Description

The ECT3408 is a 1.5MHz constant frequency current mode PWM step-down converter. It is ideal for portable equipment requiring very high current up to 1.2A from single-cell Lithium-ion batteries while still achieving over 90% efficiency during peak load conditions. The ECT3408 also can run at 100% duty cycle for low dropout operation, extending battery life in portable systems while light load operation provides very low output ripple for noise sensitive applications.

The ECT3408 can supply up to 1.2A output load current from a 2.5V to 5.5V input voltage and the output voltage can be regulated as low as 0.6V. The high switching frequency minimizes the size of external components while keeping switching losses low. The internal slope compensation setting allows the device to operate with smaller inductor values to optimize size and provide efficient operation.

The ECT3408 is available in adjustable (0.6V to VIN) and fixed (1.8V) output voltage versions. The device is available in a Pb-free, 3x3mm TDFN-10 package and is rated over the -40°C to+85°C temperature range.

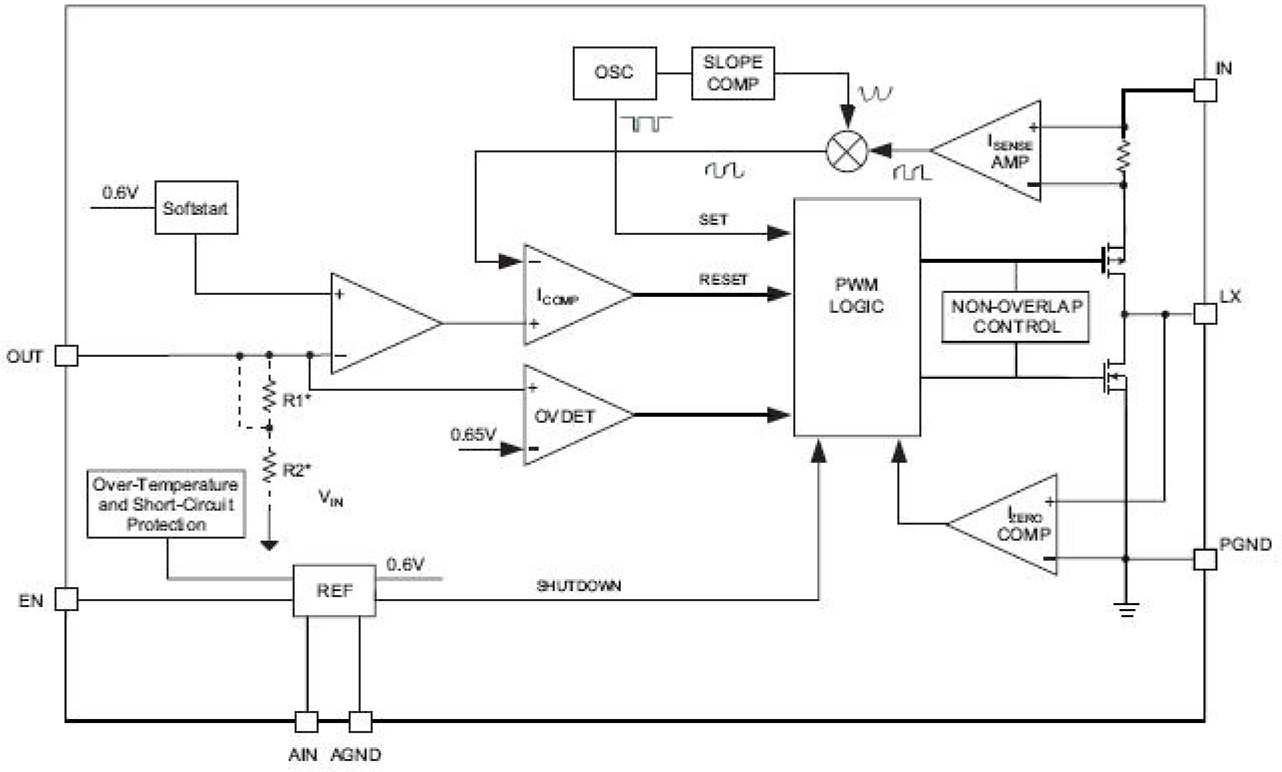
Features

- Input Voltage Range: 2.5V to 5.5V
- Output Voltages from 0.6V to V_{IN}
- 1.2A Output Current
- High Efficiency: Up to 95%
- 1.5MHz Constant Switching Frequency
- Low $R_{DS(ON)}$ Internal Switches: 0.15Ω
- Allows Use of Ceramic Capacitors
- Current Mode Operation for Excellent Line and Load Transient Response
- Short-Circuit and Thermal Fault Protection
- Soft Start
- Low Dropout Operation: 100% Duty Cycle
- Low Shutdown Current: $I_{SHUTDOWN} < 1\mu A$
- Available is the Lead Free package

Applications

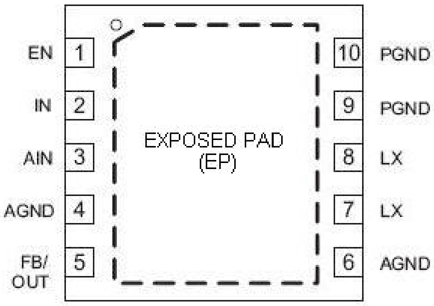
- Cellular Phones
- Digital Cameras
- DSP Core Supplies
- PDAs
- Portable Instruments
- Smart Phones

Block Diagram



Pin Assignment

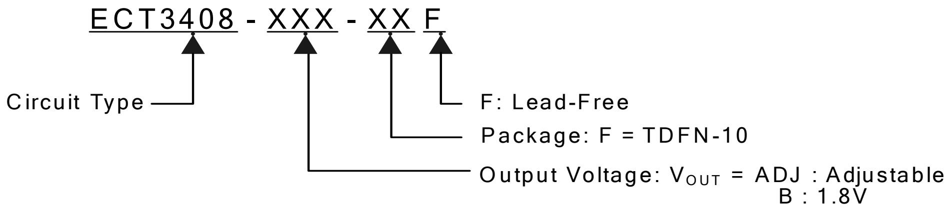
TDFN-10
(Top View)



