MP1410

2A Step-Down Switch-Mode Regulator

Monolithic Power Systems

PRELIMINARY

General Description

The MP1410 is a monolithic step-down switch-mode regulator 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 25µa of supply current.

The MP1410 requires a minimum number of readily available standard external components.

Ordering Information

Part Number *	Package	Temperature
MP1410ES	SOIC 8 pin	-20 to +85 °C
MP1410EP	PDIP 8 pin	-20 to +85 °C
EV0012	Evaluation Board	

* For Tape & Reel use suffix - Z (e.g. MP1410ES-Z)

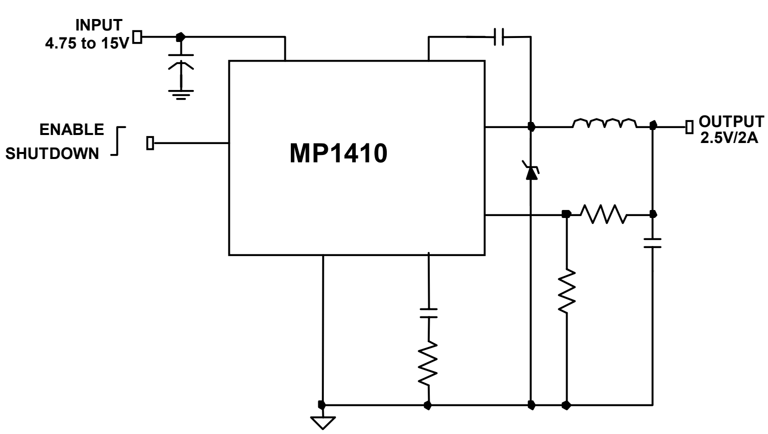
Features

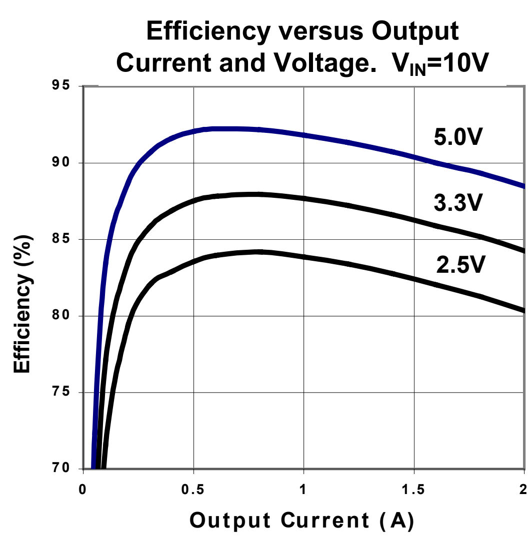
- 2A Output Current
- 0.18Ω Internal Power MOSFET Switch
- Stable with Low ESR Output Ceramic capacitors
- Up to 95% Efficiency
- 20uA Shutdown Mode
- Fixed 380kHz frequency
- Thermal Shutdown
- Cycle-by-cycle over current protection
- Wide 4.75 to 15V operating input range
- Output Adjustable from 1.22 to 13V
- Programmable under voltage lockout
- Available in 8 pin SO
- **Evaluation Board Available**

Applications

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

Figure 1: Typical Application Circuit





Absolute Maximum Ratings (Note 1)

IN Voltage	-0.3V to 16V
SW Voltage	-1V to VIN +1V
BS Voltage	V_{SW}-0.3V toV_{SW}+6V
All Other Pins	–0.3 to 6V
Junction Temperature	150°C
Lead Temperature	260°C
Storage Temperature	-65°C to 150°C

Recommended Operating Conditions (Note 2)

IN Input Voltage	4.75V to 15V
Operating Temperature	-20°C to +85°C

Package Thermal Characteristics (Note 3)

