

**DESCRIPTION**

The LX13088 is a highly integrated dual output voltage regulator ideal for low power applications that require minimal board space. The two current mode buck converters include integrated high side control switches, synchronous rectifiers, and internal compensation. The outputs of each converter are both rated for up to 1A, and the output voltages are adjustable using external resistive dividers.

The LX13088 step down converters operate at 1.3MHz fixed switching frequency under normal load, reducing external output filter component values and size. Under light load conditions, the converters operate in a pulse-skipping mode for improved efficiency.

The LX13088 incorporates out of phase switching, where converter 2 switches 180° out of phase from converter 1 in order to minimize the input ripple effects. The controller also features an E/S pin that provides an enable input function, or allows the converter to be

synchronized to an external clock. With the E/S input held low, the LX13088 draws less than 10uA.

Both converters have controlled soft start, in addition to power up sequencing. In the start-up sequence, the output of converter 1 is designed to precede the output of converter 2.

Power On Reset function is provided by means of an open-drain output at the POR pin. The Power On Reset function monitors the voltages at the V<sub>MON</sub>, FB1 and FB2 pins, and pulls low if any of these voltages drop below the stated POR threshold. The POR is internally deglitched and provides a delayed recovery and reset time.

The LX13088 provides peak over current protection, short circuit protection and thermal shutdown. Discharge-Before-Turn-On discharges the outputs completely before soft starting to always bring them up in the proper sequence at start up or after a POR event.

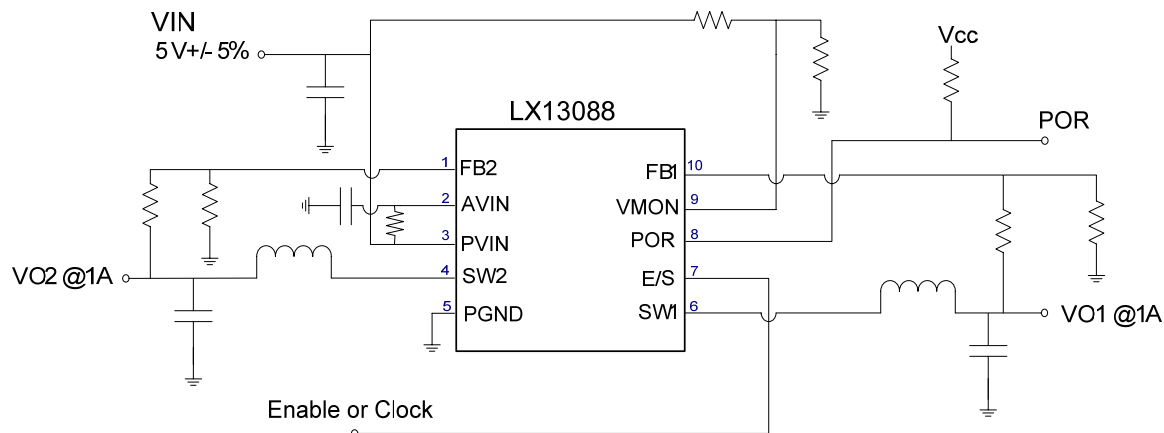
**KEY FEATURES**

- Outputs can be set from 1V to 3.6V @ 1A
- No Rectifier Diode required
- 1.3MHz Switching
- 180° Phase Shifted Switching
- Optional External Clocking (2x clock required)
- Light load Pulse Skipping
- Enable/Sleep state
- Internal Soft Start
- Open-drain Power On Reset Monitors Input and Outputs
- Discharge Before-Turn-On
- Peak Over-Current Protection
- Short Circuit Protection
- Over Temperature Shutdown

**APPLICATIONS**

- Hard Disk Drives
- Set- Top Boxes

**IMPORTANT:** For the most current data, consult MICROSEMI's website: <http://www.microsemi.com>

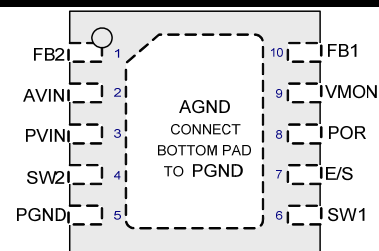
**Product Highlight**

**PACKAGE ORDER INFO**
**THERMAL DATA**

T <sub>A</sub> (°C)	<b>LD</b> Plastic 3x3 mm DFN 10-pin	$\theta_{JA} = 33 \text{ }^\circ\text{C/W}$
	RoHS Compliant / Pb-free	THERMAL RESISTANCE-JUNCTION TO AMBIENT
0 to +70	<b>LX13088CLD</b>	Junction Temperature Calculation: $T_J = T_A + (P_D \times \theta_{JA})$ .
	Note: Available in Tape & Reel. Append the letters "TR" to the part number. (i.e. LX13088CLD-TR)	The $\theta_{JA}$ numbers are guidelines for the thermal performance of the device/pc-board system. All of the above assume no ambient airflow.