Pin Descriptions

Pin#	Symbol	Function
1	EN	Enable pin. Active high. In shutdown, all functions are disabled drawing <1μA supply current. Do not leave EN floating.
2	IN	Power supply input pin. Must be closely decoupled to AGND with a 2.2μF or greater ceramic capacitor.
3	AIN	Analog supply input pin. Provides bias for internal circuitry.
4,6	AGND	Analog ground pin
5	FB/OUT	FB (ECT3408-ADJ): Adjustable Version feedback input pin. Connect FB to the center point of the external resistor divider. The feedback threshold voltage is 0.6V. OUT (ECT3408-B): Fixed version feedback input. Connect OUT to the output voltage, V_{OUT}.
7,8	LX	Switching node pin. Connect the output inductor to this pin.
9,10	PGND	Power ground pin
—	EP	Power ground exposed pad. Must be connected to bare copper ground plane.

Ordering Information



Marking Information

Package	Vout Voltage	Part Number	Marking	Marking Information
TDFN-10	ADJ	ECT3408-ADJ-FF	3408X YYWW	X is the output voltage of production. Example: Blank →Adjustable, B→1.8V. YY is the year of production. 07 means the product is manufactured in year of 2007. WW is the week of production. 25 means the Product is manufactured in the 25th week.
	1.8V	ECT3408-B-FF		

Absolute Maximum Rating (1)

Parameter Sy	mbol	Value	Units
Input Supply Voltages	V_{IN},V_{AIN}	-0.3 to 6.0	V
FB, LX Voltages	V_{FB} ,V_{LX}	-0.3 to V_{IN} + 0.3	V
EN Voltage	V_{EN}	-0.3 to V_{IN} + 0.3	V
Ground Voltages	PGND,AGND	-0.3 to 6.0	V
Operating Temperature Range	T_A	-40 to +85	°C
Storage Temperature	T_{STG}	-65 to 150	°C
Lead Temperature (Soldering, 10s)	T_{LEAD}	300	°C

Recommended Operating Conditions (3)

Parameter Sy	mbol	Value	Units
Thermal Resistance (2)	θ_{JA}	45 °C/W	
Maximum Power Dissipation at T_A = 25°C	P_D	2.2 W	

Note:

(1). Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

(2). T_J is calculated from the ambient temperature T_A and power dissipation P_D according to the following formula: $T_J = T_A + P_D x\theta_{JA}$.

(3). Thermal resistance is specified with approximately 1 square inch of 1 oz copper.

Electrical Characteristics[1]

V_{IN} = 3.6V, T_A = -40°C to +85°C unless otherwise noted; typical values are T_A = 25°C.

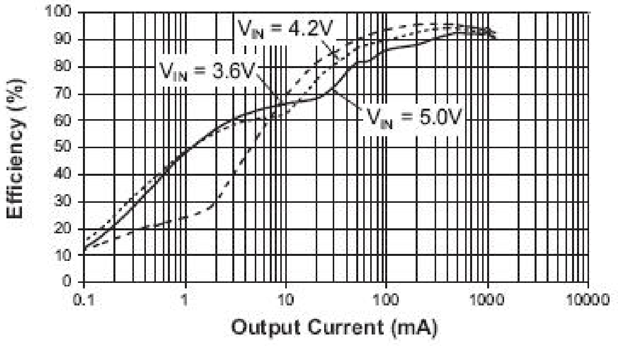
Description		Symbol	Conditions	Min	Typ	Max	Units
Input Voltage Range[2]		V_{IN}	—	2.5	—	5.5	V
Output Voltage Range		V_{OUT}	—	0.6	—	V_{IN}	V
Input DC Supply Current	Active Mode	I_Q	V_{FB} = 0.5V	—	300	500	µA
	Shutdown Mode		V_{FB} = 0V, V_{AIN}=5.5V	—	0.1	1	µA
Feedback Input Bias Current		I_{FB}	V_{FB} = 0.65V	—	—	30	nA
Regulated Feedback Voltage[3]		V_{FB}	T_A = 25°C	0.5880	0.6000	0.6120	V
			T_A = 0°C ≤ T_A ≤ 85°C	0.5865	0.6000	0.6135	
			T_A = -40°C ≤ T_A ≤ 85°C	0.5850	0.6000	0.6150	
Line Regulation		$\Delta V_{LINEREG}/\Delta V_{IN}$	V_{IN} = 2.5V to 5.5V, I_{OUT} = 10mA	—	0.10	0.20	%/V
Load Regulation		$\Delta V_{LOADREG}/\Delta I_{OUT}$	I_{OUT} = 10mA to 1200mA	—	0.50	—	%/A
Output Voltage Accuracy		V_{FB} V_{OUT}	V_{IN} = 2.5 to 4.2V, I_{OUT} = 10 to 1200mA	-3	—	+3	%
Oscillator Frequency		F_{OSC}	V_{FB} = 0.6V	1.2	1.5	1.8	MHz
Startup Time		T_S	From Enable to Output Regulation	—	1.3	—	ms
Over-Temperature Shutdown Threshold		T_{SD}	—	—	150	—	°C
Over-Temperature Shutdown Hysteresis		T_{HYS}	—	—	15	—	°C
Peak Switch Current		I_{LIM}	—	—	2.5	—	A
P-CH MOSFET		$R_{DS(ON)}$	V_{IN} = 3.6V	—	135	200	mΩ
N-CH MOSFET			V_{IN} = 3.6V	— 95		150	
Enable Threshold Low		$V_{EN(L)}$	—	—	—	0.3	V
Enable Threshold High		$V_{EN(H)}$	—	1.5	—	—	V
Input Low Current		I_{EN}	V_{IN} = V_{EN} = 5.5V	-1.0	—	1.0	µA

Note:

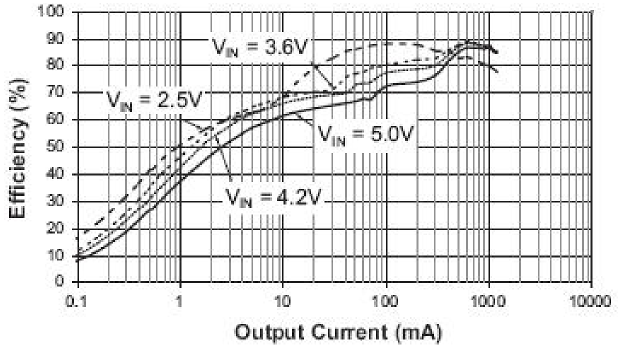
1. The ECT3408 is guaranteed to meet performance specifications over the -40°C to +85°C operating temperature range and is assured by design, characterization, and correlation with statistical process controls.
2. V_{IN} should be not less than V_{OUT} + $V_{DROPOUT}$, where $V_{DROPOUT}$ = I_{OUT} x ($R_{DS(ON)PMOS}$ + $ESR_{INDUCTOR}$), typically $V_{DROPOUT}$ = 0.3V.
3. The regulated feedback voltage is tested in an internal test mode that connects V_{FB} to the output of the error amplifier.

Typical Performance Characteristics

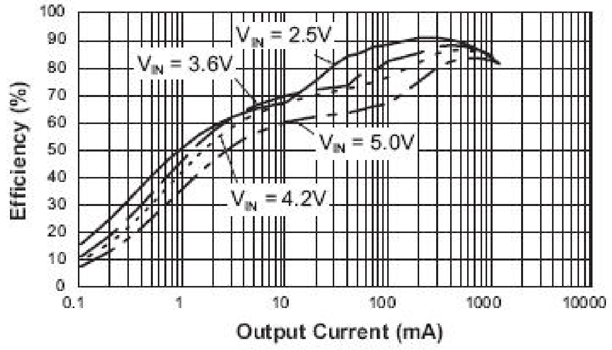
Efficiency vs. Output Current
(V_{OUT} = 3.3V; T_A = 25°C; L = 2.2μH)



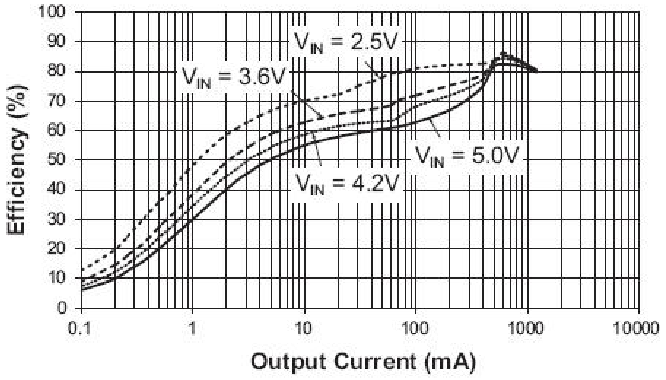
Efficiency vs. Output Current
(V_{OUT} = 1.8V; T_A = 25°C; L = 2.2μH)



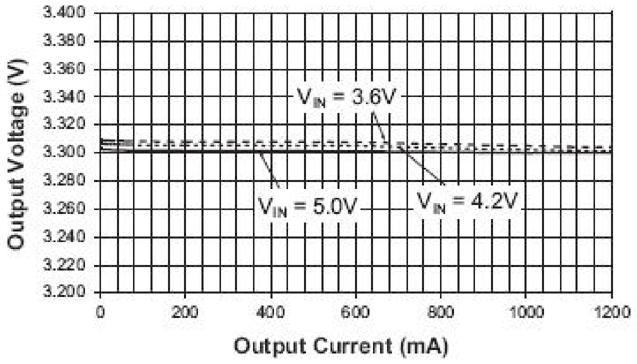
Efficiency vs. Output Current
(V_{OUT} = 1.5V; T_A = 25°C; L = 2.2μH)



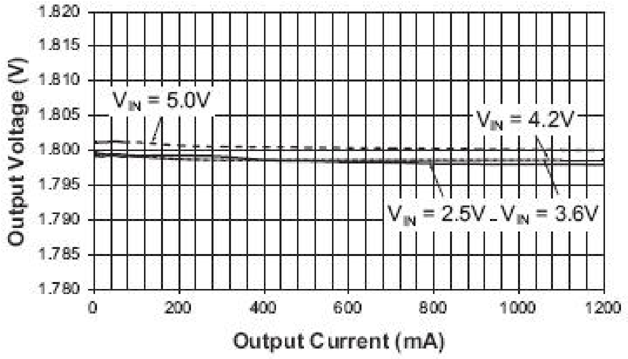
Efficiency vs. Output Current
(V_{OUT} = 1.2V; T_A = 25°C; L = 2.2μH)



Output Voltage vs. Output Current
(V_{OUT} = 3.3V; T_A = 25°C; L = 2.2μH)

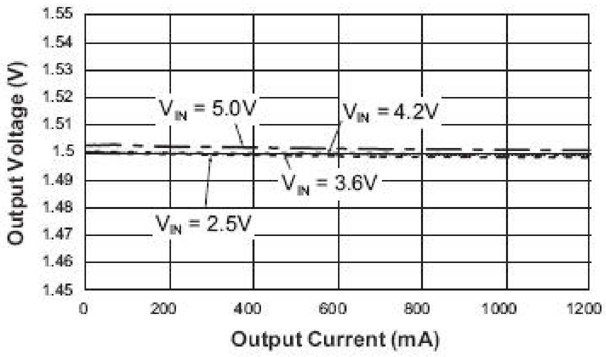


Output Voltage vs. Output Current
(V_{OUT} = 1.8V; T_A = 25°C; L = 2.2μH)

