °C. The SG2843 is specified for the industrial range of -25 °C to 85 °C.

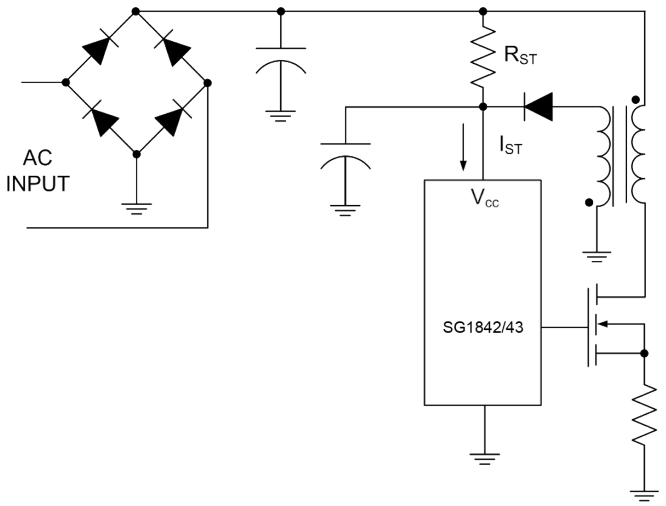
Features

- Optimized for off-line control
- Low start-up current (< 1 mA)
- Automatic feed forward compensation
- Trimmed oscillator discharge current
- Pulse-by-pulse current limiting
- Enhanced load response characteristics
- Under-voltage lockout with 6V hysteresis (SG1842 only)
- Double-pulse suppression
- High-current totem-pole output (1A peak)
- Internally trimmed bandgap reference
- 500 kHz operation
- Undervoltage lockout
  SG1842 - 16 volts
  SG1843 - 8.4 volts
- Low shoot-through current < 75 mA over temperature

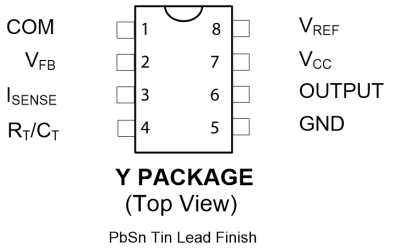
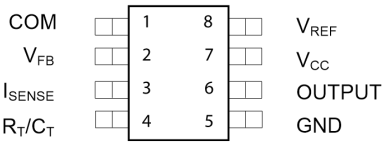
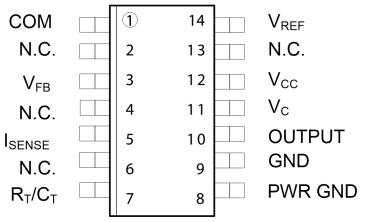
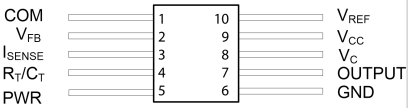
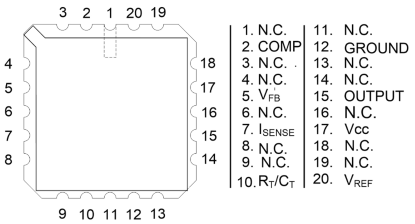
Application

- Available to MIL-STD-883 – 883
- Available to DLA
  - Standard Microcircuit Drawing (SMD)
- Microchip® level “S” processing available

Figure 1. Product Highlight



1. Connection Diagrams and Ordering Information[1-3]

Ambient Temperature	Type	Package	Part Number	Packaging Type	Connection Diagram
0 °C to 70 °C	Y	8-Pin Ceramic Dual Inline Package	—	CERDIP	 **Y PACKAGE** (Top View) PbSn Tin Lead Finish
-25 °C to 85 °C			—		
-55 °C to 125 °C			SG1842Y SG1843Y		
MIL-STD/883			SG1842Y-883B SG1843Y-883B		
DESC			SG1842Y-DESC SG1843Y-DESC		
0 °C to 70 °C	DM	8-Pin Small Outline Integrated Circuit	—	SOIC	 **DM PACKAGE** (Top View) RoHS / Pb-free 100% Matte Tin Lead Finish
-25 °C to 85 °C			SG2843DM		
0 °C to 70 °C	D	14-Pin Small Outline Integrated Circuit	—	SOIC	 **D PACKAGE** (Top View) RoHS / Pb-free 100% Matte Tin Lead Finish
-25 °C to 85 °C			SG2843D		
-55 °C to 125 °C	F	10-Pin Ceramic Flat Pack Package	SG1843F	Flat Pack	 **F PACKAGE** (Top View) PbSn Lead Finish
MIL-STD/883			—		
DESC			—		
-55 °C to 125 °C	L	20-Pin Ceramic	SG1843L	Ceramic Leadless Chip Carrier (LCC)	 **L PACKAGE** (Top View) PbSn Lead Finish
MIL-STD/883			SG1843L-883B		
DESC			SG1843L-DESC		

Notes:

1. Contact factory for JAN and DESC part availability.
2. All parts are viewed from the top.
3. Available in tape and reel. Append the letters “TR” to the part number.

2. Absolute Maximum Ratings[1-2]

Parameter	Value	Units
Supply voltage (I_{CC} < 30 mA)	Self-limiting	V
Supply voltage (low impedance source)	30	V
Output current (peak)	±1	A
Output current (continuous)	350	mA
Output energy (capacitive load)	5	µJ
Analog inputs (V_{FB}, I_{SENSE})	-0.3 to +6.3	V
Error amplifier output sink current	10	mA
Power dissipation at T_A = 25 °C (DIL-8)	1	W
Operating Junction Temperature		
Hermetic (Y, F, L packages)	150	°C
Plastic (D, DM packages)	150	°C
Storage temperature range	-65 to +150	°C
Lead temperature (soldering, 10 seconds)	300	°C
RoHS / Pb-free peak package solder reflow temp. (40 second max. exposure)	260 (+0, -5)	°C

Notes:

1. Exceeding these ratings could cause damage to the device.
2. All voltages are with respect to pin 5. All currents are positive into the specified terminal.

3. Thermal Data[1-2]

Parameter	Value	Units
DM Package		
Thermal resistance-junction to ambient, θ_{JA}	165	°C/W
D Package		
Thermal resistance-junction to ambient, θ_{JA}	120	°C/W
Y Package		
Thermal resistance-junction to ambient, θ_{JA}	130	°C/W
F Package		
Thermal resistance-junction to case, θ_{JC}	80	°C/W
Thermal resistance-junction to ambient, θ_{JA}	145	°C/W
L Package		
Thermal resistance-junction to case, θ_{JC}	35	°C/W
Thermal resistance-junction to ambient, θ_{JA}	120	°C/W

Notes:

1. Junction temperature calculation: $T_J = T_A + (P_D \times \theta_{JA})$.
2. The θ_{JA} numbers are guidelines for the thermal performance of the device/pc-board system. All of the above assume no ambient airflow.

4. Recommended Operating Conditions

Symbol	Parameter	Recommended Operating Conditions			Units
		Min	Typ	Max	
V_S	Supply voltage range	—	30	—	V
I_{PK}	Output current (peak)	—	±1	—	A
I_{OUT}	Output current (continuous)	—	200	—	mA
	Analog inputs (V_{FB}, I_{SENSE})	0	—	2.6	V
EA_{SINK}	Error amp output sink current	—	5	—	mA
OSC_{FR}	Oscillator frequency range	0.1	—	500	kHz
R_T	Oscillator timing resistor	0.52	—	150	kΩ
C_T	Oscillator timing capacitor	0.001	—	1.0	µF
Operating Ambient Temperature Range[1]					
	SG1842/43	-55	—	125	°C
	SG2843	-25	—	85	°C

Note:

1. Range over which the device is functional.

5. Electrical Characteristics

Unless otherwise specified, these specifications apply over the operating ambient temperatures for SG1842/SG1843 with -55 °C ≤ T_A ≤ 125 °C, SG2843 with -25 °C ≤ T_A ≤ 85 °C, V_{CC} = 15V, R_T = 10 kΩ, and C_T = 3.3 nF. Low duty cycle pulse testing techniques are used which maintains junction and case temperatures equal to the ambient temperature.

