MP1580
2A 380 KHz Step Down Converter

General Description

The MP1580 is a monolithic step down switch mode converter with a built in internal power MOSFET. It achieves 2A continuous output current over a wide input supply range with excellent load and line regulation.

Current mode operation provides fast transient response and eases loop stabilization.

Fault condition protection includes cycle-by-cycle current limiting and thermal shutdown. In shutdown mode the regulator draws 23µA of supply current.

The MP1580 requires a minimum number of readily available standard external components. A synchronization pin allows the part to be driven to 600KHz.

Features

- 2A Output Current
- 0.18Ω Internal Power MOSFET Switch
- Stable with Low ESR Output Ceramic Capacitors
- Up to 95% Efficiency
- 23µA Shutdown Mode
- Fixed 380KHz Frequency
- Thermal Shutdown
- Cycle-by-Cycle Over Current Protection
- Wide 4.75 to 25V Operating Input Range
- Output Adjustable from 1.22 to 21V
- Programmable Under Voltage Lockout
- Frequency Synchronization Input
- Available in 8 Pin SO Package
- **Evaluation Board Available**

Applications

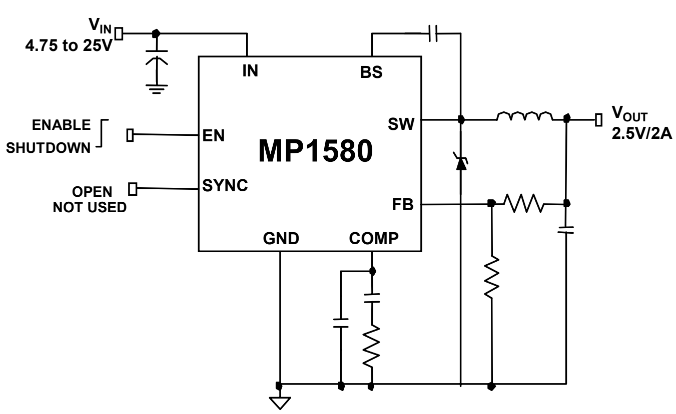
- Distributed Power Systems
- Battery Charger
- Pre-Regulator for Linear Regulators

Ordering Information

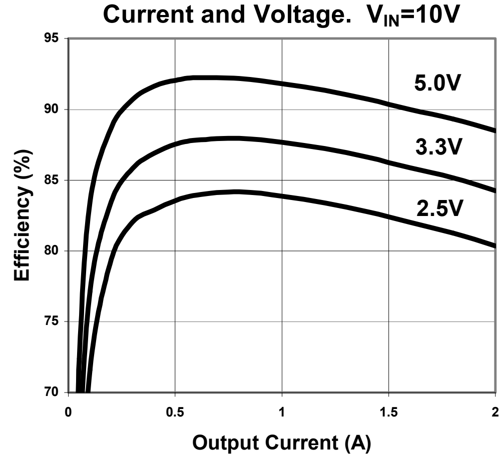
Part Number ∗	Package	Temperature
MP1580HS	SOIC8	-40 to +125 °C
MP1580HP	PDIP8	-40 to +125 °C
EV0007	Evaluation Board	

∗ For Tape & Reel use suffix - Z (e.g. MP1580HS-Z)

Typical Application Circuit



Efficiency versus Output Current and Voltage. V_{IN}=10V



Absolute Maximum Ratings (Note 1)	
Supply Voltage (V_{IN})	27V
Switch Voltage (V_{SW})	-1V to V_{IN} +1V
Bootstrap Voltage (V_{BS})	V_{SW} + 6V
Feedback Voltage (V_{FB})	-0.3 to 6V
Enable/UVLO Voltage (V_{EN})	-0.3 to 6V
Comp Voltage (V_{COMP})	-0.3 to 6V
Sync Voltage (V_{SYNC})	-0.3 to 6V
Junction Temperature	150°C
Lead Temperature	260°C
Storage Temperature	-65 to +150°C

Recommended Operating Conditions (Note 2)	
Input Voltage (V_{IN})	4.75V to 25V
Operating Temperature	-40 to +125°C