**ABSOLUTE MAXIMUM RATINGS**

PVIN, AVIN to AGND, PGND.....	-0.3 to +7.0 V
SW1 and SW2 to AGND, PGND .....	PGND -2V to xVIN+2V
All other pins to AGND.....	-0.3V to xVIN + 0.3V
Operating Junction Temperature Range .....	0°C to 150°C
Storage Temperature Range.....	-65°C to 150°C
Package Peak Temp. for Solder Reflow (40 seconds maximum exposure) ..	260°C (+0 -5)°C

Notes: Exceeding these ratings could cause damage to the device. All voltages are with respect to Ground. Currents are positive into, negative out of specified terminal. PGND must be wired to AGND externally.

**PACKAGE PIN OUT**

**LD PACKAGE**  
(Top View)

Marking

3088
Date/Lot Code
MSC

RoHS / Pb-free 100% Matte Tin Finish

**FUNCTIONAL PIN DESCRIPTION**

Name	Pin #	Description
FB2	1	Feedback from VO2. Connect voltage divider to the load side of VO2 output inductor-capacitor filter.
AVIN	2	Analog Input. Input to power the internal circuitry of the device, connect to PVIN through a 10Ω resistor and bypass through a 1μF ceramic capacitor between this pin and PGND, as close to the LX13088 as possible.
PVIN	3	Control MOSFET switch power inputs. Connect a 10μF ceramic capacitor between this pin and PGND, as close to the LX13088 as possible.
SW2	4	Converter 2 synchronous buck switching output. Connect to VO2 inductor.
PGND	5	Power Ground Connection. Synchronous rectifier MOSFET source. Provide a star connection between this pin, VO1, VO2 filter capacitor returns, VIN input capacitor return, and AGND. Keep the star connection as close to the LX13088 IC as possible.
SW1	6	Converter 1 synchronous buck switching output. Connect to VO1 inductor.
E/S	7	Enable/Synchronization. Pulling this pin high statically enables the LX13088 and pulling the pin low statically will shut down the LX13088. Applying a pulse to this pin will synchronize SW1 and SW2 switching frequency to ½ the external clock frequency.
POR	8	Power On Reset output pin. Monitors FB1, FB2 output voltage levels and VIN. POR is pulled low if an output voltage droop is detected on FB1 or FB2 or VIN, and is Hi-Z during normal operation.
VMON	9	Voltage Monitor – Supervisor for one external voltage (could be input voltage). The POR output is triggered if this output falls below the VMON threshold.
FB1	10	Feedback from VO1. Connect voltage divider to the load side of VO1 output inductor-capacitor filter.
AGND	PAD	Analog Ground. Connect the exposed pad on the bottom of the package to the GND plane for a thermal heat sink.

**ELECTRICAL CHARACTERISTICS**

Unless otherwise specified, the following specifications apply over the operating ambient temperature of  $0^{\circ}\text{C} < \text{Temp} < 70^{\circ}\text{C}$ , and the following test conditions:  $4.5 \leq V_{\text{VIN}} \leq 5.5\text{V}$ ,  $V_{\text{PGND}} = V_{\text{AGND}}$ ; E/S = High (Static)

Parameter	Symbol	Test Conditions / Comment	Min	Typ	Max	Units
<b>Input Circuitry</b>						
Operating Input Voltage	$V_{\text{VIN}}$		4.5	5.0	5.5	V
Under Voltage Lockout	$V_{\text{VIN-UVLO}}$	$V_{\text{VIN}}$ Rising	3.0	3.5	4.0	V
UVLO Hysteresis			200	300	400	mV
Input Supply Current	$I_{\text{VIN}}$	$T_{\text{A}} = 25^{\circ}\text{C}$ ; not switching; $1.2\text{V} = V_{\text{FB1}} = V_{\text{FB2}}$	0.01	0.6	1	mA
		E/S = low		0.1	10	$\mu\text{A}$
<b>VMON Input</b>						
POR Threshold VMON	$V_{\text{VMON-POR}}$	$V_{\text{VMON}}$ Falling (hysteresis = 20mV)	0.97	1.00	1.03	V
VMON input current	$I_{\text{VMON}}$	$V_{\text{VMON}} = 1.25\text{V}$	-100	0	100	nA
<b>VO1 Output</b>						
Feedback Voltage	$V_{\text{FB1}}$		0.975	1.000	1.025	V
Peak Current Limit Threshold	$I_{\text{SW1-CT}}$		1.2	1.6		A
PWM Switching Frequency	$F_{\text{SW1}}$	E/S = static logic high		1.3		MHz
Upper FET On Resistance	$R_{\text{DS}_{\text{SW1-U}}}$	$T_{\text{J}} = 80^{\circ}\text{C}$		275		m $\Omega$
		$T_{\text{J}} = 25^{\circ}\text{C}$		250		
Lower FET On Resistance	$R_{\text{DS}_{\text{SW1-L}}}$	$T_{\text{J}} = 80^{\circ}\text{C}$		230		
		$T_{\text{J}} = 25^{\circ}\text{C}$		200		
Soft Start Time	$t_{\text{SS-FB1}}$		0.5	1	2	ms
POR Threshold FB1	$V_{\text{FB1-POR}}$	FB1 Falling (hysteresis = 2% $V_{\text{FB1}}$ )	87	89.5	92	% $V_{\text{FB1}}$
Discharge Complete Threshold	$V_{\text{FB1-DCT}}$	FB1 level where discharge cycle is terminated	50	75	100	mV
<b>VO2 Output</b>						
Feedback Voltage	$V_{\text{FB2}}$		0.975	1.000	1.025	V
Current Limit	$I_{\text{SW2-CT}}$		1.2	1.6		A
PWM Switching Frequency	$F_{\text{SW2}}$	E/S = static logic high		1.3		MHz