Symbol	Parameter	Test Conditions	SG1842/43			SG2843			Units
			Min	Typ	Max	Min	Typ	Max	
Reference Section									
V_{REF}	Output voltage	T_J = 25 °C, I_O = 1mA	4.95	5.00	5.05	4.95	5.00	5.05	V
V_{REG}	Line regulation	12V ≤ V_{IN} ≤ 25V	—	6	20	—	6	20	mV
I_{REG}	Load regulation	1 ≤ I_O ≤ 20 mA	—	6	25	—	6	25	mV
	Temperature stability[1]		—	0.2	0.4	—	0.2	0.4	mV/°C
	Total output variation[1]	Line, load, temperature	4.90	—	5.10	4.90	—	5.10	V
V_N	Output noise voltage[1]	10 Hz ≤ f ≤ 10 kHz, T_J = 25 °C	—	50	—	—	50	—	µV
	Long term stability[1]	T_A = 125 °C, 1000 hrs	—	5	25	—	5	25	mV
V_{REFOSC}	Output short circuit		-30	-100	-180	-30	-100	-180	mA
Oscillator Section[3]									
f	Initial accuracy	T_J = 25 °C	47	52	57	47	52	57	kHz
f_{REG}	Voltage stability	12V ≤ V_{CC} ≤ 25V	—	0.2	1	—	0.2	1	%
	Temperature stability[1]	T_{MIN} ≤ T_A ≤ T_{MAX}	—	5	—	—	5	—	%
OSC_{PP}	Amplitude	$V_{RT/CT}$ (peak to peak)	—	1.7	—	—	1.7	—	V
I_{DSG}	Discharge current	T_J = 25 °C	7.8	8.3	8.8	7.5	8.4	9.3	mA
		T_{MIN} ≤ T_A ≤ T_{MAX}	7.0	—	9.0	7.2	—	9.5	mA
Error Amp Section									
EA_{IN}	Input voltage	V_{COMP} = 2.5V	2.45	2.50	2.55	2.45	2.50	2.55	V
EA_{IB}	Input bias current		—	-0.3	-1	—	-0.3	1	µA
A_{VOL}	Open loop gain	2V ≤ V_O ≤ 4V	65	90	—	65	90	—	dB
EA_{BW}	Unity gain bandwidth[1]	T_J = 25 °C	0.7	1	—	0.7	1	—	MHz
PSRR	Power supply rejection ratio	12V ≤ V_{CC} ≤ 25V	60	70	—	60	70	—	dB
EA_{SINK}	Output sink current	V_{VFB} = 2.7V, V_{COMP} = 1.1V	2	6	—	2	6	—	mA
EA_{SRC}	Output source current	V_{VFB} = 2.3V, V_{COMP} = 5V	-0.5	-0.8	—	-0.5	-0.8	—	mA
EA_{VOH}	V_{OUT} High	V_{VFB} = 2.3V, R_L = 15k to GND	5	6	—	5	6	—	V
EA_{VOL}	V_{OUT} Low	V_{VFB} = 2.7V, R_L = 15k to V_{REF}	—	0.7	1.1	—	0.7	1.1	V
Current Sense Section									
CS_{AVOL}	Gain [2, 3]		2.85	3	3.15	2.85	3	3.15	V/V
	Maximum input signal[2]	V_{COMP} = 5V	0.9	1	1.1	0.9	1	1.1	V
PSRR	Power supply rejection ratio[2]	12V ≤ V_{CC} ≤ 25V	—	70	—	—	70	—	dB
CS_{IB}	Input bias current		—	-2	-10	—	-2	-10	µA
CS_{DELAY}	Delay to output[1]		—	150	300	—	150	300	ns

.....continued

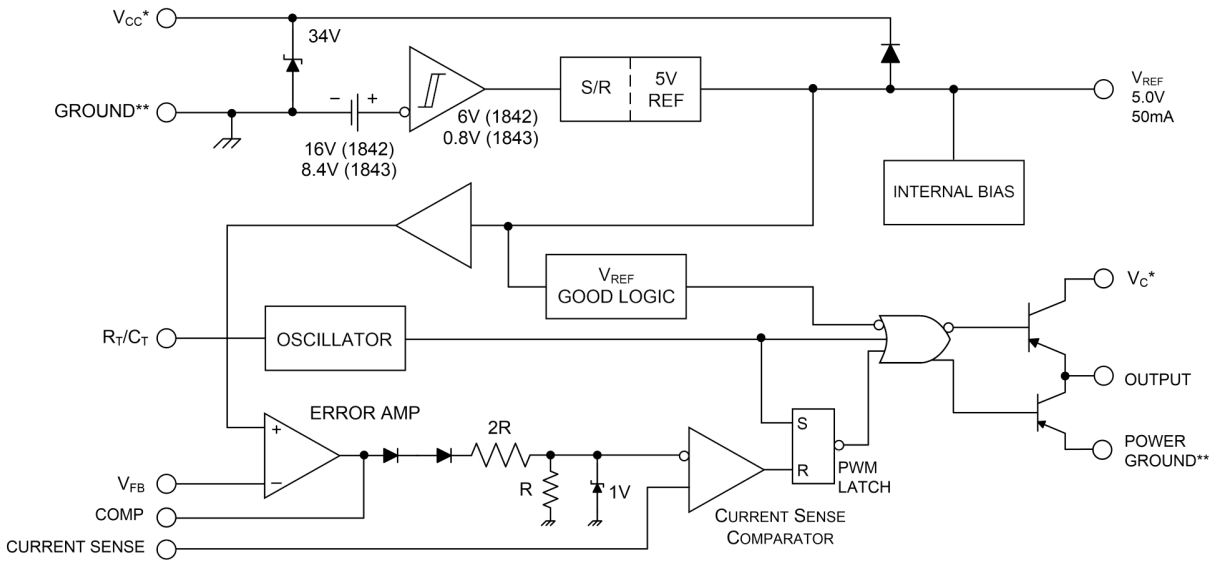
Symbol	Parameter	Test Conditions	SG1842/43			SG2843			Units
			Min	Typ	Max	Min	Typ	Max	
Output Section									
V_{OL}	Output low level	I_{SINK} = 20 mA	—	0.1	0.4	—	0.1	0.4	V
		I_{SINK} = 200 mA	—	1.5	2.2	—	1.5	2.2	V
V_{OH}	Output high level	I_{SOURCE} = 20 mA	13	13.5	—	13	13.5	—	V
		I_{SOURCE} = 200 mA	12	13.5	—	12	13.5	—	V
R_S	Rise time	T_J = 25 °C, C_L = 1 nF	—	50	150	—	50	150	ns
F_T	Fall time	T_J = 25 °C, C_L = 1 nF	—	50	150	—	50	150	ns
Under-Voltage Lockout Section									
UVLO	Start threshold	1842	15	16	17	15	16	17	V
		1843/2843	7.8	8.4	9.0	7.8	8.4	9.0	V
V_{SMIN}	Min. operation voltage after turn-on	1842	9	10	11	9	10	11	V
		1843/2843	7.0	7.6	8.3	7.0	7.6	8.2	V
PWM Section									
DC_{MAX}	Maximum duty cycle		93	95	100	90	95	100	%
DC_{MIN}	Minimum cuty cycle		—	—	0	—	—	0	%
Power Consumption Section									
I_S	Start-up current		—	0.5	1	—	0.5	1	mA
I	Operating supply current	V_{FB} = V_{ISENSE} = 0V	—	11	17	—	11	17	mA
Z	V_{CC} Zener voltage	I_{CC} = 25 mA	—	34		—	34	—	V

Notes:

1. These parameters, although guaranteed, are not 100% tested in production.
2. Parameter measured at trip point of latch with V_{VFB} = 0.
3. Gain defined as: A = ΔV_{COMP} / ΔV_{ISENSE} ; 0 ≤ V_{ISENSE} ≤ 0.8V
4. Adjust V_{CC} above the start threshold before setting at 15V.

6. Block Diagram

Figure 6-1. Block Diagram



* - V_{CC} and V_C are internally connected for 8-pin packages.
** - POWER GROUND and GROUND are internally connected for 8-pin packages.