Package Thermal Characteristics (Note 3)	
Thermal Resistance θ_{JA} (SOIC8)	105°C/W
Thermal Resistance θ_{JC} (SOIC8)	50°C/W
Thermal Resistance θ_{JC} (PDIP8)	95°C/W
Thermal Resistance θ_{JC} (PDIP8)	55°C/W

Electrical Characteristics (Unless otherwise specified V_{IN}=12V, T_A=25°C)

Parameters	Condition	Min	Typ	Max	Units
Feedback Voltage	4.75V ≤ V_{IN} ≤ 25V V_{COMP} < 2V	1.198	1.222	1.246	V
Upper Switch On Resistance			0.18		Ω
Lower Switch On Resistance			10		Ω
Upper Switch Leakage	V_{EN}=0V; V_{SW}=0V		0	10	μA
Current Limit		2.4	3.0	3.6	A
Current Limit Gain. Output Current to Comp Pin Voltage			1.95		A/V
Error Amplifier Voltage Gain			400		V/V
Error Amplifier Transconductance	ΔI_C = ±10 μA	500	770	1100	μA/V
Oscillator Frequency		342	380	418	KHz
Short Circuit Frequency	V_{FB} = 0V	26	40	54	KHz
Sync Frequency	Sync Drive 0 to 2.7V	445		600	KHz
Maximum Duty Cycle	V_{FB} = 1.0V		90		%
Minimum Duty Cycle	V_{FB} = 1.5V			0	%
Enable Threshold	I_{CC} > 100μA	0.7	1.0	1.3	V
Enable Pull Up Current	V_{EN} = 0V	1.15	1.46	1.8	μA
Under Voltage Lockout Threshold Rising		2.37	2.495	2.62	V
Under Voltage Lockout Threshold Hysteresis			210		mV
Supply Current (shutdown)	V_{EN} ≤ 0.4V		23	36	μA
Supply Current (quiescent)	V_{EN} ≥ 2.6V; V_{FB} =1.4V		1.0	1.2	mA
Thermal Shutdown			160		°C

Note 1. Exceeding these ratings may damage the device.
Note 2. The device is not guaranteed to function outside its operating rating.
Note 3. Measured on approximately 1" square of 1 oz. copper surrounding device leads.

Pin Descriptions

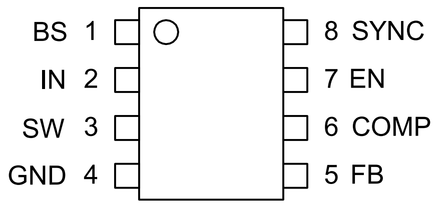
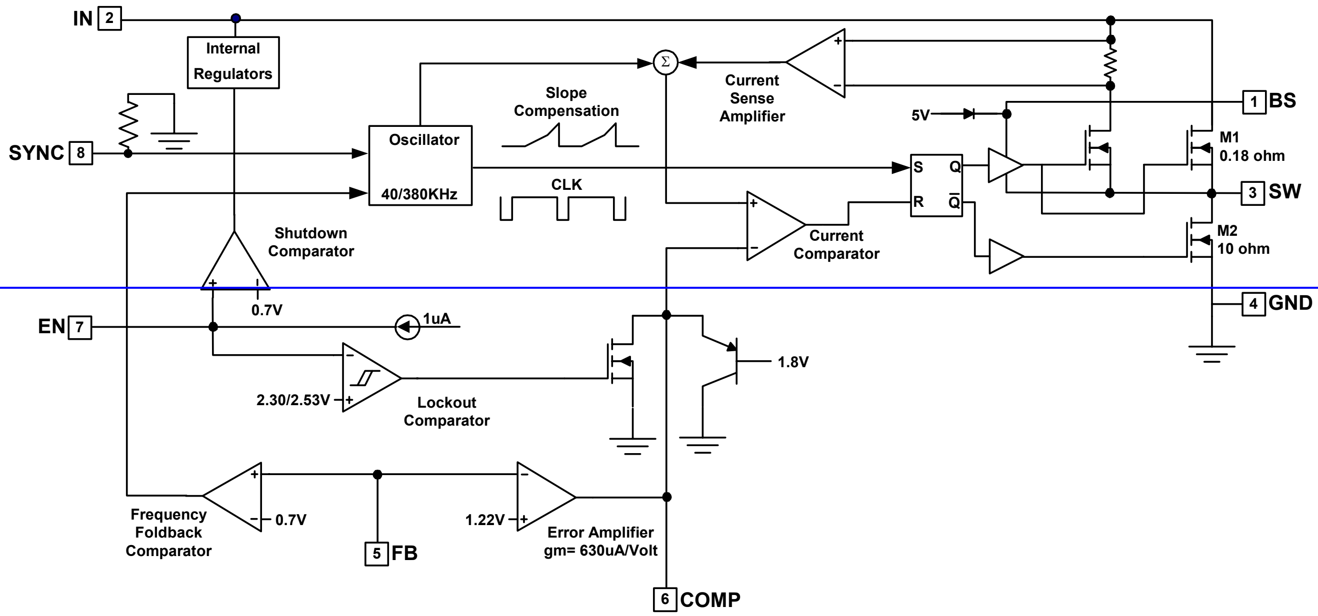