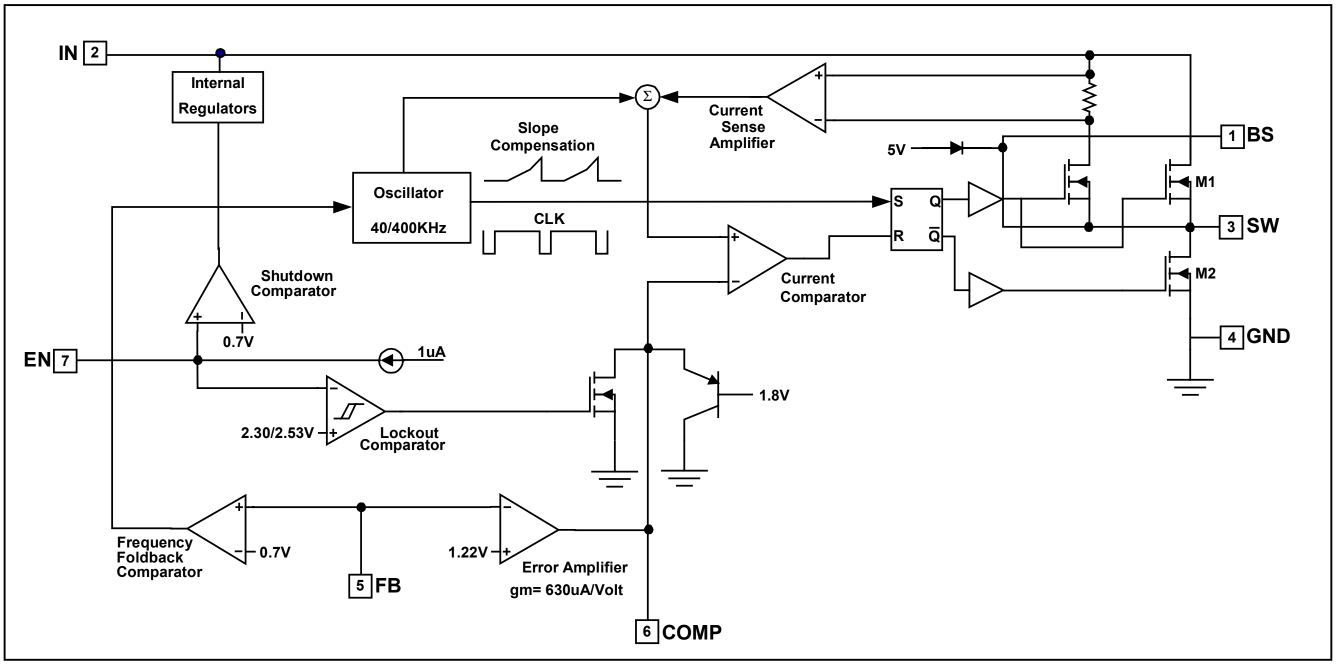
θ_{JA} (8 pin SOIC)	105°C/W

Electrical Characteristics (Unless otherwise specified Circuit of Figure1, V_{EN}=5V, V_{IN}=12V, T_A=25 C)

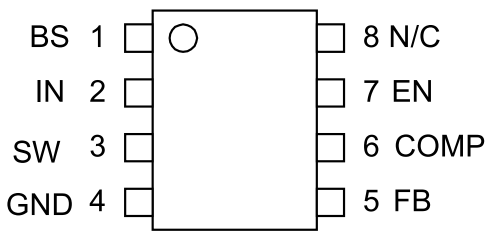
Parameters	Condition	Min	Typ	Max	Units
Feedback Voltage	4.75V ≤ V_{IN} ≤ 25V	1.184	1.222	1.258	V
Upper Switch On Resistance			0.25		Ω
Lower Switch On Resistance			10		Ω
Upper Switch Leakage	V_{EN}=0V; V_{SW}=0V			10	µA
Current Limit		2.4	2.95		A
Oscillator Frequency		320	380	440	KHz
Short Circuit Frequency	FB = 0V		42		KHz
Maximum Duty Cycle	FB = 1.0V		90		%
Minimum Duty Cycle	FB = 1.5V			0	%
Enable Threshold		0.7	1.0	1.3	V
Under Voltage Lockout Threshold High Going		2.0	2.5	3.0	V
Under Voltage Lockout Threshold Hysteresis			200		mV
Shutdown Supply current	V_{EN}=0V		25	50	µA
Operating Supply current	V_{EN}=0V; V_{FB} =1.4V		1.0	1.5	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 1” square of 1 oz. copper FR4 board.