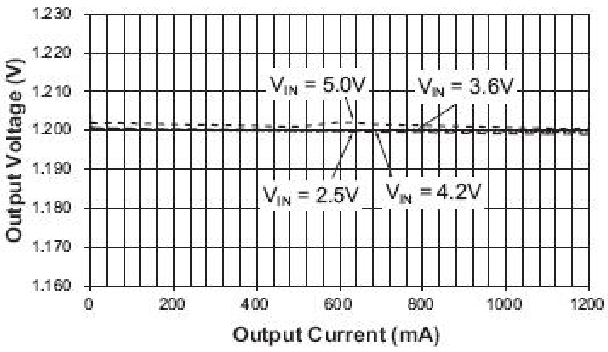


Typical Performance Characteristics (Continued)

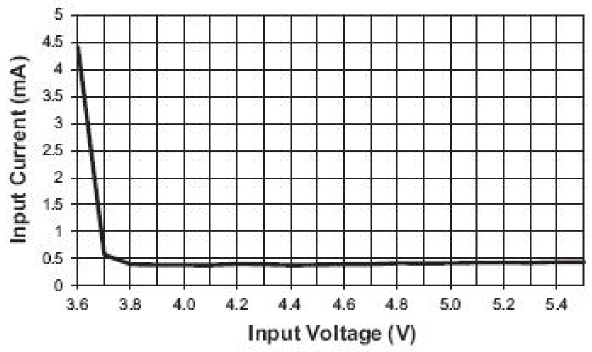
Output Voltage vs. Output Current
(V_{OUT} = 1.5V; T_A = 25°C; L = 2.2µH)



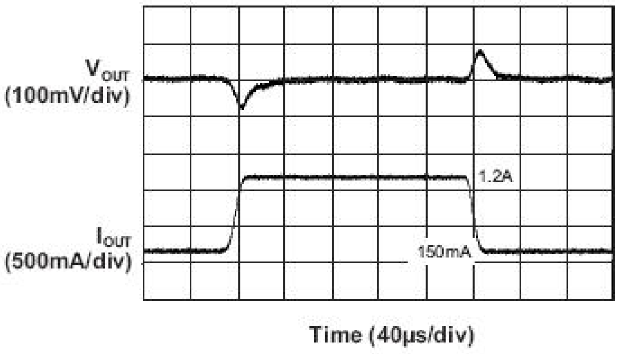
Output Voltage vs. Output Current
(V_{OUT} = 1.2V; T_A = 25°C; L = 2.2µH)



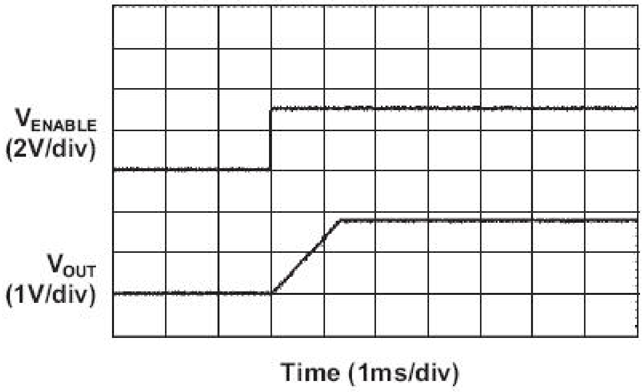
Input Current vs. Input Voltage
(V_{OUT} = 3.3V; L = 2.2µH)



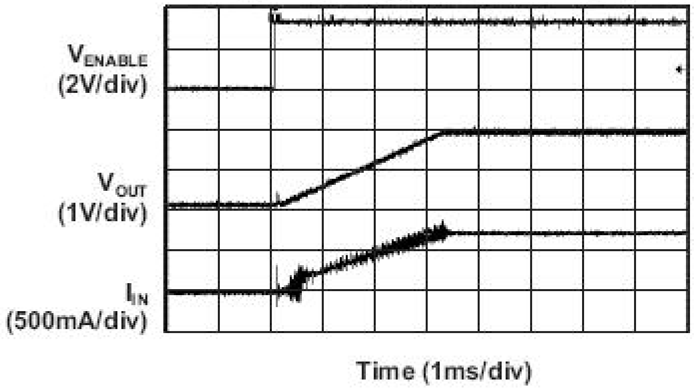
Load Transient Response
(V_{OUT} = 1.8V, AC Coupled; V_{IN} = 3.6V;
150mA to 1.2A; L = 2.2µH)



Start-Up Response
(V_{OUT} = 1.8V; V_{IN} = 3.6V; No Load;
C_{IN} = 10µF; C_{OUT} = 22µF; L = 2.2µH)



Start-Up Response
(V_{OUT} = 1.8V; V_{IN} = 3.6V; I_{LOAD} = 1.2A;
C_{IN} = 10µF; C_{OUT} = 22µF; L = 2.2µH)



Functional Description

The ECT3408 is a high output current monolithic switch-mode step-down DC-DC converter. The device operates at a fixed 1.5MHz switching frequency, and uses slope compensated current mode architecture. This step down DC-DC converter can supply up to 1200mA output current at V_{IN} = 3V and has an input voltage range from 2.5V to 5.5V. It minimizes external component size and optimizes efficiency at the heavy load range. The slope compensation allows the device to remain stable over a wider range of inductor values so that smaller values (1μH to 4.7μH) with lower DCR can be used to achieve higher efficiency. Apart from the small bypass input capacitor, only a small L-C filter is required at the output. The fixed output version requires only three external power components (C_{IN}, C_{OUT}, and L). The adjustable version can be programmed with external feedback to any voltage, ranging from 0.6V to near the input voltage. It uses internal MOSFETs to achieve high efficiency and can generate very low output voltages by using an internal reference of 0.6V. At dropout, the converter duty cycle increases to100% and the output voltage tracks the input voltage minus the low $R_{DS\ (ON)}$ drop of the P-channel high-side MOSFET and the inductor DCR. The Internal error amplifier and compensation provides excellent transient response, load and line regulation. Internal soft start eliminates any output voltage overshoot when the enable or the input voltage is applied.