**ELECTRICAL CHARACTERISTICS**

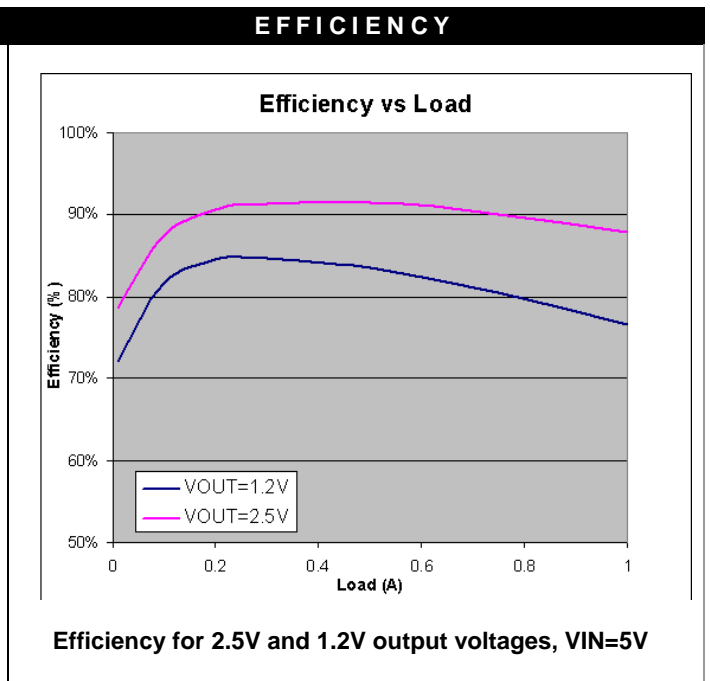
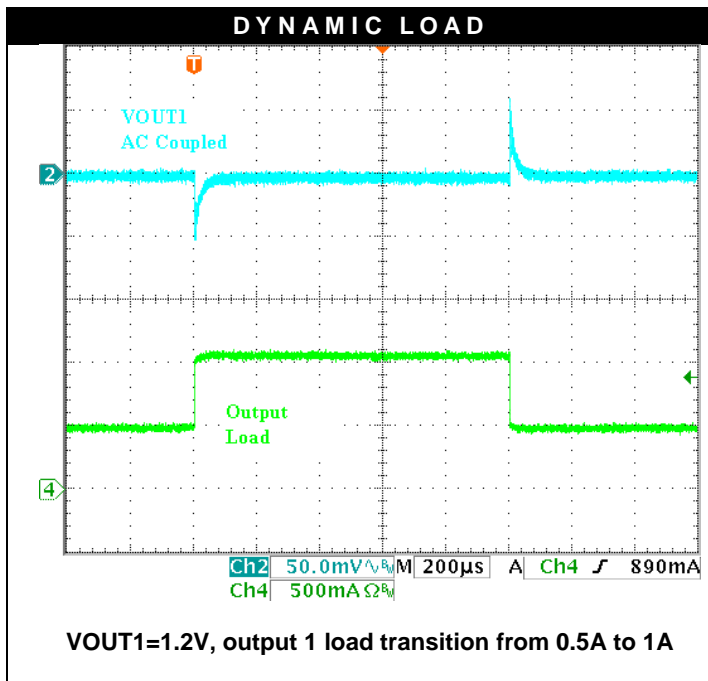
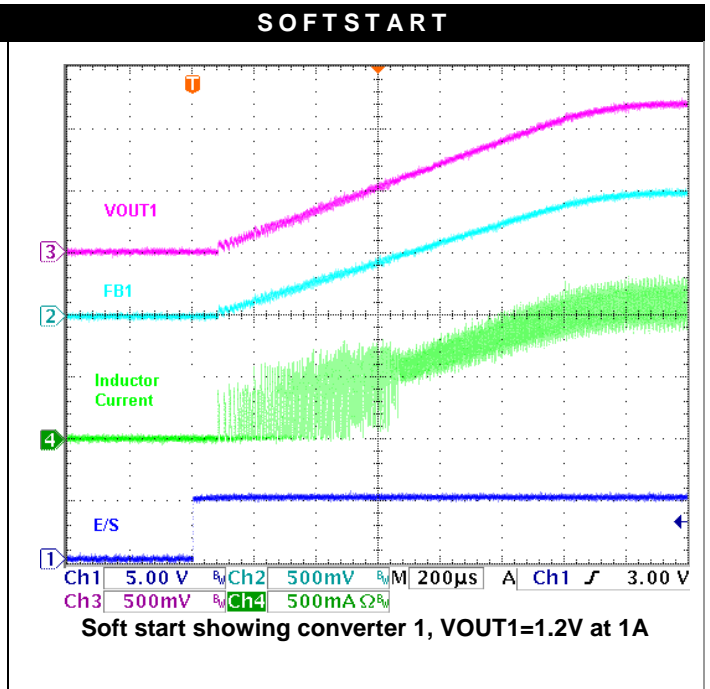
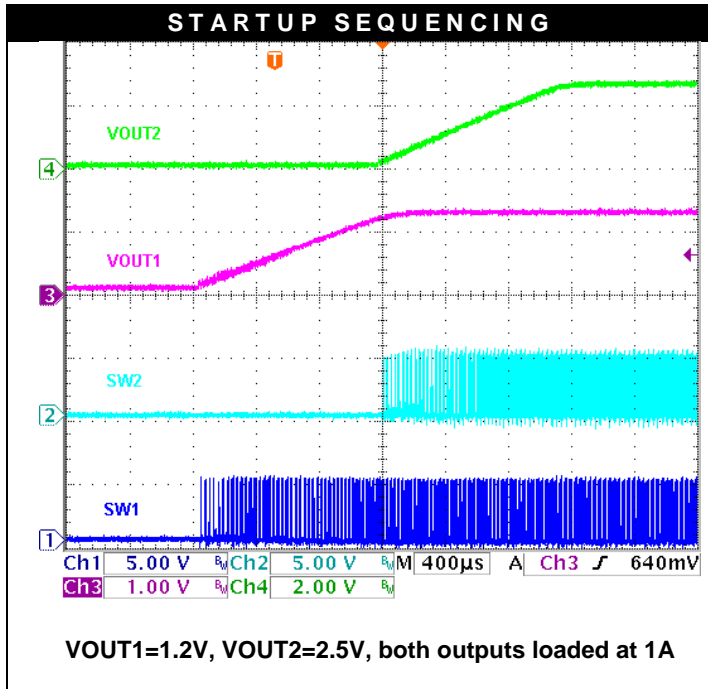
Unless otherwise specified, the following specifications apply over the operating ambient temperature of  $0^{\circ}\text{C} < \text{Temp} < 70^{\circ}\text{C}$ , and the following test conditions:  $4.5 \leq V_{\text{VIN}} \leq 5.5\text{V}$ ,  $V_{\text{PGND}} = V_{\text{AGND}}$ ; E/S = High (Static)