7. Characteristic Curves

Figure 7-1. Dropout Voltage Vs. Temperature

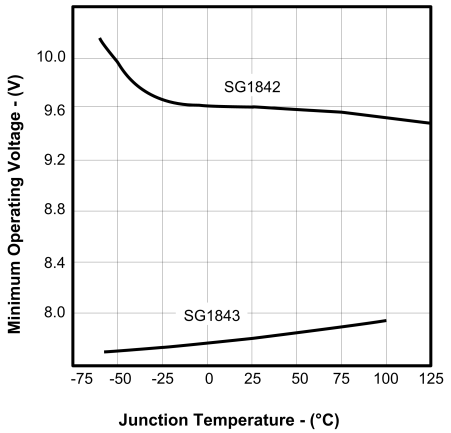


Figure 7-2. Oscillator Temperature Stability

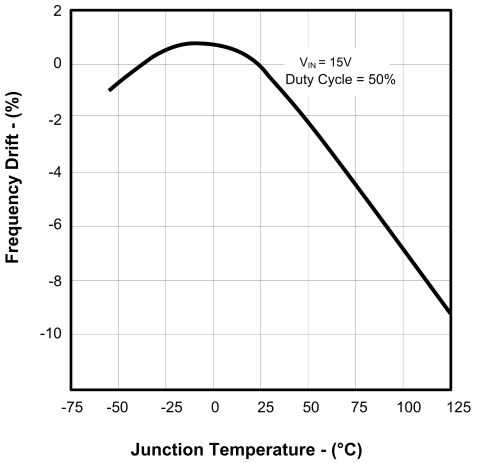


Figure 7-3. Current Sense to Output Delay Vs. Temperature

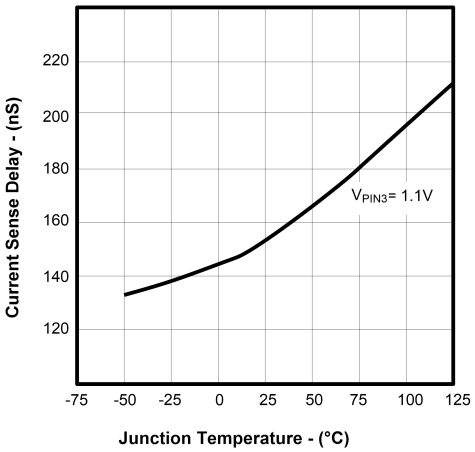


Figure 7-4. Output Duty Cycle Vs. Temperature

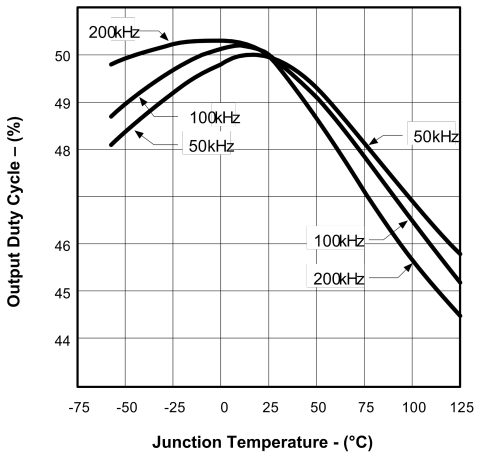


Figure 7-5. Start-Up Current Vs. Temperature

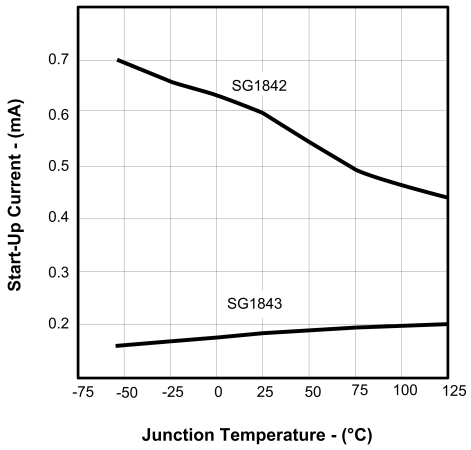


Figure 7-6. Reference Voltage Vs. Temperature

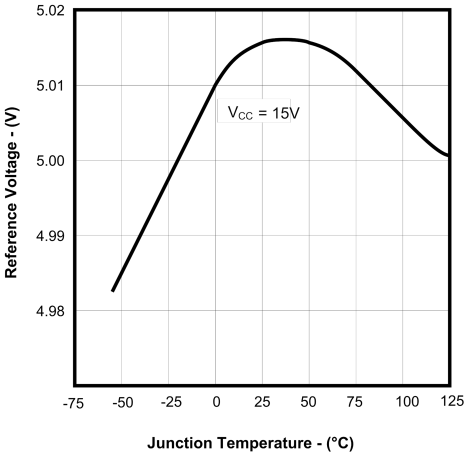


Figure 7-7. Start-Up Voltage Threshold Vs. Temperature

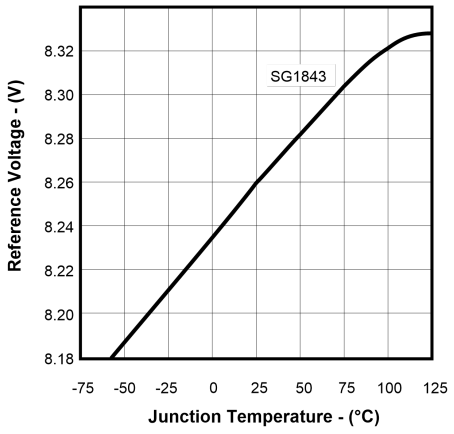


Figure 7-8. Start-Up Voltage Threshold Vs. Temperature

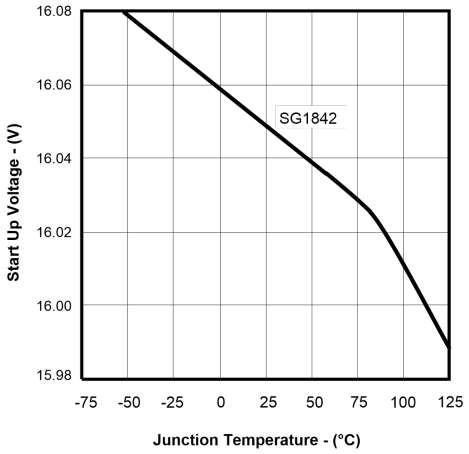


Figure 7-9. Oscillator Discharge Current Vs. Temperature

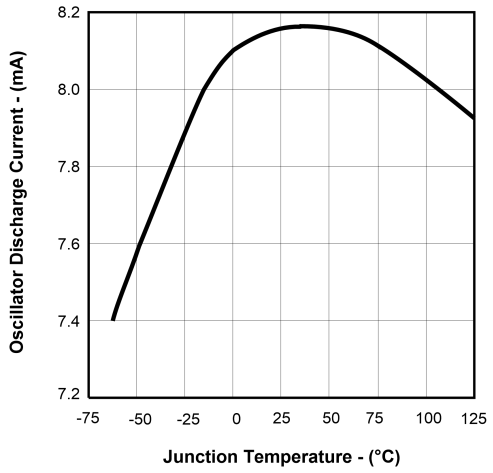


Figure 7-10. Output Saturation Voltage Vs. Output Current and Temperature (Sink Transistor)

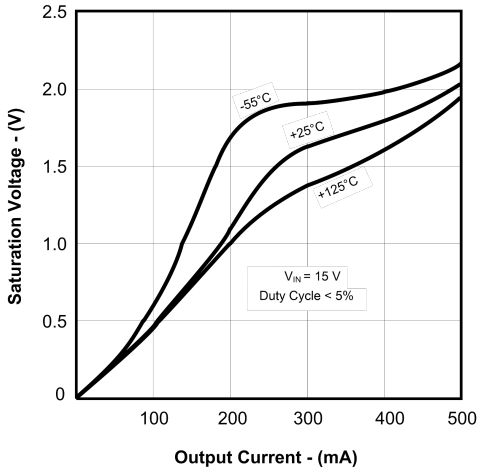


Figure 7-11. Current Sense Threshold Vs. Error Amplifier Output

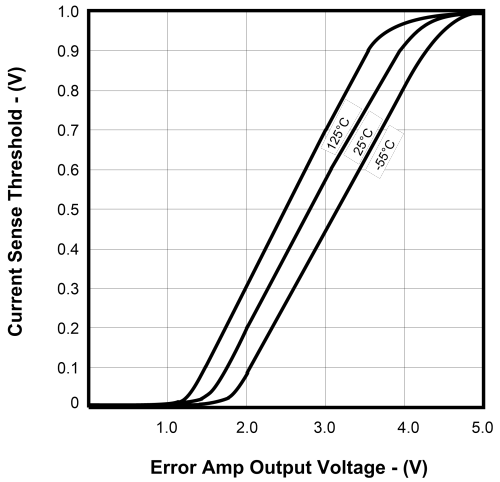
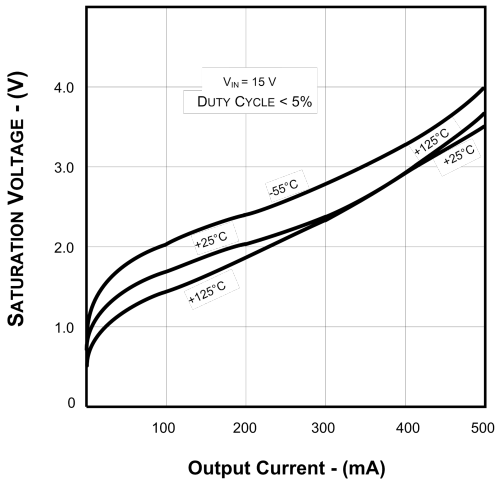


Figure 7-12. Output Saturation Voltage Vs. Output Current and Temperature



8. Application Information

The oscillator of the 1842/43 family of PWM's is designed such that many values of R_T and C_T will give the same oscillator frequency, but only one combination will yield a specific duty cycle at a given frequency.