Current Mode PWM Control

Slope compensated current mode PWM control provides stable switching and cycle-by-cycle current limit for excellent load and line response and protection of the internal main switch (P-channel MOSFET) and synchronous rectifier (N-channel MOSFET). During normal operation, the internal P-channel MOSFET is turned on for a specified time to ramp the inductor current at each rising edge of the internal oscillator, and is switched off when the peak inductor current is above the error voltage. The current comparator, I_{COMP}, limits the peak inductor current. When the main switch is off, the synchronous rectifier turns on immediately and stays on until either the inductor current starts to reverse, as indicated by the current reversal comparator, I_{ZERO}, or the beginning of the next clock cycle.

Control Loop

The ECT3408 is a peak current mode step-down converter. The current through the P-channel MOSFET (high side) is sensed for current loop control, as well as short circuit and overload protection. A slope compensation signal is added to the sensed current to maintain stability for duty cycles greater than 50%. The peak current mode loop appears as a voltage-programmed current source in parallel with the output capacitor. The output of the voltage error amplifier programs the current mode loop for the necessary peak switch current to force a constant output voltage for all load and line conditions. Internal loop compensation terminates the Transconductance voltage error amplifier output. For fixed voltage versions, the error amplifier reference voltage is internally set to program the converter output voltage. For the adjustable output, the error amplifier reference is fixed at 0.6V.

Soft Start / Enable

Soft start limits the current surge seen at the input and eliminates output voltage overshoot. The enable pin is active high. When pulled low, the enable input (EN) forces the ECT3408 into a low- power, non-switching state. The total input current during shutdown is less than 1μA.

Current Limit and Over-Temperature Protection

For overload conditions, the peak input current is limited to 2.5A. To minimize power dissipation and stresses under current limit and short-circuit conditions, switching is terminated after entering current limit for a series of pulses. The termination lasts for seven consecutive clock cycles after a current limit has been sensed during a series of four consecutive clock cycles.

Thermal protection completely disables switching when internal dissipation becomes excessive. The junction over-temperature threshold is 150 °C with 15°C of hysteresis. Once an over-temperature or over-current fault conditions is removed, the output voltage automatically recovers.

Dropout Operation

When the battery input voltage decreases near the value of the output voltage, the ECT3408 allows the main switch to remain on for more than one switching cycle and increases the duty cycle until it reaches 100%.

The duty cycle D of a step-down converter is defined as:

$$D = T_{ON} * F_{OSC} * 100\% \approx \frac{V_{OUT}}{V_{IN}} * 100\%$$

Where T_{ON} is the main switch on time and F_{OSC} is the oscillator frequency.

The output voltage then is the input voltage minus the voltage drop across the main switch and the inductor. At low input supply voltage, the $R_{DS\,(ON)}$ of the P-channel MOSFET increases and the efficiency of the converter decreases. Caution must be exercised to ensure the heat dissipated does not exceed the maximum junction temperature of the IC.

Maximum Load Current

The ECT3408 will operate with an input supply voltage as low as 2.5V; however, the maximum load current decreases at lower input due to the large IR drop on the main switch and synchronous rectifier. The slope compensation signal reduces the peak inductor current as a function of the duty cycle to prevent sub-harmonic oscillations at duty cycles greater than 50%. Conversely, the current limit increases as the duty cycle decreases.

Applications Information

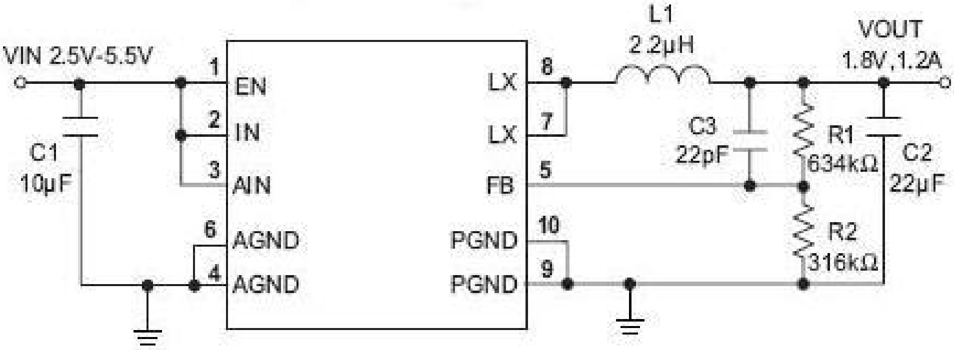


Figure1. Basic Application Circuit for the Adjustable Output Version

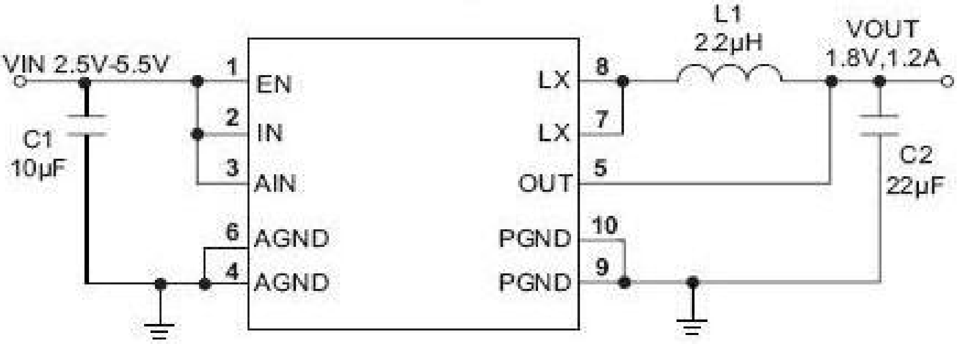


Figure2. Basic Application Circuit for the Fixed Output Version

Setting the Output Voltage

Figure 1 shows the basic application circuit with the ECT3408 adjustable output version while Figure 2 shows the application circuit with the ECT3408 fixed output version. For applications requiring an adjustable output voltage, the ECT3408 adjustable version can be externally programmed. Resistors R1 and R2 in Figure 1 program the output to regulate at a voltage higher than 0.6V. To limit the bias current required for the external feedback resistor string while maintaining good noise immunity, the minimum suggested value for R2 is 59kΩ. Although a larger value will further reduce quiescent current, it will also increase the impedance of the feedback node, making it more sensitive to external noise and interference. Table 1 summarizes the resistor values for various output voltages with R2 set to either 59kΩ for good noise immunity or 316kΩ for reduced no load input current.