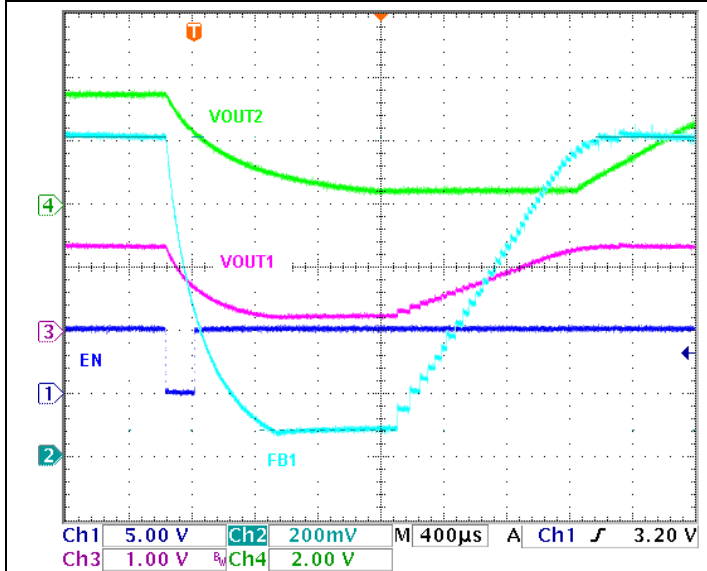
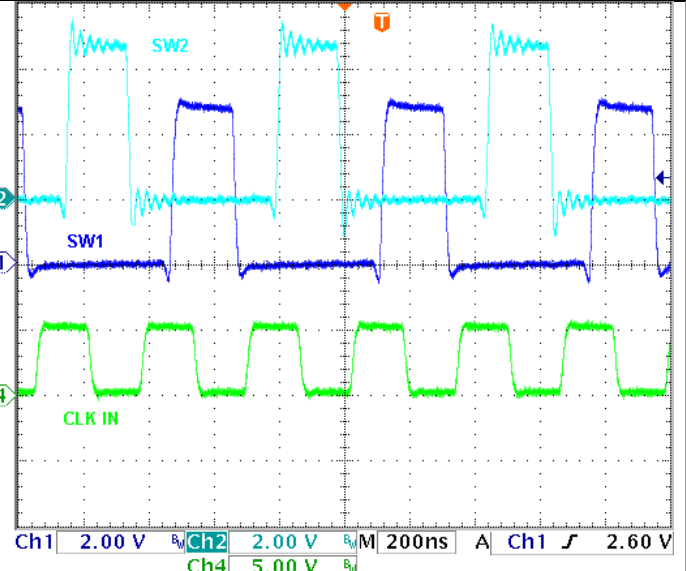
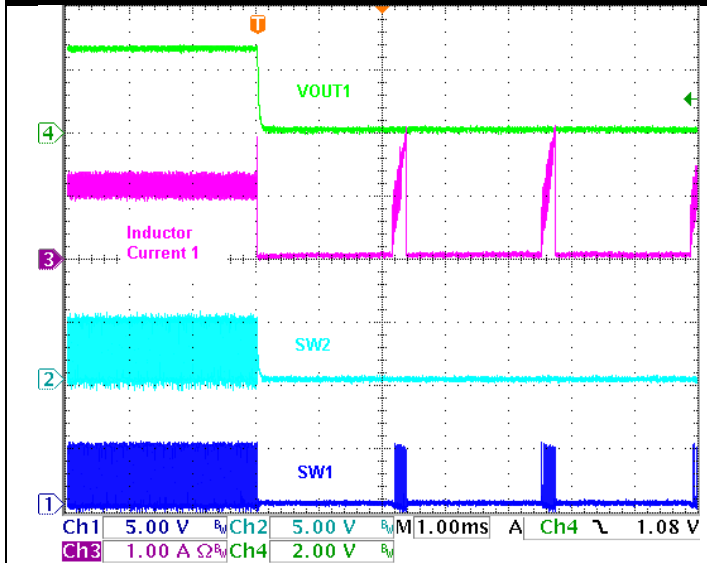
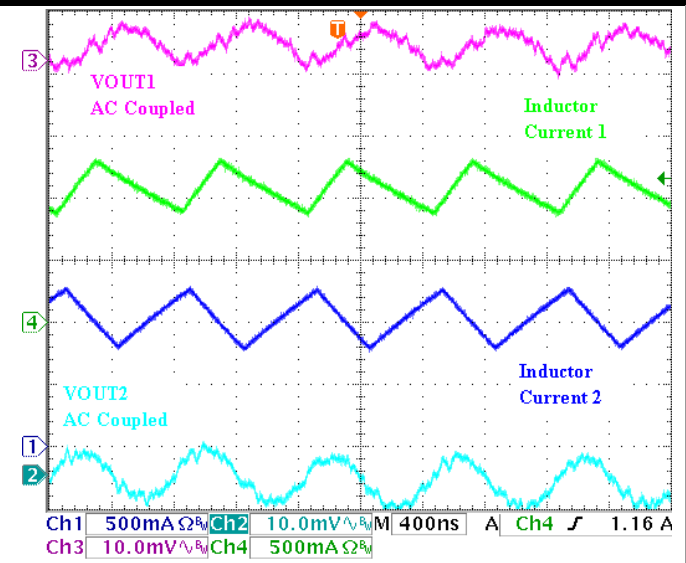
Parameter	Symbol	Test Conditions / Comment	Min	Typ	Max	Units
Upper FET On Resistance	RDS <sub>SW2-U</sub>	T <sub>J</sub> = 80°C		240		mΩ
		T <sub>J</sub> = 25°C		250		
Lower FET On Resistance	RDS <sub>SW2-L</sub>	T <sub>J</sub> = 80°C		155		mΩ
		T <sub>J</sub> = 25°C		150		
Soft Start Time	t <sub>SS-FB2</sub>		0.5	1	2	ms
POR Threshold FB2	V <sub>FB2-POR</sub>	FB2 Falling (hysteresis = 2% V <sub>FB2</sub> )	87	90	92	%V <sub>FB2</sub>
Discharge Complete Threshold	V <sub>FB2-DCT</sub>	FB2 level where discharge cycle is terminated	50	75	100	mV
<b>E/S</b>						
E/S Threshold	V <sub>E/S-H</sub>		1.5			V
	V <sub>E/S-L</sub>				0.6	V
E/S Leakage Current	I <sub>E/S</sub>	0 < V <sub>E/S</sub> < V <sub>VIN</sub>	-100		100	nA