Figure 2: Functional Block Diagram



Pin Description



#	Name	Description
1	BS	High-Side Gate Drive Boost Input. BS supplies the drive for the high-side n-channel MOSFET switch. Connect a 0.1µF or greater capacitor from SW to BS to power the high-side switch.
2	IN	Power Input. IN supplies the power to the IC, as well as the step-down converter switches. Drive IN with a 4.75V to 15V power source. Bypass IN to GND with a suitably large capacitor to eliminate noise on the input to the IC. See *Input Capacitor*.
3	SW	Power Switching Output. SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load. Note that a capacitor is required from SW to BS to power the high-side switch.
4	GND	Ground.
5	FB	Feedback Input. FB senses the output voltage to regulate that voltage. Drive FB with a resistive voltage divider from the output voltage. The feedback threshold is 1.22V. See *Setting the Output Voltage*.
6	COMP	Compensation Node. COMP is used to compensate the regulation control loop. Connect a series RC network from COMP to GND to compensate the regulation control loop. See *Compensatiionr*.
7	EN	Enable Input. EN is a digital input that turns the regulator on or off. Drive EN high to turn on the regulator, drive it low to turn it off. For automatic startup, leave EN unconnected.
8	N/C	No Connect

Functional Description

The MP1410 is a current-mode step-down switch-mode regulator. It regulates input voltages from 4.75V to 15V down to an output voltage as low as 1.22V, and is able to supply up to 2A of load current.

The MP1410 uses current-mode control to regulate the output voltage. The output voltage is measured at FB through a resistive voltage divider and amplified through the internal error amplifier. The output current of the transconductance error amplifier is presented at COMP where a network compensates the regulation control system. The voltage at COMP is compared to the switch current measured internally to control the output voltage.

The converter uses an internal n-channel MOSFET switch to step-down the input voltage to the regulated output voltage. Since the MOSFET requires a gate voltage greater than the input voltage, a boost capacitor connected between SW and BS drives the gate. The capacitor is internally charged while the switch is off. An internal 10Ω switch from SW to GND is used to insure that SW is pulled to GND when the switch is off to fully charge the BS capacitor.

Application Information

Setting the Output Voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB. The voltage divider divides the output voltage down by the ratio:

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

Thus the output voltage is:

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

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

R1 ~= 8.18 * (VOUT – 1.222) (kΩ).

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

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 C_{IN} should be placed as close to the IC as possible. Alternately a smaller high quality ceramic 0.1uF capacitor may be placed closer to the IC 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 places close to the MP1410.

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.

Application Information (Continued)

The characteristics of the output capacitor also effect 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 switching 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} ~= 1.4 * V_{IN} * (f_{LC}/f_{SW})^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_{SW} is the switching frequency.

In the case of tantalum or low-ESR electrolytic capacitors, the ESR dominates the impedance at the switching frequency, and so the output ripple is calculated as:

V_{RIPPLE} ~= ΔI * 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 high-side switch is off. To reduce losses due to the diode forward voltage and recovery times, use a Schottky rectifier.

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.

Table 1 provides a list of manufacturer's and their websites.

Table 1: Schottky Diode Manufacturers

#	Manufacturer	Website
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

Compensation

The output of the transconductance error amplifier is used to compensate the regulation system. Typically compensation capacitors, C_C sets the dominant pole. The compensation resistor sets a zero that should have the same frequency as the pole set by the load resistance and the output capacitor. If the output capacitor is not ceramic type, then there may need to be another capacitor from COMP to GND (C_{CA}) to compensate for the zero produced by the output capacitor and its ESR.

One of the critical parameters is the DC loop gain. This can be determined by the equation:

$$A_{VL} = (V_{FB} / V_{OUT}) * A_{EA} * A_{CS} * R_L$$

Where A_{VL} is the loop gain, V_{FB} is the feedback threshold, 1.22V, V_{OUT} is the regulated output voltage, A_{EA} is the error amplifier voltage gain, A_{CS} is the current sense gain, and R_L is the load resistance, or V_{OUT} / I_{LOAD}.

Simplifying the equation:

$A_{VL} = A_{EA} * A_{CS} * (V_{FB} / I_{LOAD(MAX)})$ ~= 1663 / $I_{LOAD(MAX)}$

Another critical parameter is the desired crossover frequency.