The adjustable version of the ECT3408, combined with an external feed forward capacitor (C3 in Figure 1), delivers enhanced transient response for extreme pulsed load applications. The addition of the feed forward capacitor typically requires a larger output capacitor C2 for stability. The external resistor sets the output voltage according to the following equation:

$$V_{OUT} = 0.6V * \left[1 + \frac{R1}{R2}\right] \quad \textbf{or} \quad R1 = \left[\left(\frac{V_{OUT}}{0.6V}\right) - 1\right] * R2$$

Table1. Resistor Selection for Output Voltage Setting; Standard 1% Resistor Values Substituted Closest to the Calculated Values.

V_{OUT} (V)	R1=59K R2 (KΩ) R1	=316K R2(KΩ)
0.8 19.6		105
0.9 29.4		158
1.0 39.2		210
1.1 49.9		261
1.2 59.0		316
1.3 68.1		365
1.4 78.7		422
1.5 88.7		475
1.8 118		634
1.85 124		655
2.0 137		732
2.5 187		1000
3.3 267		1430

Inductor Selection

For most designs, the ECT3408 operates with inductor values of 1μH to 4.7μH. Low inductance values are physically smaller, but require faster switching, which results in some efficiency loss. The inductor value can be derived from the following equation:

$$L = \frac{V_{OUT} * (V_{IN} - V_{OUT})}{V_{IN} * \Delta I_L * f_{osc}}$$

Where ΔI_L is inductor ripple current. Large value inductors lower ripple current and small value inductors result in high ripple currents. Choose inductor ripple current approximately 30% of the maximum load current 1200mA, or

$\Delta I_L = 360mA$.

For output voltages above 2.0V, when light-load efficiency is important, the minimum recommended inductor is 2.2μH Manufacturer's specifications list both the inductor.
DC current rating, which is a thermal limitation and the peak current rating, which is determined by the saturation characteristics. The inductor should not show any appreciable saturation under normal load conditions. Some inductors may meet the peak and average current ratings yet result in excessive losses due to a high DCR.
Always consider the losses associated with the DCR and its effect on the total converter efficiency when selecting an inductor. For optimum voltage- positioning load transients, choose an inductor with DC series resistance in the 20mΩ to 100mΩ range. For higher efficiency at heavy loads (above 200mA), or minimal load regulation (but some transient overshoot), the resistance should be kept below 100mΩ. The DC current rating of the inductor should be at least equal to the maximum load current plus half the ripple current to prevent core saturation (1200mA + 360mA).
Table 2 lists some typical surface mount inductors that meet target applications for the ECT3408.
For example, the 2.2μH SD3118-2R2-R inductor selected from Coiltronics has a 74mΩDCR and a 2.00ADC current rating. At full load, the inductor DC loss is 106mW which gives a 5% loss in efficiency for a 1200mA, 1.8V output.

Table2. Suggested Component Selection Information

Manufacturer	**Part Number**	**Inductance (μH)**	**Max DC Current (A)**	**DCR (mΩ)**	**Size (mm) LxWxH**	**Type**
Sumida	CDRH2D14NP	2.2	1.5	75	3.2x3.2x1.55	Shielded
Sumida	CDRH3D14	3.3	1.35	80	4x4x1.5	Shielded
Sumida	CDRH3D14/HP	4.7	1.45	171	4x4x1.5	Shielded
Coiltronics	SD3118-2R2-R	2.2	2.00	74	3.1x3.1x1.8	Shielded
Coiltronics	SD3114-2R2-R	2.2	1.74	110	3.1x3.1x1.4	Shielded
Coiltronics	SD3118-3R3-R	3.3	1.59	113	3.1x3.1x1.8	Shielded
Coiltronics	SD3118-4R7-R	4.7	1.31	162	3.1x3.1x1.8	Shielded
Manufacturer	**Part Number**		**Value**	**Voltage (V)**	**Temp. Co.**	**Case**
Murata	GRM219R60J106KE19		10μF	6.3	X5R	0805
Murata	GRM21BR60J226ME39		22μF	6.3	X5R	0805
Murata	GRM1551X1E220JZ01B		22pF	25	JIS	0402

Input Capacitor Selection

The input capacitor reduces the surge current drawn from the input and switching noise from the device. The input capacitor impedance at the switching frequency should be less than the input source impedance to prevent high frequency switching current passing to the input. The calculated value varies with input voltage and is a maximum when V_{IN} is double the output voltage.

$$C_{IN} = \frac{\frac{V_O}{V_{IN}} * \left(1 - \frac{V_O}{V_{IN}}\right)}{\left(\frac{V_{PP}}{I_O} - ESR\right) * F_S}$$

$$C_{IN(MIN)} = \frac{1}{\left(\frac{V_{PP}}{I_O} - ESR\right) * 4 * F_S}$$

A low ESR input capacitor sized for maximum RMS current must be used. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. A 22µF ceramic capacitor for most applications is sufficient. A large value may be used for improved input voltage filtering.

The maximum input capacitor RMS current is:

$$I_{RMS} = I_O \cdot \sqrt{\frac{V_O}{V_{IN}} \cdot \left(1 - \frac{V_O}{V_{IN}}\right)}$$

The input capacitor RMS ripple current varies with the input and output voltage and will always be less than or equal to half of the total DC load current

$$I_{RMX(MAX)} = \frac{I_O}{2}$$

To minimize stray inductance, the capacitor should be placed as closely as possible to the IC. This keeps the high frequency content of the input cur- rent localized, minimizing EMI and input voltage ripple.

A laboratory test set-up typically consists of two long wires running from the bench power supply to the evaluation board input voltage pins. The inductance of these wires, along with the low-ESR ceramic input capacitor, can create a high Q net- work that may affect converter performance. This problem often becomes apparent in the form of excessive ringing in the output voltage during load transients. Errors in the loop phase and gain measurements can also result.