Table 1: Pin Designators

Pin Number	Pin Name	Description
1	BS	Bootstrap (C5) - This capacitor is needed to drive the power switch's gate above the supply voltage. It is connected between SW and BS pins to form a floating supply across the power switch driver. The voltage across C5 is about 5V and is supplied by the internal +5V supply when the SW pin voltage is low.
2	IN	Supply Voltage - The MP1580 operates from a +4.75V to +25V unregulated input. C1 is needed to prevent large voltage spikes from appearing at the input.
3	SW	Switch - This connects the inductor to either IN through M1 or to GND through M2.
4	GND	Ground - This pin is the voltage reference for the regulated output voltage. For this reason care must be taken in its layout. This node should be placed outside of the D1 to C1 ground path to prevent switching current spikes from inducing voltage noise into the part.
5	FB	Feedback - An external resistor divider from the output to GND, tapped to the FB pin sets the output voltage. To prevent current limit run away during a short circuit fault condition the frequency foldback comparator lowers the oscillator frequency when the FB voltage is below 700mV.
6	COMP	Compensation - This node is the output of the transconductance error amplifier and the input to the current comparator. Frequency compensation is done at this node by connecting a series R-C to ground. See the compensation section for exact details.
7	EN	Enable/UVLO - A voltage greater than 2.495V enables operation. Leave EN unconnected if unused. An Under Voltage Lockout (UVLO) function can be implemented by the addition of a resistor divider from V_{IN} to GND. For complete low current shutdown it's the EN pin voltage needs to be less than 700mV.
8	SYNC	Synchronization Input - This pin is used to synchronize the internal oscillator frequency to an external source. There is an internal 11KΩ pull down resistor to GND, therefore leave SYNC unconnected if unused.