Application Information (Continued)

This should be approximately one-fifth of the switching frequency or approximately f_C = 75kHz. This and the loop gain determines the frequency of the dominant pole, $f_{P1} = f_C / A_{VL}$. The dominant pole occurs when $G_M / 2^* \pi * f_{P1} * C_C = A_{EA}$, where G_M is the error amplifier transconductance. This CC can be determined by:

$C_C \sim= 306 * A_{VL} / f_C \sim= 6.8 / I_{LOAD(MAX)}$ (nF).

The zero of the compensation network is determined by the compensation resistor RC. RC should be at the same frequency as the pole due to the output capacitor and the load resistor. Or:

$R_C * C_C = R_L * C_{OUT}$

Solving for RC:

$R_C = R_L * C_{OUT} / C_C = V_{OUT} * C_{OUT} / I_{LOAD(MAX)} * C_C$

If non-ceramic capacitors are used, the second compensation capacitor is required to compensate for the zero formed from the capacitor and its ESR. The second compensation capacitor can be determined by:

$R_C * C_{CA} = C_{OUT} * R_{ESR}$

Solving for C_{CA}:

$C_{CA} = C_{OUT} * R_{ESR} / R_C$.

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 will result in less ripple current that will result in lower output ripple voltage. However, the larger value inductor will have a larger physical size, higher series resistance, and/or lower saturation current. Choose an inductor that will not saturate under the worst-case load conditions.

Table 2 provides a list of manufacturer's and their websites.

Table 2: Inductor Manufacturers

#	Manufacturer	Website
1	Sumida Corporation	www.sumida.com
2	Toko, Inc.	www.toko.com
3	Coilcraft, Inc.	www.coilcraft.com

A good rule for determining the inductance to use, 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:

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

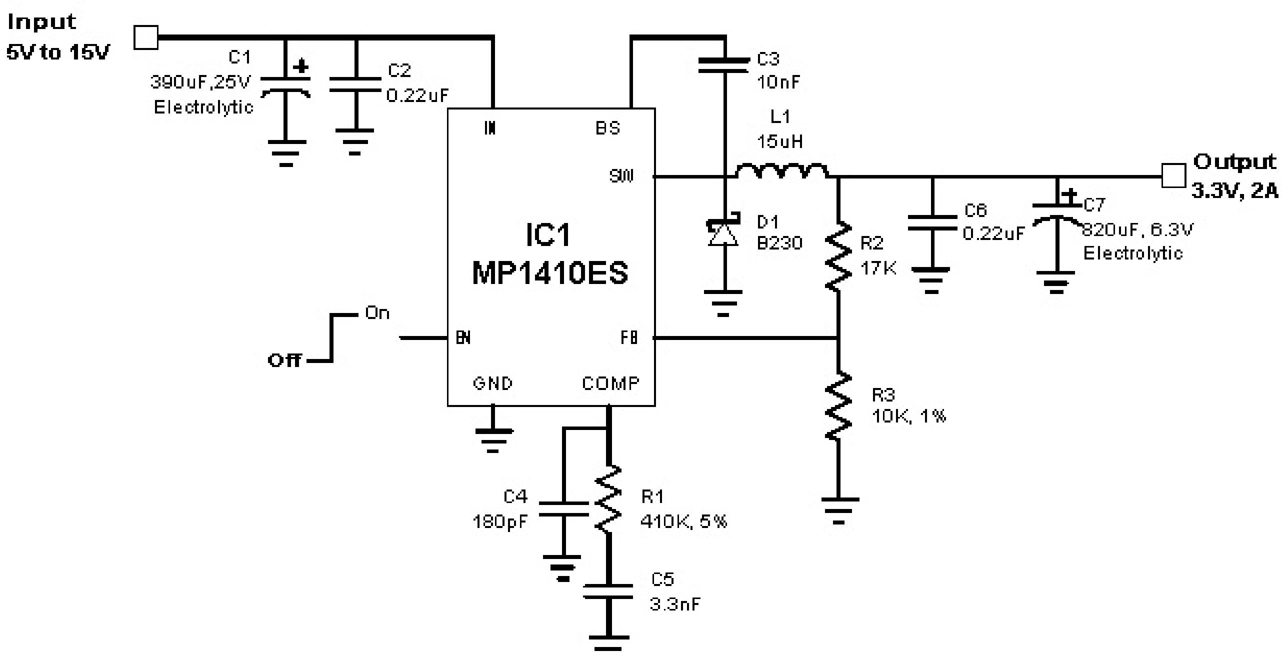
Where VOUT is the output voltage, VIN is the input voltage, f is the switching frequency, and ΔI is the peak-to-peak inductor ripple current.