Since the inductance of a short PCB trace feeding the input voltage is significantly lower than the power leads from the bench power supply, most applications do not exhibit this problem. In applications where the input power source lead inductance cannot be reduced to a level that does not affect the converter performance, a high ESR tantalum or aluminum electrolytic should be placed in parallel with the low ESR, ESL bypass ceramic.

This dampens the high Q network and stabilizes the system.

Output Capacitor Selection

The function of output capacitance is to store energy to attempt to maintain a constant voltage. The energy is stored in the capacitor's electric field due to the voltage applied.

The value of output capacitance is generally selected to limit output voltage ripple to the level required by the specification. Since the ripple current in the output inductor is usually determined by L, V_{OUT} and V_{IN}, the series impedance of the capacitor primarily determines the output voltage ripple. The three elements of the capacitor that contribute to its impedance (and output voltage ripple) are equivalent series resistance (ESR), equivalent series inductance (ESL), and capacitance (C).

The output voltage droop due to a load transient is dominated by the capacitance of the ceramic out- put capacitor. During a step increase in load current, the ceramic output capacitor alone supplies the load current until the loop responds. Within two switching cycles, the loop responds and the inductor current increases to match the load current demand. The relationship of the output voltage droop during the two switching cycles to the output capacitance can be estimated by:

$$C_{OUT} = \frac{2*\Delta I_{LOAD}}{V_{DROOP}*F_S}$$

In many practical designs, to get the required ESR, a capacitor with much more capacitance than is needed must be selected.

For both continuous and discontinuous inductor current mode operation, the ESR of the C_{OUT} needed to limit the ripple to ΔV_O, V peak-to-peak is:

$$ESR \le \frac{\Delta V_0}{\Delta I_L}$$

Ripple current flowing through a capacitor's ESR causes power dissipation in the capacitor. This power dissipation causes a temperature increase internal to the capacitor. Excessive temperature can seriously shorten the expected life of a capacitor. Capacitors have rippled current ratings that are dependent on ambient temperature and should not be exceeded. The output capacitor ripple current is the inductor current, I_L, minus the output current, I_O. The RMS value of the ripple current flowing in the output capacitance (continuous inductor current mode operation) is given by:

$$I_{RMS(MAX)} = \frac{\sqrt{3}}{6} = \Delta I_L * 0.289$$

ESL can be a problem by causing ringing in the low megahertz region but can be controlled by choosing low ESL capacitors, limiting lead length (PCB and capacitor), and replacing one large device with several smaller ones connected in parallel.

In conclusion, in order to meet the requirement of output voltage ripple small and regulation loop stability, ceramic capacitors with X5R or X7R dielectrics are recommended due to their low ESR and high ripple current ratings. The output ripple V_{OUT} is determined by:

$$\Delta V_{OUT} \le \frac{V_{OUT}*(V_{IN}-V_{OUT}}{V_{IN}*f_{osc}*L}*\left(ESR+\frac{1}{8*f_{OSC}*C_{OUT}}\right)$$

A 22µF ceramic capacitor can satisfy most applications.

Slope Compensation

The ECT3408 step-down converter uses peak current mode control with a unique adaptive slope compensation scheme to maintain stability with lower value inductors for duty cycles greater than 50%. The slope compensation is set to maintain stability with lower value inductors which provide better overall efficiency. The output inductor value must be selected so the inductor current down slope meets the internal slope compensation requirements. As an example, the value of the slope compensation is set to 1A/µs which is large enough to guarantee stability when using a 2.2µH inductor for all output voltage levels from 0.6V to 3.3V.

The worst case external current slope (m) using the2.2µH inductor is when V_{OUT} = 3.3V and is:

$$m = \frac{V_{OUT}}{L} = \frac{3.3}{2.2} = 1.5A/\mu s$$

To keep the power supply stable when the duty cycle is above 50%, the internal slope compensation (mA) should be:

$$m_a \geq \frac{1}{2} * m = 0.75A/\mu s$$

Therefore, to guarantee current loop stability, the slope of the compensation ramp must be greater than one-half of the down slope of the current waveform . So the internal slope compensated value of 1A/µs will guarantee stability using a 2.2µH inductor value for all output voltages from 0.6V to 3.3V.

Thermal Calculations

There are three types of losses associated with the ECT3408 step-down converter: switching losses, conduction losses, and quiescent current losses. Conduction losses are associated with the $R_{DS(ON)}$ characteristics of the power output switching devices. Switching losses are dominated by the gate charge of the power output switching. At full load, assuming continuous conduction mode (CCM), a simplified form of the losses is given by

$$P_{TOTAL} = \frac{I_O{}^2 * \left(R_{DSON(HS)} * V_O + R_{DSON(LS)} * [V_{IN} - V_O]\right)}{V_{IN}}$$

I_Q is the step-down converter quiescent current. The term t_{sw} is used to estimate the full load step-down converter switching losses.

For the condition where the step-down converter is in dropout at 100% duty cycle, the total device dissipation reduces to:

$$P_{TOTAL} = I_O{}^2 * R_{DSON(HS)} + I_Q * V_{IN}$$

Since $R_{DS(ON)}$, quiescent current and switching losses all vary with input voltage, the total losses should be investigated over the complete input voltage range. Given the total losses, the maximum junction temperature can be derived from the θ_{JA} for the TDFN-10 package which is 45°C/W.

$$T_{J(MAX)} = P_{TOTAL} * \theta_{JA} + T_{AMB}$$

Step-Down Converter Design Example

Specifications

V_O = 1.8V @1.2A

V_{IN} = 2.7V to 4.2V (3.6V nominal)

f_S = 1.5MHz

Transient droop = 80mV.