Given:

Frequency ≡ f

Maximum Duty Cycle ≡ D_m

Calculate:

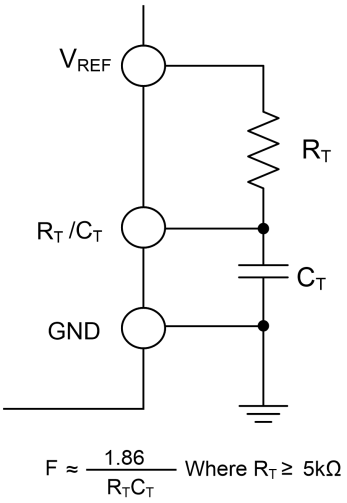
$$R_T = 267\left[\frac{(1.76)^{1/D_m}-1}{(1.76)^{(1-D_m)/D_m}-1}\right] (\Omega)$$

where $0.3 < D_m < 0.95$

$$C_T = \frac{1.86 * D_m}{f * R_T} (\mu F)$$

For Duty-Cycles above 95% use:

Figure 8-1. Oscillator Timing Circuit



A set of formulas are given to determine the values of R_T and C_T for a given frequency and maximum duty cycle. (Note: These formulas are less accurate for smaller duty cycles or higher frequencies. This will require trimming of R_T or C_T to correct for this error.)

Example:

A Flyback power supply requires a maximum of 45% duty cycle at a switching frequency of 50 kHz. What are the values of R_T and C_T?

Given:

f = 50 kHz

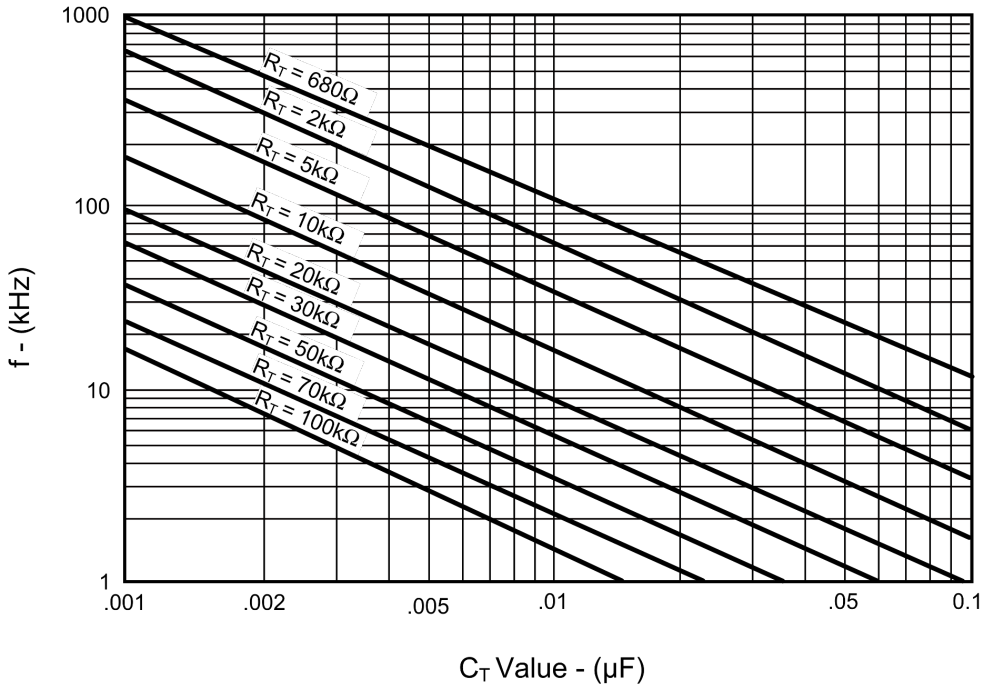
D_m = 0.45

Calculate:

$$R_T = 267\left[\frac{(1.76)^{\frac{1}{.45}} - 1}{(1.76)^{\frac{.55}{.45}} - 1}\right] = 674\ \Omega$$

$$C_T = \frac{1.86 * 0.45}{50000 * 674} = .025\ (\mu F)$$

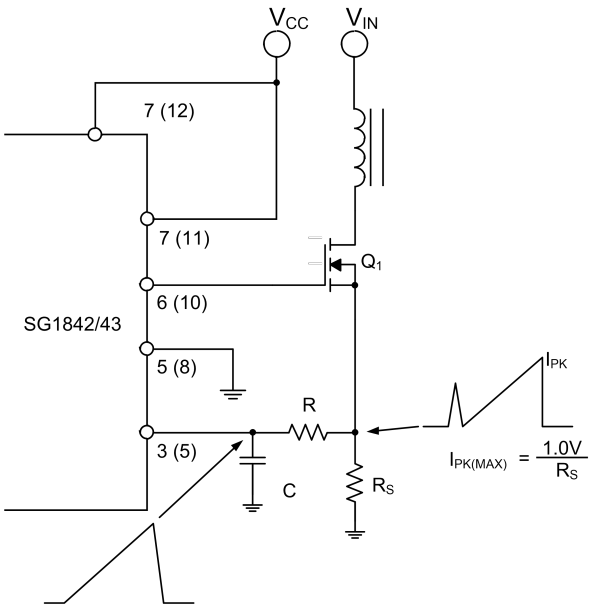
Figure 8-2. Oscillator Frequency Vs. R_T For Various C_T



9. Typical Application Circuits

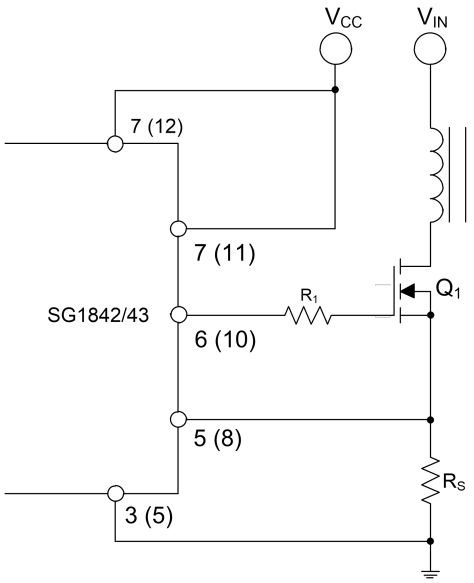
Pin numbers referenced are for 8-pin package and pin numbers in parenthesis are for 14-pin package.

Figure 9-1. Current Sense Spike Suppression



The RC low-pass filter eliminates the leading edge current spike caused by parasitic of Power MOSFET.

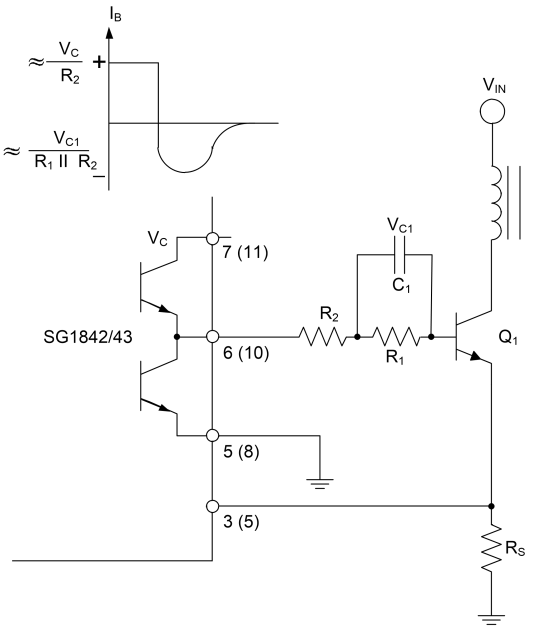
Figure 9-2. MOSFET Parasitic Oscillations



A resistor (R1) in series with the MOSFET gate reduce overshoot and ringing caused by the MOSFET input capacitance and any inductance in series with the gate drive. (Note: It is very important to have

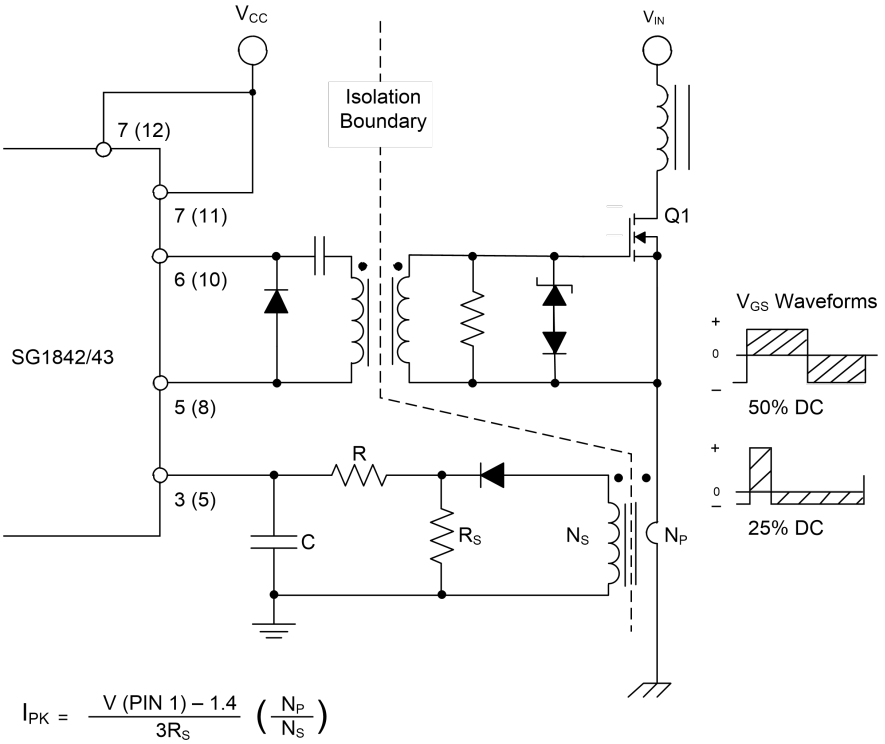
a low inductance ground path to insure correct operation of the I.C. This can be done by making the ground paths as short and as wide as possible.)