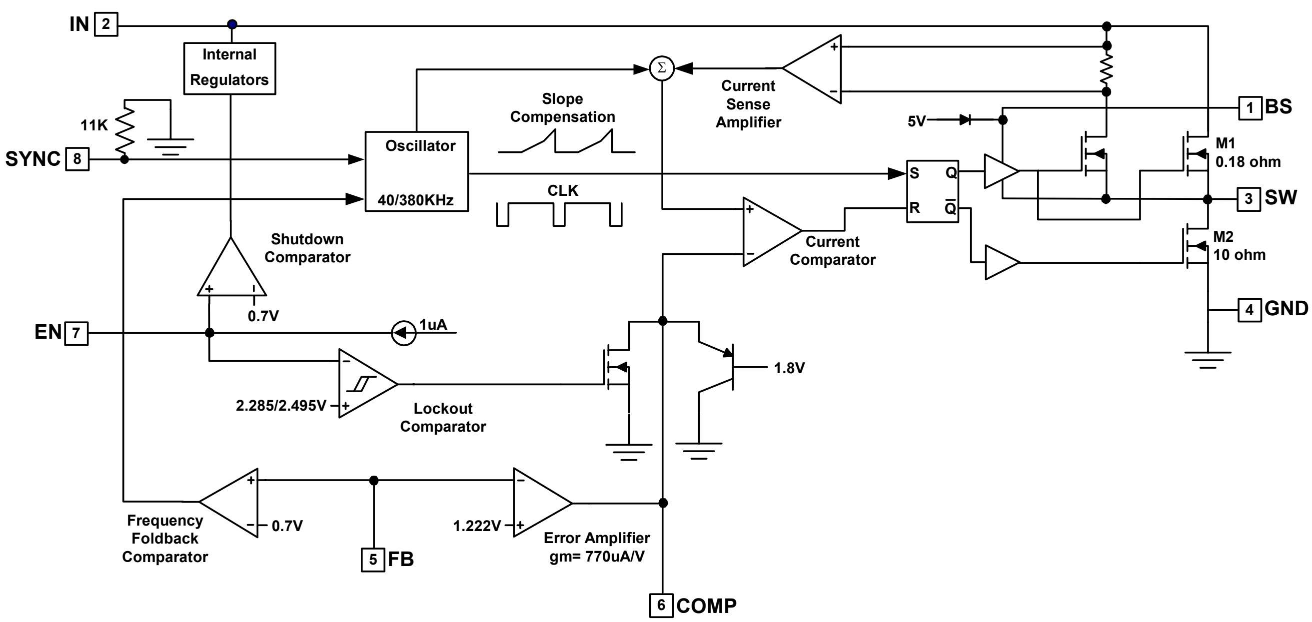


Figure 1: Functional Block Diagram

Functional Description

The MP1580 is a current mode regulator. That is, the COMP pin voltage is proportional to the peak inductor current. At the beginning of a cycle: the upper transistor M1 is off; the lower transistor M2 is on (refer to Figure 2); the COMP pin voltage is higher than the current sense amplifier output; and the current comparator's output is low. The rising edge of the 380KHz CLK signal sets the RS Flip-Flop. Its output turns off M2 and turns on M1 thus connecting the SW pin and inductor to the input supply. The increasing inductor current is sensed and amplified by the Current Sense Amplifier. Ramp compensation is summed to Current Sense Amplifier output and compared to the Error Amplifier output by the Current Comparator. When the Current Sense Amplifier plus Slope Compensation signal exceeds the COMP pin voltage, the RS Flip-Flop is reset and the MP1580 reverts to its initial M1 off, M2 on state. If the Current Sense Amplifier plus Slope Compensation signal does not exceed the COMP voltage, then the falling edge of the CLK resets the Flip-Flop.

The output of the Error Amplifier integrates the voltage difference between the feedback and the 1.222V bandgap reference. The polarity is such that the FB pin voltage lower than 1.222V increases the COMP pin voltage. Since the COMP pin voltage is proportional to the peak inductor current an increase in its voltage increases current delivered to the output. The lower 10Ω switch ensures that the bootstrap capacitor voltage is charged during light load conditions. External Schottky Diode D1 carries the inductor current when M1 is off (see Figure 2)