Frequency lock in range	F <sub>E/S-MIN</sub>	Switching frequency is ½ E/S frequency when externally clocked.			1.5	MHz
	F <sub>E/S-MAX</sub>		3.0			
Shutdown delay	t <sub>E/S-SHDN</sub>	Shutdown initiated if logic low is of longer duration than delay.	2	4	10	μs
<b>POR</b>						
POR Assert Delay Time	t <sub>POR-DELAY</sub>	Fault Flag set to POR pull low		25		μs
POR Release Delay Time	t <sub>POR-HOLD</sub>	Fault Flag reset to POR Hi-Z state	10	20	30	ms
POR Low Voltage	V <sub>POR-LOW</sub>	POR sinking 4mA		200	300	mV
POR High Leakage	I <sub>POR-HI</sub>	POR High Level		0.003	1	μA
<b>Power Up Sequencing</b>						
VO2 Start Threshold	V <sub>FB1-ST</sub>	FB1 rising voltage for FB2 to initiate soft start	87	90	92	%V <sub>FB1</sub>
<b>Brown Out Discharge</b>						
SW1, SW2 Discharge Resistance	R <sub>STOP-SW1,2</sub>	Discharge Resistance for SW1 and VO2	15	30	45	Ω
SW1, SW2 Discharge Resistance matching	R <sub>STOP-SW1</sub> / R <sub>STOP-SW2</sub>		0.90	1	1.1	