Figure 9-3. Bipolar Transistor Drive



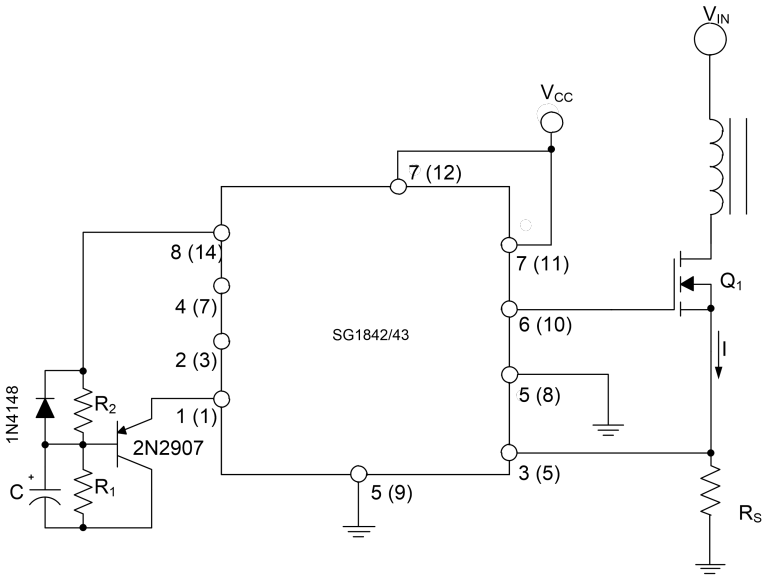
The 1842/43 output stage can provide negative base current to remove base charge of power transistor (Q_1) for faster turn off. This is accomplished by adding a capacitor (C_1) in parallel with a resistor (R_1). The resistor (R_1) is to limit the base current during turn on.

Figure 9-4. Isolated MOSFET Drive



Current transformers can be used where isolation is required between PWM and Primary ground. A drive transformer is then necessary to interface the PWM output with the MOSFET.

Figure 9-5. Adjustable Buffered Reduction of Clamp Level with Softstart



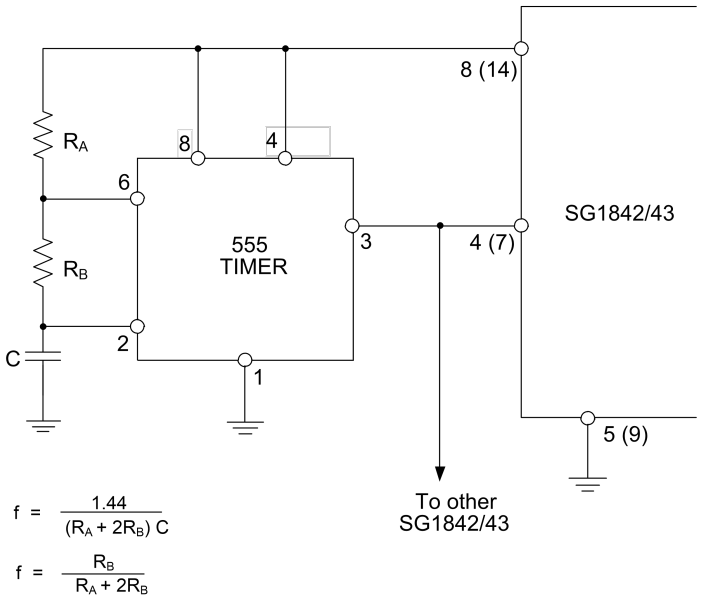
$$I_{PK} = \frac{V_{CS}}{R_S}$$

Where, V_{CS}=1.67 $\left(\frac{R_1}{R_1+R_2}\right)$ and $V_{C.S.MAX}$ = 1V (Typ.)

$$t_{SOFTSTART} = -\ln\left[1 - \frac{V_{EAO} - 1.3}{5\left(\frac{R_1}{R_1+R_2}\right)}\right]\left(\frac{R_1R_2}{R_1+R_2}\right)C$$

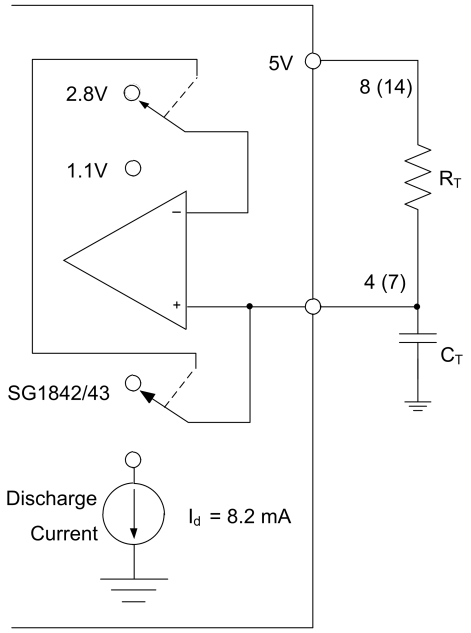
Where, V_{EAO} ≡ voltage at the Error Amp Output under minimum line and maximum load conditions
Softstart and adjustable peak current can be done with the external circuitry shown in Figure 9-5.

Figure 9-6. External Duty Cycle Clamp and Multi-Unit Synchronization



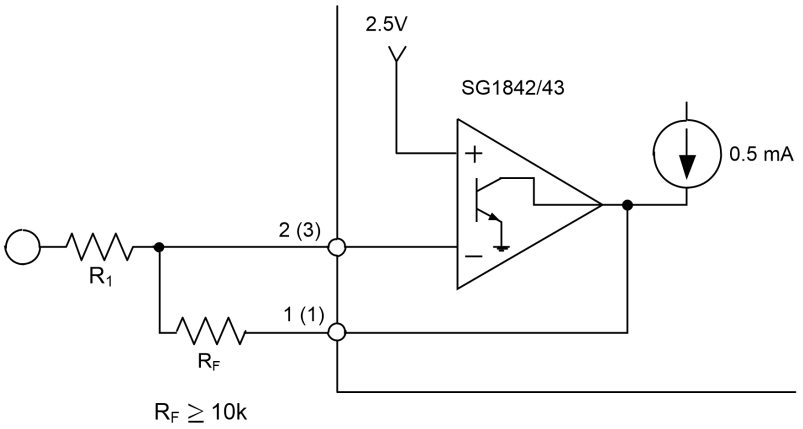
Precision duty cycle limiting as well as synchronizing several 1842/1843's is possible with circuitry shown in Figure 9-6.

Figure 9-7. Oscillator Connection



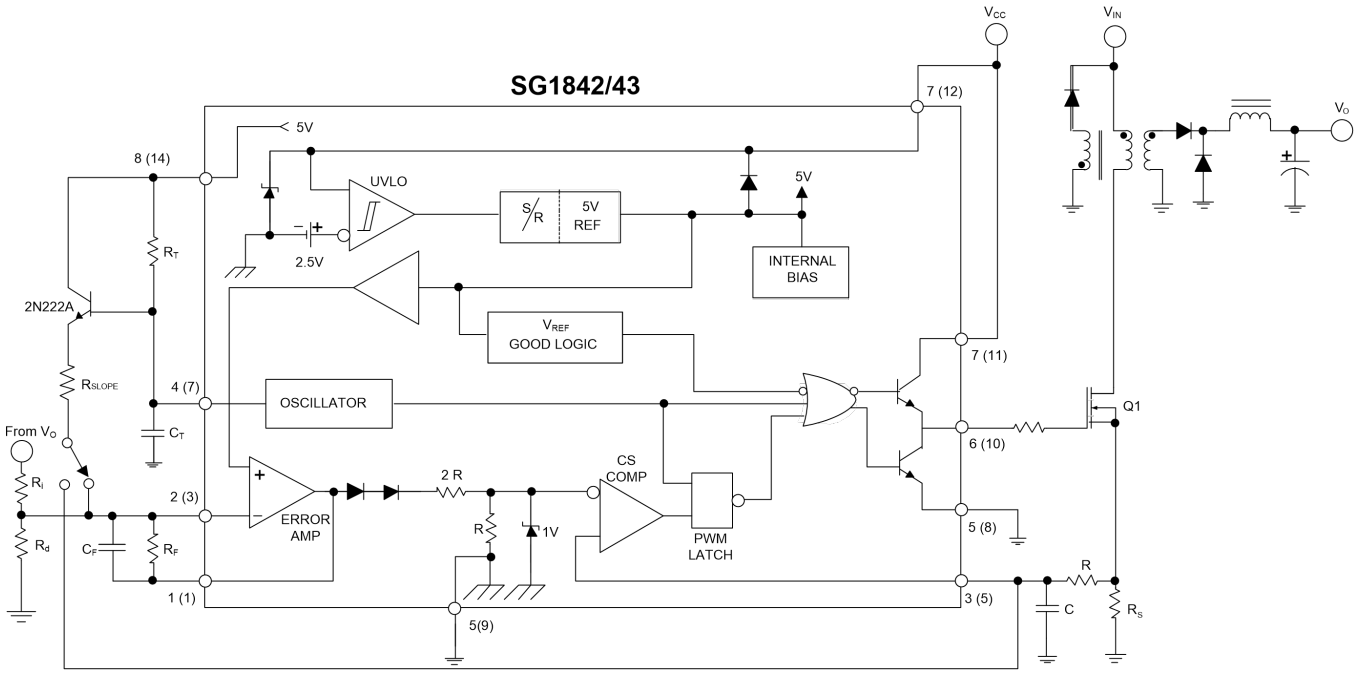
The oscillator is programmed by the values selected for the timing components R_T and C_T. Refer to application information for calculation of the component values.