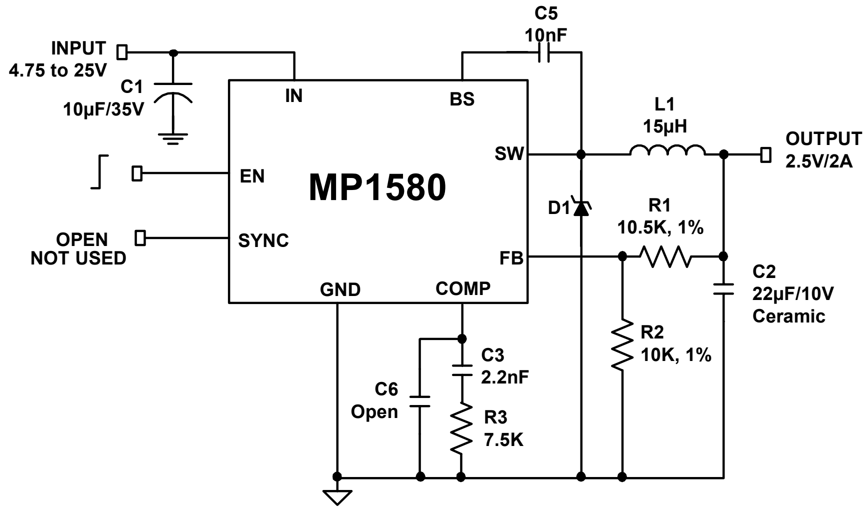


Figure 2: MP1580 with Murata 22µF / 10V Ceramic Output Capacitor

Application Information

Sync Pin Operation

The SYNC pin driving waveform should be a square wave with a rise time less than 20ns. Minimum High voltage level is 2.7V. Low level is less than 0.8V. The frequency of the external sync signal needs to be greater than 445 KHz.

A rising edge on the SYNC pin forces a reset of the oscillator. The upper transistor M1 is switched off immediately if it is not already off. 250ns later M1 turns on connecting SW to V_{IN}.

Setting the Output Voltage

The output voltage is set using a resistive voltage divider from the output to FB (see Figure 2). The voltage divider divides the output voltage down by the ratio:

$$V_{FB} = V_{OUT} * R2 / (R1 + R2)$$

Thus the output voltage is:

$$V_{OUT} = 1.222 * (R1 + R2) / R2$$

R2 can be as high as 100KΩ, but a typical value is 10KΩ. Using that value, R1 is determined by:

$$R1 \sim= 8.18 * (V_{OUT} - 1.222)\ (K\Omega)$$

For example, for a 3.3V output voltage, R2 is 10KΩ, and R1 is 17KΩ.

Inductor

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor results in less ripple current that in turn results in lower output ripple voltage. However, the larger value inductor has a larger physical size, higher series resistance, and/or lower saturation current. Choose an inductor that does not saturate under the worst-case load conditions. A good rule for determining the inductance is to allow the peak-to-peak ripple current in the inductor to be approximately 30% of the maximum load current. Also, make sure that the peak inductor current (the load current plus half the peak-to-peak inductor ripple current) is below the 2.4A minimum current limit. The inductance value can be calculated by the equation:

$$L = (V_{OUT}) * (V_{IN}-V_{OUT}) / (V_{IN} * f * \Delta I)$$

Where V_{OUT} is the output voltage, V_{IN} is the input voltage, f is the oscillator frequency, and

ΔI is the peak-to-peak inductor ripple current. Table 2 lists a number of suitable inductors from various manufacturers.

Table 2: Inductor Selection Guide

Vendor/ Model	Core Type	Core Material	Package Dimensions (mm) W	L	H
Sumida					
CR75	Open	Ferrite	7.0	7.8	5.5
CDH74	Open	Ferrite	7.3	8.0	5.2
CDRH5D28	Shielded	Ferrite	5.5	5.7	5.5
CDRH5D28	Shielded	Ferrite	5.5	5.7	5.5
CDRH6D28	Shielded	Ferrite	6.7	6.7	3.0
CDRH104R	Shielded	Ferrite	10.1	10.0	3.0
Toko					
D53LC Type A	Shielded	Ferrite	5.0	5.0	3.0
D75C	Shielded	Ferrite	7.6	7.6	5.1
D104C	Shielded	Ferrite	10.0	10.0	4.3
D10FL	Open	Ferrite	9.7	11.5	4.0
Coilcraft					
DO3308	Open	Ferrite	9.4	13.0	3.0
DO3316	Open	Ferrite	9.4	13.0	5.1

Input Capacitor

The input current to the step-down converter is discontinuous, and so a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. A low ESR capacitor is required to keep the noise at the IC to a minimum. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice.

The input capacitor value should be greater than 10µF. The capacitor can be electrolytic, tantalum or ceramic. However since it absorbs the input switching current it requires an adequate ripple current rating. Its RMS current rating should be greater than approximately 1/2 of the DC load current.