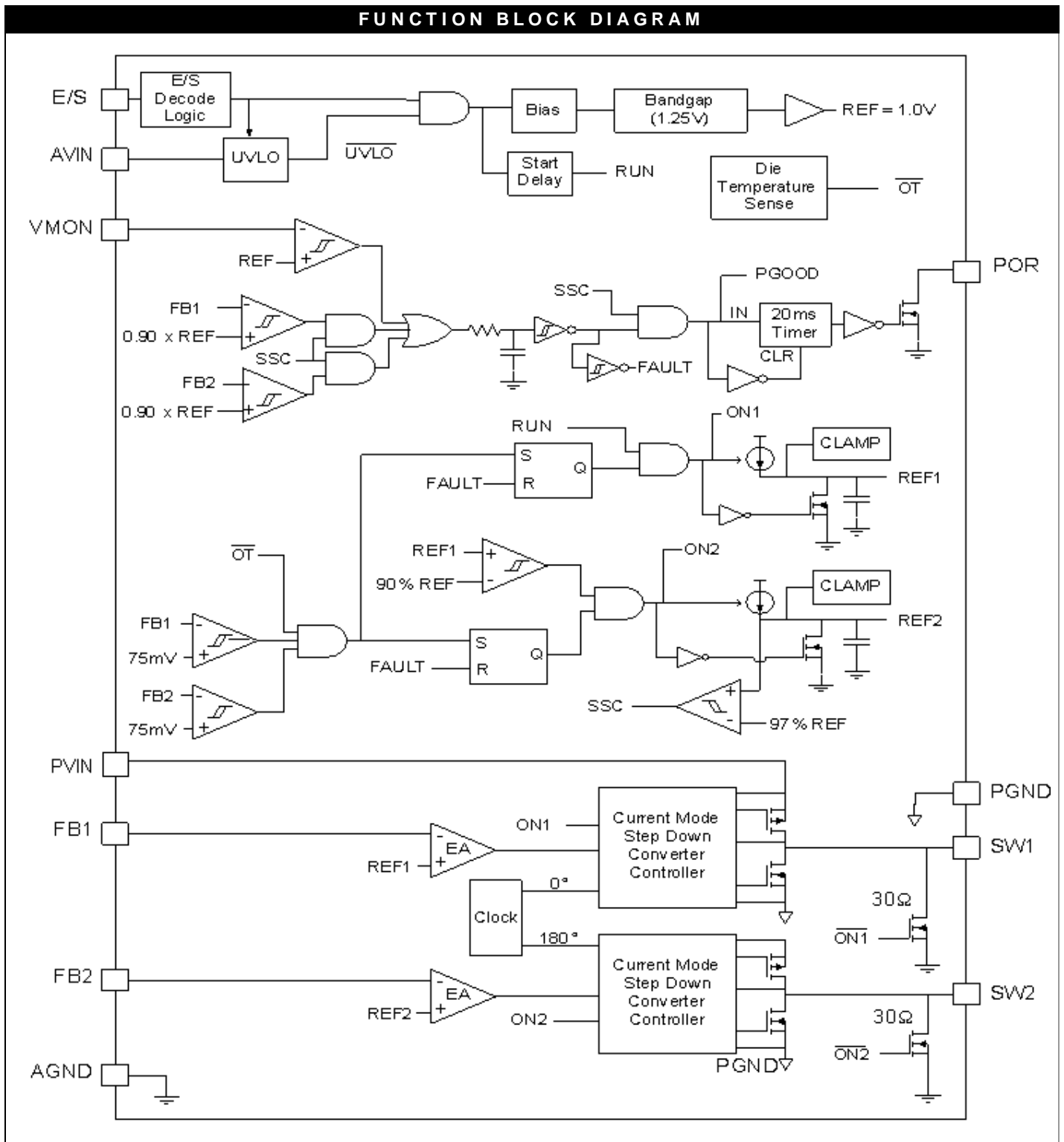
**SYSTEM CHARACTERISTICS**

Unless otherwise specified, the following specifications apply over the operating ambient temperature of  $0^{\circ}\text{C} < \text{Temp} < 70^{\circ}\text{C}$ , and the following test conditions:  $4.5 \leq V_{\text{VIN}} \leq 5.5\text{V}$ , E/S = High. Configured per application circuit. System Characteristics are closed loop tests that are verified as part of characterization but are not tested in production.