Table 3 gives a list of inductors for the various inductor manufacturers.

Table 3: Inductor Selection Guide

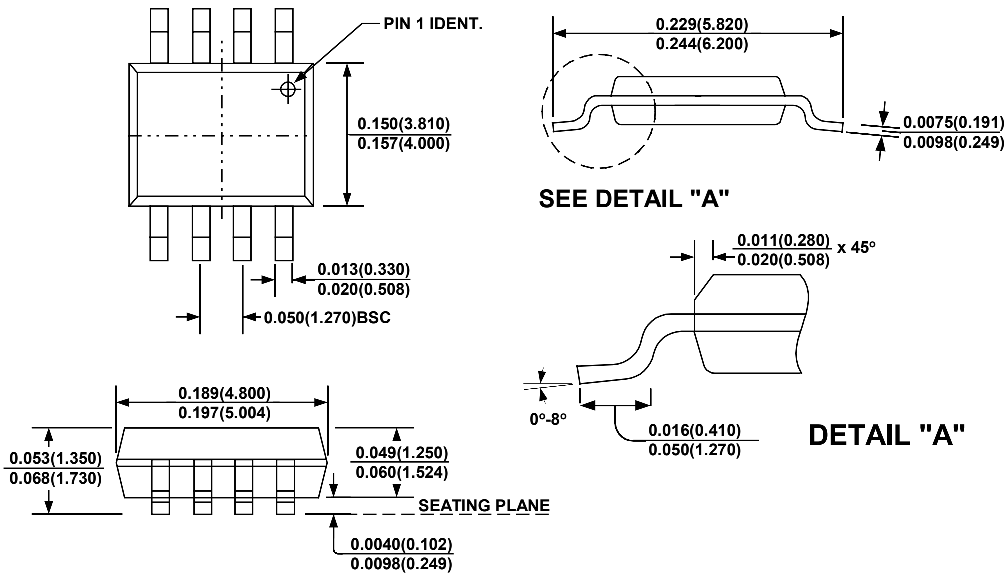
Vendor/Model	Value (uH)	Max I_{DC} (A)	Max DCR (Ω)	Core Type	Core Material	Package Dimensions (mm) W	L	H
Sumida								
CR75	10	2.3	0.070	Open	Ferrite	7.0	7.8	5.5
CR75	15	1.8	0.090	Open	Ferrite	7.0	7.8	5.5
CR75	22	1.5	0.110	Open	Ferrite	7.0	7.8	5.5
CDH74	10	2.75	0.056	Open	Ferrite	7.3	8.0	5.2
CDH74	15	2.1	0.083	Open	Ferrite	7.3	8.0	5.2
CDH74	22	1.7	0.130	Open	Ferrite	7.3	8.0	5.2
CDRH5D28	6.8	1.6	0.053	Shielded	Ferrite	5.5	5.7	5.5
CDRH5D28	10	1.3	0.065	Shielded	Ferrite	5.5	5.7	5.5
CDRH5D28	15	1.1	0.103	Shielded	Ferrite	5.5	5.7	5.5
CDRH6D28	6.8	2.3	0.031	Shielded	Ferrite	6.7	6.7	3.0
CDRH6D28	10	1.7	0.065	Shielded	Ferrite	6.7	6.7	3.0
CDRH6D28	15	1.6	0.057	Shielded	Ferrite	6.7	6.7	3.0
CDRH6D28	22	1.3	0.096	Shielded	Ferrite	6.7	6.7	3.0
CDRH6D38	6.8	2.3	0.031	Shielded	Ferrite	6.7	6.7	4.0
CDRH6D38	10	2.0	0.038	Shielded	Ferrite	6.7	6.7	4.0
CDRH6D38	15	1.6	0.057	Shielded	Ferrite	6.7	6.7	4.0
CDRH6D38	22	1.3	0.096	Shielded	Ferrite	6.7	6.7	4.0
CDRH104R	6.8	4.8	0.027	Shielded	Ferrite	10.1	10.0	3.0
CDRH104R	10	4.4	0.035	Shielded	Ferrite	10.1	10.0	3.0
CDRH104R	15	3.6	0.050	Shielded	Ferrite	10.1	10.0	3.0
CDRH104R	22	2.9	0.073	Shielded	Ferrite	10.1	10.0	3.0
Toko								
D53LC Type A	6.8	2.01	0.068	Shielded	Ferrite	5.0	5.0	3.0
D53LC Type A	10	1.77	0.090	Shielded	Ferrite	5.0	5.0	3.0
D53LC Type A	15	1.40	0.142	Shielded	Ferrite	5.0	5.0	3.0
D53LC Type A	22	1.15	0.208	Shielded	Ferrite	5.0	5.0	3.0
D75C	6.8	1.79	0.050	Shielded	Ferrite	7.6	7.6	5.1
D75C	10	1.63	0.055	Shielded	Ferrite	7.6	7.6	5.1
D75C	15	1.33	0.081	Shielded	Ferrite	7.6	7.6	5.1
D75C	22	1.09	0.115	Shielded	Ferrite	7.6	7.6	5.1
D104C	10	4.3	0.0265	Shielded	Ferrite	10.0	10.0	4.3
D104C	16	3.3	0.0492	Shielded	Ferrite	10.0	10.0	4.3
D104C	22	2.5	0.0265	Shielded	Ferrite	10.0	10.0	4.3
D10FL	10	2.26	0.051	Open	Ferrite	9.7	11.5	4.0
D10FL	15	2.00	0.066	Open	Ferrite	9.7	11.5	4.0
D10FL	22	1.83	0.100	Open	Ferrite	9.7	11.5	4.0
Coilcraft								
DO3308	10	2.4	0.030	Open	Ferrite	9.4	13.0	3.0
DO3308	15	2.0	0.040	Open	Ferrite	9.4	13.0	3.0
DO3308	22	1.6	0.050	Open	Ferrite	9.4	13.0	3.0
DO3316	10	3.8	0.030	Open	Ferrite	9.4	13.0	5.1
DO3316	15	3.0	0.040	Open	Ferrite	9.4	13.0	5.1
DO3316	22	2.6	0.050	Open	Ferrite	9.4	13.0	5.1