For insuring stable operation C1 should be placed as close to the IN pin as possible. Alternately a smaller high quality ceramic 0.1µF capacitor may be placed closer to the IN pin and a larger capacitor placed further away. If using this technique, it is recommended that the larger capacitor be a tantalum or electrolytic type. All ceramic capacitors should be placed close to the MP1580.

Output Capacitor

The output capacitor is required to maintain the DC output voltage. Low ESR capacitors are preferred to keep the output voltage ripple low. The characteristics of the output capacitor also affect the stability of the regulation control system. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. In the case of ceramic capacitors, the impedance at the oscillator frequency is dominated by the capacitance, and so the output voltage ripple is mostly independent of the ESR. The output voltage ripple is estimated to be:

$$V_{RIPPLE} \sim= 1.4 * V_{IN} * (f_{LC}/f)^2$$

Where V_{RIPPLE} is the output ripple voltage, V_{IN} is the input voltage, f_{LC} is the resonant frequency of the LC filter, f is the oscillator frequency. In the case of tanatalum or low-ESR electrolytic capacitors, the ESR dominates the impedance at the oscillator frequency, therefore the output ripple is calculated as:

$$V_{RIPPLE} \sim= \Delta I * R_{ESR}$$

Where V_{RIPPLE} is the output voltage ripple, ΔI is the inductor ripple current, and R_{ESR} is the equivalent series resistance of the output capacitors.

Output Rectifier Diode

The output rectifier diode supplies the current to the inductor when the upper transistor M1 is off. To reduce losses due to the diode forward voltage and recovery times, use a Schottky rectifier.

Table 3 provides the Schottky rectifier part numbers based on the maximum input voltage and current rating.

Table 3: Schottky Rectifier Selection Guide

V_{IN} (Max)	2A Load Current	
	Part Number	**Vendor**
15V	30BQ015	4
20V	B220	1
	SK23	6
	SR22	6
26V	20BQ030	4
	B230	1
	SK23	6
	SR23	3, 6
	SS23	2, 3

Table 4 lists some rectifier manufacturers.

Table 4: Schottky Diode Manufacturers

#	Vendor	Web Site
1	Diodes, Inc.	www.diodes.com
2	Fairchild Semiconductor	www.fairchildsemi.com
3	General Semiconductor	www.gensemi.com
4	International Rectifier	www.irf.com
5	On Semiconductor	www.onsemi.com
6	Pan Jit International	www.panjit.com.tw

Choose a rectifier who's maximum reverse voltage rating is greater than the maximum input voltage, and who's current rating is greater than the maximum load current.

Compensation

The system stability is controlled through the COMP pin. COMP is the output of the internal transconductance error amplifier. A series capacitor-resistor combination sets a pole-zero combination to control the characteristics of the control system.

The DC loop gain is:

$$A_{VDC} = (V_{FB} / V_{OUT}) * A_{VEA} * G_{CS} * R_{LOAD}$$

Where:
V_{FB} is the feedback threshold voltage, 1.222V
V_{OUT} is the desired output regulation voltage
A_{VEA} is the transconductance error amplifier voltage gain, 400 V/V
G_{CS} is the current sense gain, (roughly the output current divided by the voltage at COMP), 1.95 A/V
R_{LOAD} is the load resistance (V_{OUT} / I_{OUT} where I_{OUT} is the output load current)

The system has 2 poles of importance, one is due to the compensation capacitor (C3), and the other is due to the output capacitor (C2). These are:

$$f_{P1} = G_{EA} / (2\pi * A_{VEA} * C3)$$

Where P1 is the first pole, and G_{EA} is the error amplifier transconductance (770μA/V).

and

$$f_{P2} = 1 / (2\pi * R_{LOAD} * C2)$$

The system has one zero of importance, due to the compensation capacitor (C3) and the compensation resistor (R3). The zero is:

$$f_{Z1} = 1 / (2\pi * R3 * C3)$$

If a large value capacitor (C2) with relatively high equivalent-series-resistance (ESR) is used, the zero due to the capacitance and ESR of the output capacitor can be compensated by a third pole set by R3 and C6. The pole is:

$$f_{P3} = 1 / (2\pi * R3 * C6)$$

The system crossover frequency (the frequency where the loop gain drops to 1, or 0dB) is important. A good rule of thumb is to set the crossover frequency to approximately 1/10 of the switching frequency. In this case, the switching frequency is 380KHz, so use a crossover frequency, f_C, of 40KHz. Lower crossover frequencies result in slower response and worse transient load recovery. Higher crossover frequencies can result in instability.