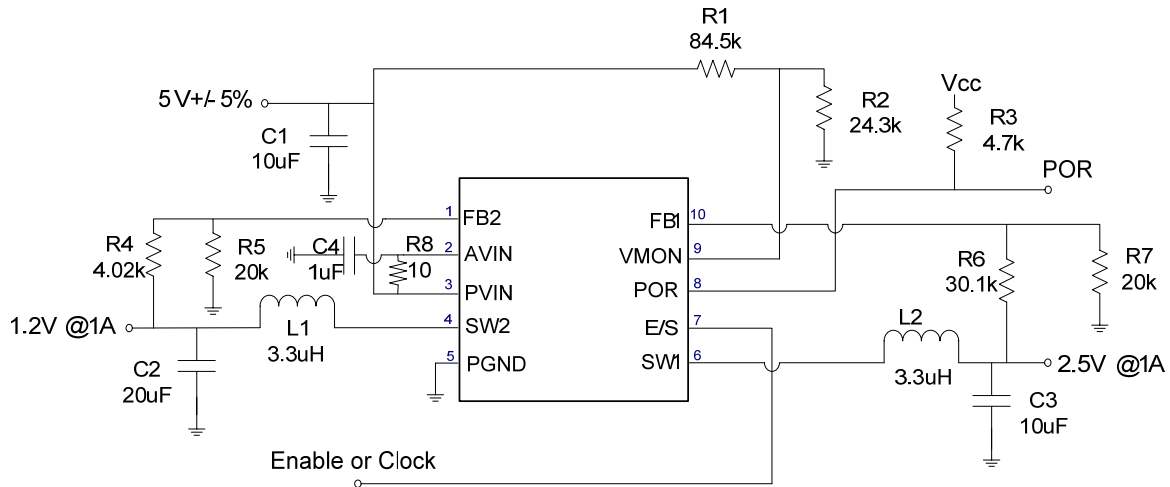
Parameter	Symbol	Test Conditions / Comment	Min	Typ	Max	Units
<b>VO1 Output</b>						
Line Regulation	VO1	$I_{\text{SW1(avg)}} = 300\text{mA}; 4.50\text{V} < V_{\text{VIN}} < 5.50\text{V}$		0.1		%
Load Regulation	VO1	$5\text{mA} \leq I_{\text{SW1(avg)}} \leq 1000\text{mA}$		0.5		%
Dynamic Load Response	VO1	Transient Response = 500mA step anywhere within 10mA to 1000mA range, $\Delta I / \Delta t = 1\text{A}/\mu\text{s}$	-5		+5	%VO 1
Efficiency ( $L_1$ DCR = 44m $\Omega$ )	$\eta_{\text{VO1}}$	$I_{\text{SW1(avg)}} = 1000\text{mA}; \text{VO1} = 2.5\text{V}$		87		%
		$I_{\text{SW1(avg)}} = 200\text{mA}; \text{VO1} = 2.5\text{V}$		94		
		$I_{\text{SW1(avg)}} = 10\text{mA}; \text{VO1} = 2.5\text{V}$		82		
<b>VO2 Output</b>						
Line Regulation	VO2	$I_{\text{SW2(avg)}} = 300\text{mA}; 4.50\text{V} < V_{\text{VIN}} < 5.50\text{V}$		0.1		%
Load Regulation	VO2	$5\text{mA} \leq I_{\text{SW2(avg)}} \leq 1000\text{mA}$		0.5		%
Efficiency ( $L_2$ DCR = 44m $\Omega$ )	$\eta_{\text{VO2}}$	$I_{\text{SW2(avg)}} = 1000\text{mA}; \text{VO2} = 1.2\text{V}$		80		%
		$I_{\text{SW2(avg)}} = 200\text{mA}; \text{VO2} = 1.2\text{V}$		90		
		$I_{\text{SW2(avg)}} = 10\text{mA}; \text{VO2} = 1.2\text{V}$		75		
<b>Thermal Shutdown</b>						
Thermal Shutdown Threshold				160		$^{\circ}\text{C}$
Thermal Shutdown Hysteresis				20		$^{\circ}\text{C}$



**STARTUP AFTER OUTPUT DISCHARGE**
**SYNCHRONIZATION**

**Outputs must discharge to <10% before repeat startup**

**Synchronization & out of phase, 3MHz CLK IN at E/S Input**
**CURRENT LIMIT & SHORT CIRCUIT**
**OUTPUT RIPPLE**

**VOUT1 shorted to ground continuously after normal regulation**

**Both outputs loaded at 1A, peak to peak output ripple is ~10mV**



**Figure 1. Functional Block Diagram**

**TYPICAL APPLICATION**

**Figure 2. Typical Application Circuit**

**THEORY OF OPERATION****DC-DC SWITCHING STEP DOWN CONVERTERS**

The LX13088 dual DC-DC converters are current mode buck converters with integrated high side switch, synchronous rectifier and internal compensation. They are designed to be stable with a 3.3 $\mu$ H inductor value and 10 $\mu$ F to 22 $\mu$ F output capacitor. Both output voltages are resistor divider programmable. The switching frequency of the converter is fixed and the switches turn on at alternating 180° phase intervals.