Figure 9-8. Error Amplifier Connection



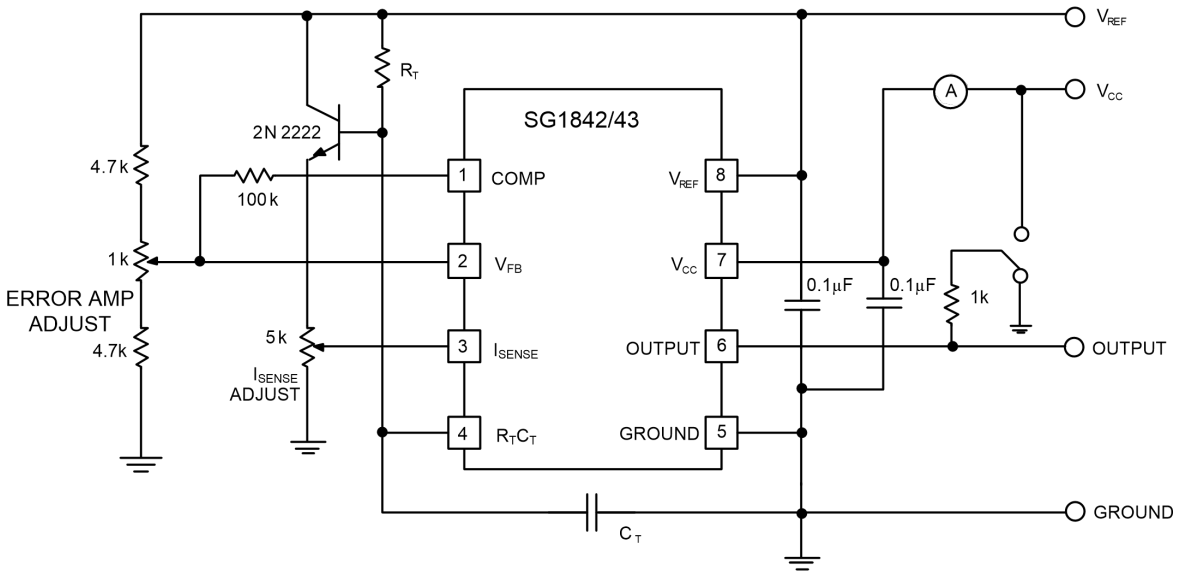
Error amplifier is capable of sourcing and sinking current up to 0.5 mA.

Figure 9-9. Slope Compensation



Due to inherent instability of current mode converters running above 50% duty cycle, slope compensation should be added to either current sense pin or the error amplifier. Figure 9-9 shows a typical slope compensation technique.

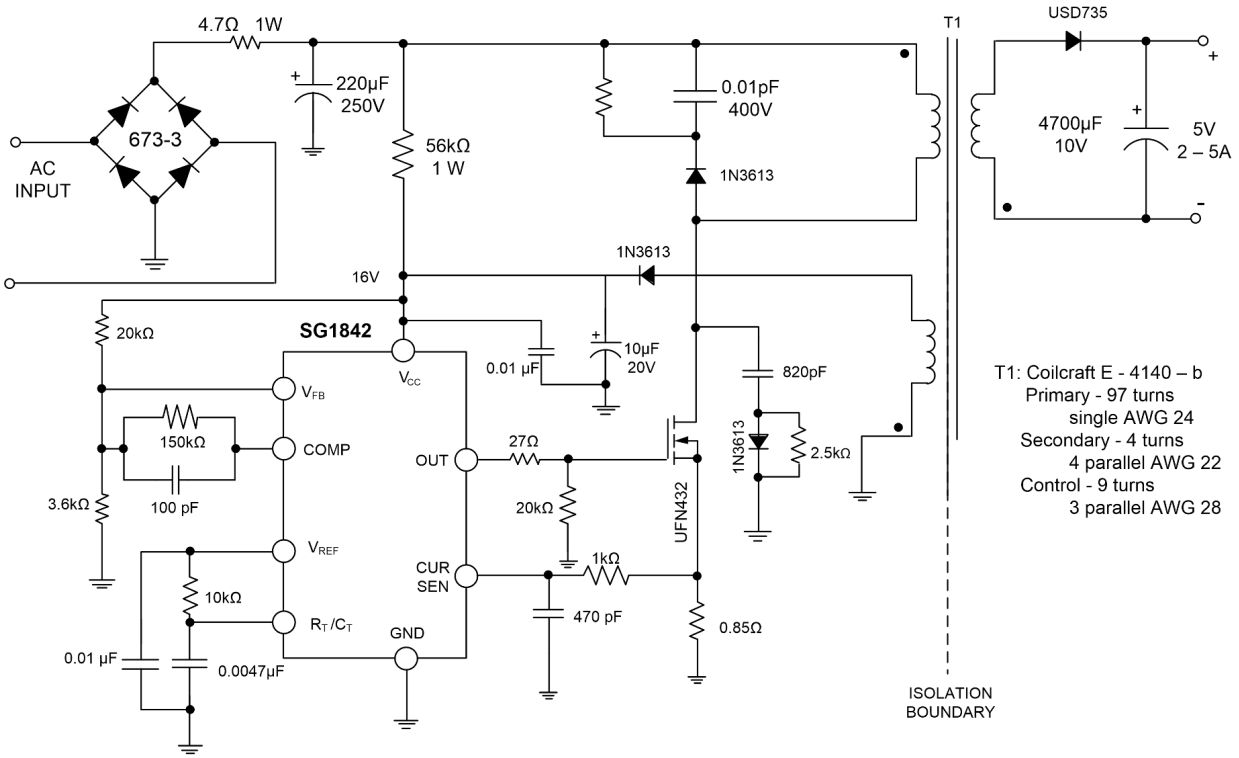
Figure 9-10. Open Loop Laboratory Fixture



High-peak currents associated with capacitive loads necessitate careful grounding techniques. Timing and bypass capacitors should be connected to pin 5 in a single point ground.

The transistor and 5 kΩ potentiometer are used to sample the oscillator waveform and apply an adjustable ramp to pin 3.

Figure 9-11. Off-line Flyback Regulator



Specifications

Input line voltage: 90 VAC to 130 VAC

Input frequency:	50 or 60 Hz
Switching frequency:	40 kHz ±10%
Output power:	25W maximum
Output voltage:	5V +5%
Output current:	2 to 5A
Line regulation:	0.01 %/V
Load regulation:	8 %/A[1]
Efficiency at 25 Watt:	V_{IN} = 90 VAC: 70% V_{IN} = 130 VAC: 65%
Output short-circuit current:	2.5 A average

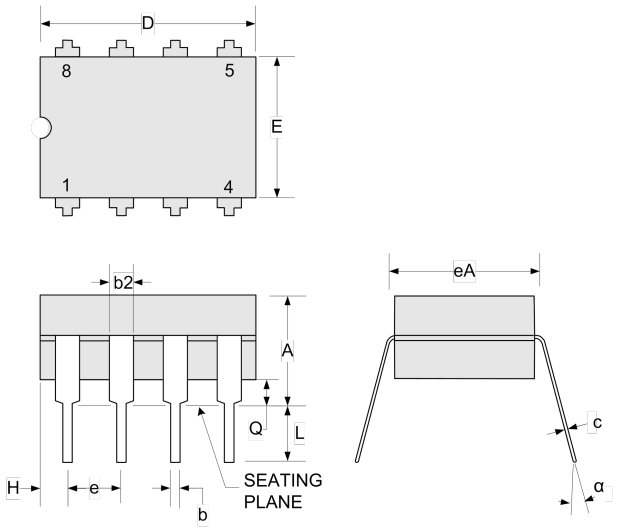
Note:

1. This circuit uses a low-cost feedback scheme in which the DC voltage developed from the primary-side control winding is sensed by the SG1842 error amplifier. Load regulation is therefore dependent on the coupling between secondary and control windings and on transformer leakage inductance.