Table 5: Compensation Values for Typical Output Voltage/Capacitor Combinations

V_{OUT}	C2	R3	C3	C6
2.5V	22µF Ceramic	7.5KΩ	2.2nF	None
3.3V	22µF Ceramic	10KΩ	1.5nF	None
5V	22µF Ceramic	10KΩ	2.2nF	None
12V	22µF Ceramic	10KΩ	5.6nF	None
2.5V	560µF/6.3V (30mΩ ESR)	10KΩ	30nF	None
3.3V	560µF/6.3V (30mΩ ESR)	10KΩ	39nF	None
5V	470µF/10V (30mΩ ESR)	10KΩ	47nF	None
12V	220µF/25V (30mΩ ESR)	10KΩ	56nF	None

Choosing the Compensation Components

The values of the compensation components given in Table 5 yield a stable control loop for the output voltage and capacitor given. To optimize the compensation components for conditions not listed in Table 5, use the following procedure:

Choose the compensation resistor to set the desired crossover frequency. Determine the value by the following equation:

$$R3 = 2\pi * C2 * V_{OUT} * f_C / (G_{EA} * G_{CS} * V_{FB})$$

Putting in the known constants and setting the crossover frequency to the desired 40KHz:

$$R3 \approx 1.37x10^{8} * C2 * V_{OUT}$$

The value of R3 is limited to 10KΩ to prevent output overshoot at startup, so if the value calculated for R3 is greater than 10KΩ, use 10KΩ. In this case, the actual crossover frequency is less than the desired 40KHz, and is calculated by:

$$f_C = R3 * G_{EA} * G_{CS} * V_{FB} / (2\pi * C2 * V_{OUT})$$

or

$$f_C \approx 2.92 \times 10^{-4} * R3 / (C2 * V_{OUT})$$

Choose the compensation capacitor to set the zero to ¼ of the crossover frequency. Determine the value by the following equation:

$$C3 = 0.22 * C2 * V_{OUT} / R3$$

Determine if the second compensation capacitor, C6 is required. It is required if the ESR zero of the output capacitor happens at less than four times the crossover frequency. Or:

$$8\pi * C2 * R_{ESR} * f_C \geq 1$$

or

$$(7.34x10^{-5} * R3 * R_{ESR}) / V_{OUT} \geq 1$$

Where R_{ESR} is the equivalent series resistance of the output capacitor.

If this is the case, add the second compensation capacitor. Determine the value by the equation:

$$C6 = C2 * R_{ESR(max)} / R3$$

Where $R_{ESR(MAX)}$ is the maximum ESR of the output capacitor.

Example:

V_{OUT} = 3.3V
C2= 22µF Ceramic (ESR = 10mΩ)

R3 ≈ $1.37x10^{8}$ $(22x10^{-6})$ (3.3) = 9.9KΩ. Use the nearest standard value of 10KΩ.

$$C3 = (0.22 * 22x10^{-6} * 3.3) / 10x10^{3} = 1.6nF$$

Use the nearest standard value of 1.5nF.