ΔV_O = 50mV

1.8V Output Inductor

$$\Delta I_L = 30\% \cdot I_O = 0.3 \cdot 1.2 = 360\text{mA}$$

$$L = \frac{V_{OUT} \cdot (V_{IN(MAX)} - V_{OUT})}{V_{IN(MAX)} \cdot \Delta I_L \cdot f_{OSC}} = \frac{1.8 \cdot (4.2 - 1.8)}{4.2 \cdot 0.36 \cdot 1.5 \cdot 10^6} = 1.90\mu\text{H}$$

For Sumida 2.2μH inductor (CDRH2D14) with DCR 75mΩ, the ΔI_L should be

$$\Delta I_L = \frac{V_O}{L} \cdot \left(1 - \frac{V_O}{V_{IN}}\right) \cdot T = 312\text{mA}$$

$$I_{PKL} = I_O + \frac{\Delta I_L}{2} = 1.2 + \frac{0.312}{2} = 1.356\text{A}$$

$$P_L = I_O^2 \cdot DCR = 1.2^2 \cdot 0.0359 = 51.7\text{mW}$$

1.8V Output Capacitor

$$C_{OUT} = \frac{2 \cdot \Delta I_{LOAD}}{V_{DROOP} \cdot f_S} = \frac{2 \cdot 1.2}{0.08 \cdot 1.5 \cdot 10^6} = 20\mu\text{F; use } 22\mu\text{F}$$

$$ESR \le \frac{\Delta V_O}{\Delta I_L} = \frac{0.05}{0.312} = 0.16\Omega$$

Select a 22μF, 10mΩ ESR ceramic capacitor to meet the ripple 50mV requirement.

$$\Delta V_{OUT} \le \frac{V_{OUT} \cdot (V_{IN} - V_{OUT})}{V_{IN} \cdot f_{OSC} \cdot L} \cdot \left(ESR + \frac{1}{8 \cdot f_{OSC} \cdot C_{OUT}}\right)$$

$$= \frac{1.8 \cdot (4.2 - 1.8)}{4.2 \cdot 1.5 \cdot 10^6 \cdot 2.2 \cdot 10^{-6}} \cdot \left(0.01 + \frac{1}{8 \cdot 1.5 \cdot 10^6 \cdot 22 \cdot 10^{-6}}\right) = 46.8\text{mV}$$

$$I_{RMS} = \Delta I_L \cdot 0.289 = 0.312 \cdot 0.289 = 90.2\text{mArms}$$

$$P_{COUT} = E_{SR} \cdot I^2_{RMS} = 0.01 \cdot 0.0902^2 = 81.4\mu\text{W}$$

Step-Down Converter Design Example (Continued)

Input Capacitor

Input ripple V_{PP} = 25mV

$$C_{IN(MIN)} = \frac{1}{\left(\frac{V_{PP}}{I_O} - ESR\right) \cdot 4 \cdot f_S} = \frac{1}{\left(\frac{0.025}{1.2} - 0.01\right) \cdot 4 \cdot 1.5 \cdot 10^6} = 15.4\mu F;\ \text{use } 22\mu F$$

$$I_{RMS} = \frac{I_O}{2} = \frac{1.2}{2} = 600mArms$$

$$P_{CIN} = ESR \cdot {I_{RMS}}^2 = 0.01 \cdot 0.6^2 = 3.6mW$$

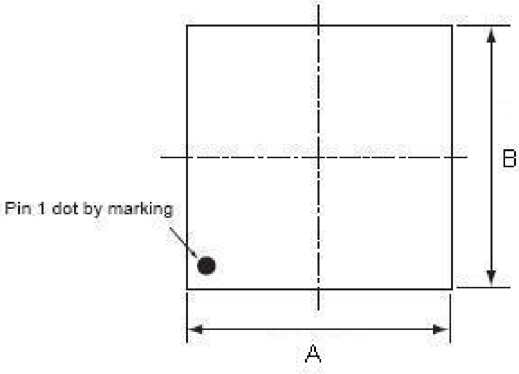
ECT3408 Losses

$$P_{TOTAL} = {I_O}^2 \cdot R_{DS(ON)P} \cdot D + {I_O}^2 \cdot R_{DS(ON)N} \cdot (1 - D) + (t_{SW} \cdot f_S \cdot I_O) \cdot V_{IN}$$

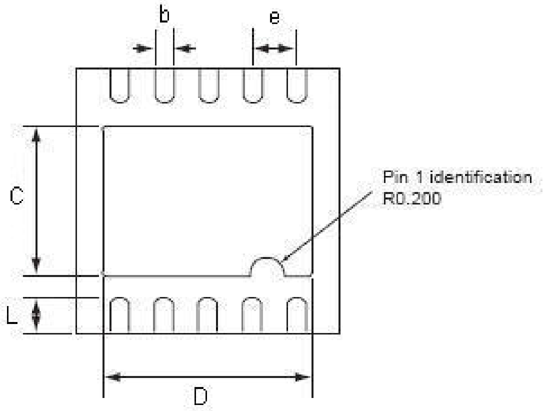
$$= 1.2^2 \cdot 0.207 \cdot \frac{1.8}{4.2} + 1.2^2 \cdot 0.146 \cdot \left(1 - \frac{1.8}{4.2}\right) + (5 \cdot 10^{-9} \cdot 1.5 \cdot 10^6 \cdot 1.2) \cdot 4.2 = 286mW$$

Mechanical Dimensions

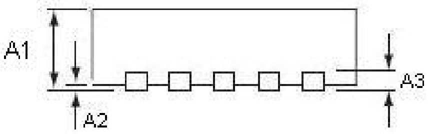
OUTLINE DRAWING TDFN-10



Top View



Bottom View



Side View

DIMENSIONS				
DIMN	INCHES		MM	
	MIN MAX		MIN	MAX
A 0.1	16	0.119	2.95	3.05
B 0.1	16	0.119	2.95	3.05
C 0.065		0.069	1.65	1.75
D 0.093		0.096	2.35	2.45
b 0.007		0.011	0.18	0.28
e 0.020			0.500 BSC	
L 0.014		0.018	0.35	0.45
A1 0.028		0.031	0.70	0.80
A2 0.000		0.004	0.00	0.10
A3 0.008			0.203REF	