Figure 3. MP1410 with Murata 22uF/10V Ceramic Output Capacitor



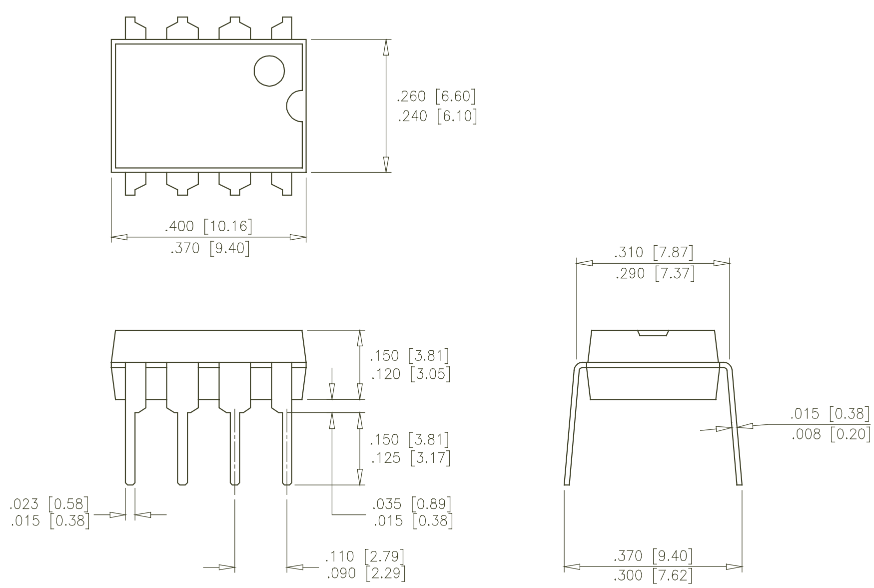
Packaging

SOIC 8 Pin



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

PDIP 8 Pin



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