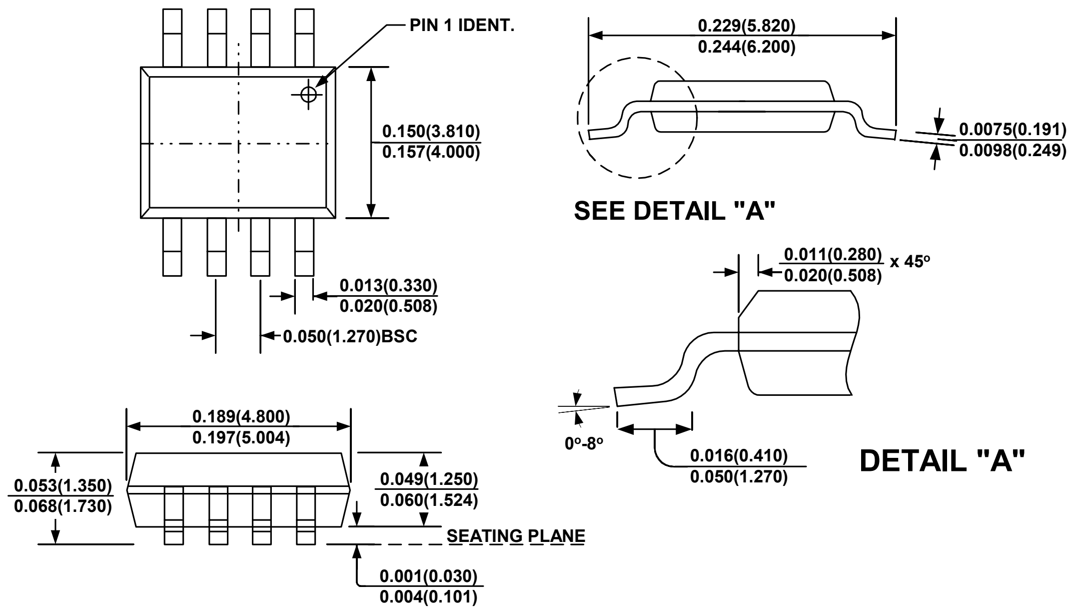
$2\pi * C2 * R_{ESR} * f_C$ = 0.014 which is less than 1, therefore no second compensation capacitor is required.

Table 6. Recommended Components for Standard Output Voltages

V_{OUT}	R1	L1 Minimum
1.22V	0Ω	6.8µH
1.5V	2.32KΩ	6.8µH
1.8V	4.75KΩ	10µH
2.5V	10.5KΩ	10µH
3.3V	16.9KΩ	15µH
5.0V	30.9KΩ	22µH

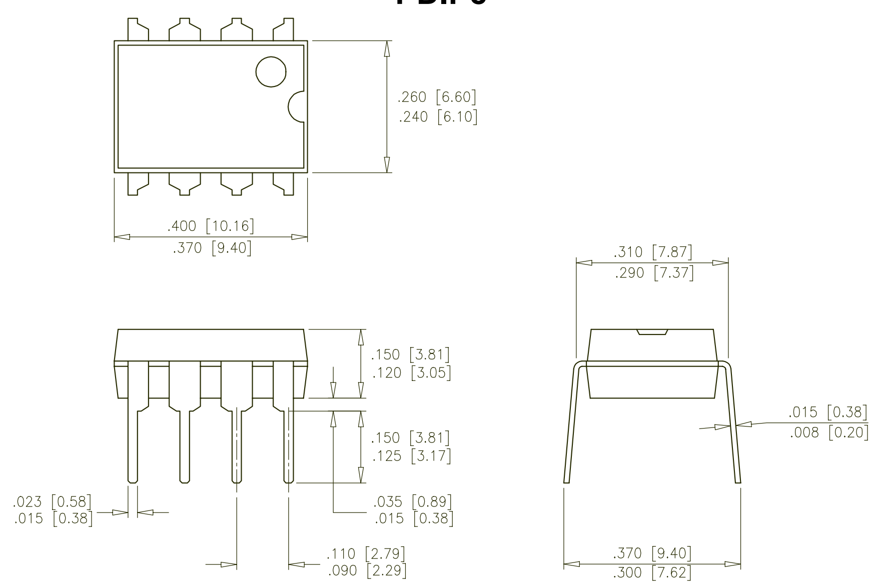
Packaging

SOIC8



NOTE:
1) Control dimension is in inches. Dimension in bracket is millimeters.

PDIP8



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