10. Package Outline Dimensions

Controlling dimensions are in inches. Metric equivalents are shown for general information.

Figure 10-1. Y 8-Pin CERDIP Package Dimensions

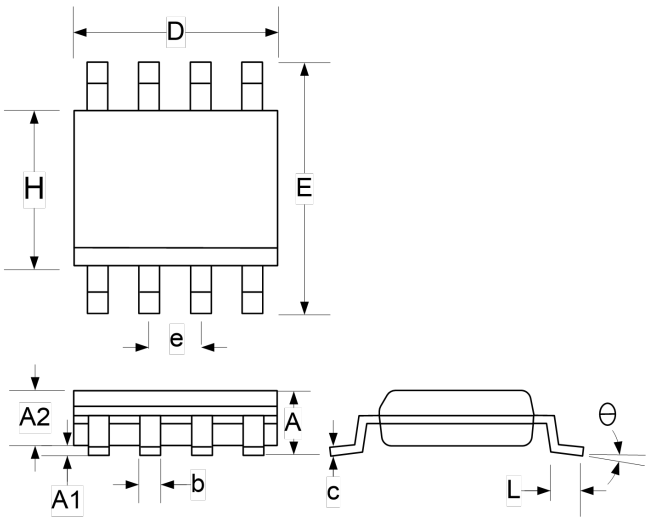


Dim[1]	Millimeters		Inches	
	Min	Max	Min	Max
A	4.32	5.08	0.170	0.200
b	0.38	0.51	0.015	0.020
b2	1.04	1.65	0.045	0.065
c	0.20	0.38	0.008	0.015
D	9.52	10.29	0.375	0.405
E	5.59	7.11	0.220	0.280
e	2.54 BSC		0.100 BSC	
eA	7.37	7.87	0.290	0.310
H	0.63	1.78	0.025	0.070
L	3.18	4.06	0.125	0.160
α	—	15°	—	15°
Q	0.51	1.02	0.020	0.040

Note:

1. Dimensions do not include protrusions; these shall not exceed 0.155 mm (.006”) on any side. Lead dimension shall not include solder coverage.

Figure 10-2. DM 8-Pin SOIC Package Dimensions

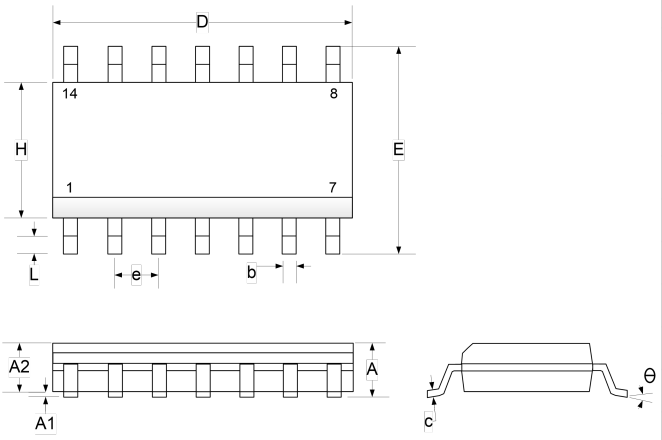


Dim[1]	Millimeters		Inches	
	Min	Max	Min	Max
A	1.35	1.75	0.053	0.069
A1	0.10	0.25	0.004	0.010
A2	1.25	1.52	0.049	0.060
b	0.33	0.51	0.013	0.020
c	0.19	0.25	0.007	0.010
D	4.83	5.21	0.189	0.205
E	5.79	6.20	0.228	0.244
e	1.27 BSC		0.050 BSC	
H	3.81	4.01	0.150	0.158
L	0.40	1.27	0.016	0.050
θ	0°	8°	0°	8°
LC[2]	—	.010	—	0.004

Notes:

1. Dimensions do not include mold flash or protrusions; these shall not exceed 0.155 mm (.006”) on any side. Lead dimension shall not include solder coverage.
2. Lead co-planarity

Figure 10-3. D 14-Pin SOIC Package Dimensions

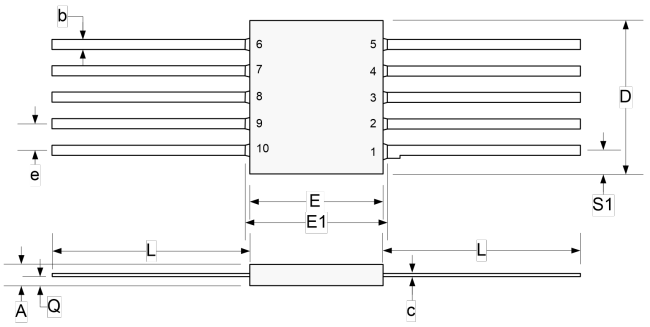


Dim[1]	Millimeters		Inches	
	Min	Max	Min	Max
A	1.35	1.75	0.053	0.069
A1	0.10	0.25	0.004	0.010
A2	1.25	1.52	0.049	0.060
b	0.33	0.51	0.013	0.020
c	0.19	0.25	0.007	0.010
D	8.54	8.74	0.336	0.344
E	5.79	6.20	0.228	0.244
e	1.27 BSC		0.050 BSC	
H	3.81	4.01	0.150	0.158
L	0.40	1.27	0.016	0.050
θ	0°	8°	0°	8°
LC[2]	—	.010	—	0.004

Notes:

1. Dimensions do not include mold flash or protrusions; these shall not exceed 0.155 mm (.006”) on any side. Lead dimension shall not include solder coverage.
2. Lead co-planarity

Figure 10-4. F 10-Pin Ceramic Flatpack Package Dimensions

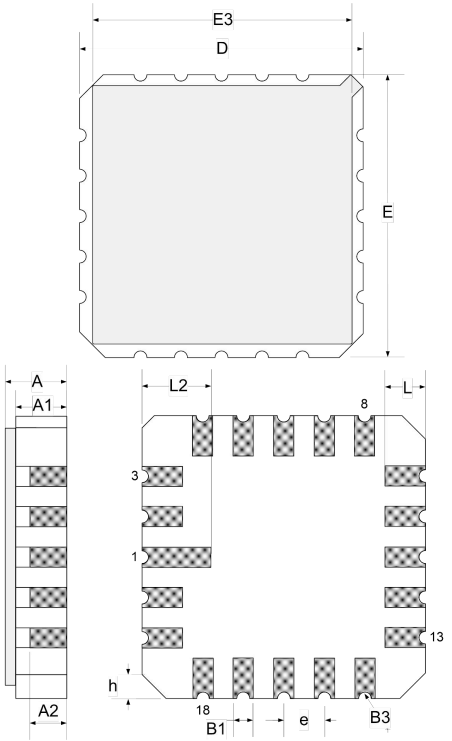


Dim	Millimeters		Inches	
	Min	Max	Min	Max
A	1.45	1.90	0.057	0.075
b	0.25	0.483	0.010	0.019
c	0.102	0.152	0.004	0.006
D	—	7.37	—	0.290
E	6.04	6.40	0.238	0.252
E1	—	6.91	—	0.272
e	1.27 BSC		0.050 BSC	
L	6.35	9.40	0.250	0.370
Q	0.51	1.02	0.020	0.040
S1	0.20	0.38	0.008	0.015

Notes:

1. Lead No. 1 is identified by tab on lead or dot on cover.
2. Leads are within 0.13 mm (.0005”) radius of the true position (TP) at maximum material condition.
3. Dimension “e” determines a zone within which all body and lead irregularities lie.

Figure 10-5. L 20-Pin Leadless Chip Carrier Package Dimensions



Dim	Millimeters		Inches	
	Min	Max	Min	Max
D/E	8.64	9.14	0.340	0.360
E3	—	8.128	—	0.320
e	1.270 BSC		0.050 BSC	
B1	0.635 TYP		0.025 TYP	
L	1.02	1.52	0.040	0.060
A	1.626	2.286	0.064	0.090
h	1.016 TYP		0.040 TYP	
A1	1.372	1.68	0.054	0.066
A2	—	1.168	—	0.046
L2	1.91	2.41	0.075	0.95
B3	0.203R		0.008R	

Note:

1. All exposed metalized area shall be gold plated 60 micro-inch minimum thickness over nickel plated unless otherwise specified in purchase order.

11. Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

Revision	Date	Description
A	09/2023	Initial revision.

Microchip Information

The Microchip Website

Microchip provides online support via our website at www.microchip.com/. This website is used to make files and information easily available to customers. Some of the content available includes:

- **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 (FAQs), technical support requests, online discussion groups, Microchip design partner 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

Product Change Notification Service

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

To register, go to www.microchip.com/pcn and follow the registration instructions.

Customer Support

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Embedded Solutions Engineer (ESE)
- Technical Support

Customers should contact their distributor, representative or ESE for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in this document.

Technical support is available through the website at: www.microchip.com/support

Microchip Devices Code Protection Feature

Note the following details of the code protection feature on Microchip products:

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner, within operating specifications, and under normal conditions.
- Microchip values and aggressively protects its intellectual property rights. Attempts to breach the code protection features of Microchip product is strictly prohibited and may violate the Digital Millennium Copyright Act.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is "unbreakable". Code protection is constantly evolving. Microchip is committed to continuously improving the code protection features of our products.

Legal Notice

This publication and the information herein may be used only with Microchip products, including to design, test, and integrate Microchip products with your application. Use of this information in any other manner violates these terms. Information regarding device applications 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. Contact your local Microchip sales office for additional support or, obtain additional support at www.microchip.com/en-us/support/design-help/client-support-services.

THIS INFORMATION IS PROVIDED BY MICROCHIP "AS IS". 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 ANY IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE, OR WARRANTIES RELATED TO ITS CONDITION, QUALITY, OR PERFORMANCE.

IN NO EVENT WILL MICROCHIP BE LIABLE FOR ANY INDIRECT, SPECIAL, PUNITIVE, INCIDENTAL, OR CONSEQUENTIAL LOSS, DAMAGE, COST, OR EXPENSE OF ANY KIND WHATSOEVER RELATED TO THE INFORMATION OR ITS USE, HOWEVER CAUSED, EVEN IF MICROCHIP HAS BEEN ADVISED OF THE POSSIBILITY OR THE DAMAGES ARE FORESEEABLE. TO THE FULLEST EXTENT ALLOWED BY LAW, MICROCHIP'S TOTAL LIABILITY ON ALL CLAIMS IN ANY WAY RELATED TO THE INFORMATION OR ITS USE WILL NOT EXCEED THE AMOUNT OF FEES, IF ANY, THAT YOU HAVE PAID DIRECTLY TO MICROCHIP FOR THE INFORMATION.

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 unless otherwise stated.

Trademarks

The Microchip name and logo, the Microchip logo, Adaptec, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, CryptoMemory, CryptoRF, dsPIC, flexPWR, HELDO, IGLOO, JukeBlox, KeeLoq, Kleer, LANCheck, LinkMD, maXStylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

AgileSwitch, ClockWorks, The Embedded Control Solutions Company, EtherSynch, Flashtec, Hyper Speed Control, HyperLight Load, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet-Wire, SmartFusion, SyncWorld, TimeCesium, TimeHub, TimePictra, TimeProvider, and ZL are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, Augmented Switching, BlueSky, BodyCom, Clockstudio, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, Espresso T1S, EtherGREEN, EyeOpen, GridTime, IdealBridge, IGaT, In-Circuit Serial Programming, ICSP, INICnet, Intelligent Paralleling, IntelliMOS, Inter-Chip Connectivity, JitterBlocker, Knob-on-Display, MarginLink, maxCrypto, maxView, memBrain, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, mSiC, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, Power MOS IV, Power MOS 7, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, RTAX, RTG4, SAM-ICE, Serial Quad I/O, simpleMAP, SimpliPHY, SmartBuffer, SmartHLS, SMART-I.S., storClad, SQI, SuperSwitcher, SuperSwitcher II, Switchtec, SynchroPHY, Total Endurance, Trusted Time, TSHARC, Turing, USBCheck, VariSense, VectorBlox, VeriPHY, ViewSpan, WiperLock, XpressConnect, 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.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, and Symmcom are registered trademarks of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

ISBN: 978-1-6683-3101-9

Quality Management System

For information regarding Microchip's Quality Management Systems, please visit www.microchip.com/quality.

Worldwide Sales and Service

AMERICAS	ASIA/PACIFIC	ASIA/PACIFIC	EUROPE
Corporate Office	**Australia - Sydney**	**India - Bangalore**	**Austria - Wels**
2355 West Chandler Blvd.	Tel: 61-2-9868-6733	Tel: 91-80-3090-4444	Tel: 43-7242-2244-39
Chandler, AZ 85224-6199	**China - Beijing**	**India - New Delhi**	Fax: 43-7242-2244-393
Tel: 480-792-7200	Tel: 86-10-8569-7000	Tel: 91-11-4160-8631	**Denmark - Copenhagen**
Fax: 480-792-7277	**China - Chengdu**	**India - Pune**	Tel: 45-4485-5910
Technical Support:	Tel: 86-28-8665-5511	Tel: 91-20-4121-0141	Fax: 45-4485-2829
www.microchip.com/support	**China - Chongqing**	**Japan - Osaka**	**Finland - Espoo**
Web Address:	Tel: 86-23-8980-9588	Tel: 81-6-6152-7160	Tel: 358-9-4520-820
www.microchip.com	**China - Dongguan**	**Japan - Tokyo**	**France - Paris**
Atlanta	Tel: 86-769-8702-9880	Tel: 81-3-6880- 3770	Tel: 33-1-69-53-63-20
Duluth, GA	**China - Guangzhou**	**Korea - Daegu**	Fax: 33-1-69-30-90-79
Tel: 678-957-9614	Tel: 86-20-8755-8029	Tel: 82-53-744-4301	**Germany - Garching**
Fax: 678-957-1455	**China - Hangzhou**	**Korea - Seoul**	Tel: 49-8931-9700
Austin, TX	Tel: 86-571-8792-8115	Tel: 82-2-554-7200	**Germany - Haan**
Tel: 512-257-3370	**China - Hong Kong SAR**	**Malaysia - Kuala Lumpur**	Tel: 49-2129-3766400
Boston	Tel: 852-2943-5100	Tel: 60-3-7651-7906	**Germany - Heilbronn**
Westborough, MA	**China - Nanjing**	**Malaysia - Penang**	Tel: 49-7131-72400
Tel: 774-760-0087	Tel: 86-25-8473-2460	Tel: 60-4-227-8870	**Germany - Karlsruhe**
Fax: 774-760-0088	**China - Qingdao**	**Philippines - Manila**	Tel: 49-721-625370
Chicago	Tel: 86-532-8502-7355	Tel: 63-2-634-9065	**Germany - Munich**
Itasca, IL	**China - Shanghai**	**Singapore**	Tel: 49-89-627-144-0
Tel: 630-285-0071	Tel: 86-21-3326-8000	Tel: 65-6334-8870	Fax: 49-89-627-144-44
Fax: 630-285-0075	**China - Shenyang**	**Taiwan - Hsin Chu**	**Germany - Rosenheim**
Dallas	Tel: 86-24-2334-2829	Tel: 886-3-577-8366	Tel: 49-8031-354-560
Addison, TX	**China - Shenzhen**	**Taiwan - Kaohsiung**	**Israel - Ra'anana**
Tel: 972-818-7423	Tel: 86-755-8864-2200	Tel: 886-7-213-7830	Tel: 972-9-744-7705
Fax: 972-818-2924	**China - Suzhou**	**Taiwan - Taipei**	**Italy - Milan**
Detroit	Tel: 86-186-6233-1526	Tel: 886-2-2508-8600	Tel: 39-0331-742611
Novi, MI	**China - Wuhan**	**Thailand - Bangkok**	Fax: 39-0331-466781
Tel: 248-848-4000	Tel: 86-27-5980-5300	Tel: 66-2-694-1351	**Italy - Padova**
Houston, TX	**China - Xian**	**Vietnam - Ho Chi Minh**	Tel: 39-049-7625286
Tel: 281-894-5983	Tel: 86-29-8833-7252	Tel: 84-28-5448-2100	**Netherlands - Drunen**
Indianapolis	**China - Xiamen**		Tel: 31-416-690399
Noblesville, IN	Tel: 86-592-2388138		Fax: 31-416-690340
Tel: 317-773-8323	**China - Zhuhai**		**Norway - Trondheim**
Fax: 317-773-5453	Tel: 86-756-3210040		Tel: 47-72884388
Tel: 317-536-2380			**Poland - Warsaw**
Los Angeles			Tel: 48-22-3325737
Mission Viejo, CA			**Romania - Bucharest**
Tel: 949-462-9523			Tel: 40-21-407-87-50
Fax: 949-462-9608			**Spain - Madrid**
Tel: 951-273-7800			Tel: 34-91-708-08-90
Raleigh, NC			Fax: 34-91-708-08-91
Tel: 919-844-7510			**Sweden - Gothenberg**
New York, NY			Tel: 46-31-704-60-40
Tel: 631-435-6000			**Sweden - Stockholm**
San Jose, CA			Tel: 46-8-5090-4654
Tel: 408-735-9110			**UK - Wokingham**
Tel: 408-436-4270			Tel: 44-118-921-5800
Canada - Toronto			Fax: 44-118-921-5820
Tel: 905-695-1980			
Fax: 905-695-2078			