The converters operate in 3 possible modes: continuous mode (CM), discontinuous mode (DM), and pulse skipping mode (PSM). CM is the default mode under normal loading. DM occurs under light loads, where switching still occurs at the programmed frequency. In DM, a zero crossing detector shuts off the synchronous rectifier to prevent reverse rectifier current; this results in a portion of the switch period where neither switch is on. Under very light loads, PSM mode occurs, where switching cycles are skipped if the current demand is low in order to provide better efficiency.

**SOFTSTART**

The DC-DC converters contain a soft start function that brings the output voltages up via a slowly increasing ramp with any resistive load from open circuit to 1A. The output voltage waveform shall not vary by more than 50mV from a straight line drawn from the initial voltage to the final steady state voltage. During soft start, the peak inductor current shall not exceed 750mA until the output voltage reaches 25% of its final value. Current limit shall be active but not trip during soft start into a rated resistive load. Overshoot voltage during soft start is limited to 1%.

**ENABLE AND POWER UP SEQUENCING**

When power is applied at VIN and if the E/S input is asserted (High) or is toggling, the DC-DC converters will enter RUN mode after a short settling period. If the E/S pin is a static low, the IC will enter a SLEEP state where it draws very little input current, less than 10 $\mu$ A.

When in RUN mode, if there is no fault condition, the VO1 output of converter 1 will be the first output to begin soft start. When the reference voltage for FB1 reaches approximately 90% of the final value, the VO2 output of converter 2 will begin soft start.

**POR**

Under-voltage comparators are provided to monitor the output voltages and the voltage at VMON which could be the input supply voltage. If any of these voltages falls below its POR threshold, the POR open drain output will turn on which pulls the POR pin low. Note that the fault to POR assert delay time is approximately 20 $\mu$ S. If the POR fault condition is cleared, there is a delay of 20ms before the POR output transistor is turned off; when off the POR pin is high Z and may be pulled up high via a resistor.

The POR function has built in deglitching. Once the POR is detected, the power supply outputs will be discharged prior to a restart condition, where soft start and power up sequencing will occur.

**OUTPUT DISCHARGE**

After the occurrence of a POR situation, and the POR fault condition is immediately cleared, startup and soft start is delayed until the outputs are discharge to <10%. During the discharge phase, the soft start internal reference voltages (REFx) are shorted to ground to quickly discharge it. The output capacitors are discharged via an internal 30 $\Omega$  pull down switch on each of the SW1 and SW2 pins. When the FBx voltage and the REFx voltage are fully discharged and if there is not an OT condition, the outputs are then allowed to begin the normal soft start power up sequence. During the discharge phase, the control high side and synchronous rectifier MOSFETs are in the high-Z off state.

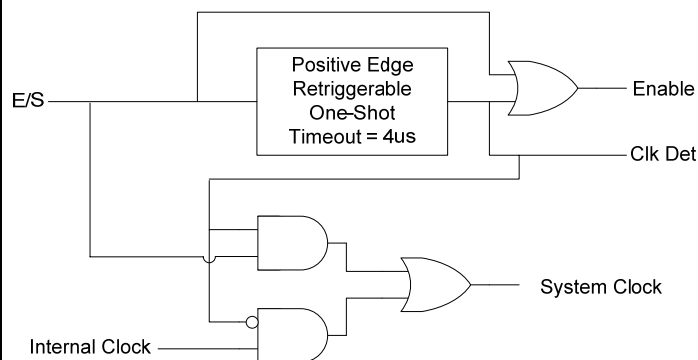
**OVER CURRENT AND SHORT CIRCUIT PROTECTION**

The DC-DC converters have over current and short circuit protection. During any mode of operation, any value of load resistance (including 0 ohms) can be applied to the DC-DC outputs instantaneously and held in place indefinitely without the switch current exceeding the peak current limit and without the IC suffering any permanent damage or loss of performance. The output voltage is allowed to drop under over current or short circuit conditions. Both converters will stop switching if either one experiences an over current condition for various cycles.

Recovery to output voltage regulation occurs within 10ms of the instant the loading is reduced to maximum allowable rated load; the output voltage shall not exceed the dynamic load excursion limits (+/-5% excursion) upon recovery.

**OPERATION**
**E/S DECODER LOGIC**

The E/S pin serves a dual purpose. It will enable the IC if it detects either a valid clock signal or a static high logic level. A static low logic level for longer than 4μs is determined to be a shutdown signal. The decode logic is shown below. The One-shot function will produce a logic high output (Clock Detect) as long as the E/S pin is toggling. Clock Detect is used to keep ENABLE high and to select the E/S clock as the system clock. If E/S is a static high (non-toggling) input, the retriggerable one-shot will go low after 4μs; this will set Clk Det low and select the internal oscillator as the system clock.


**SYNCHRONIZATION**

The converters can be synchronized to an external system clock present at the E/S input pin. During synchronization, the converter's switching frequency will be ½ the frequency of the external clock, and the two converters will still be 180 degrees out of phase. The lock in frequency for synchronization is specified to be between 1.5MHz to 3MHz, minimum sync pulse width is 100ns.

**OVER TEMPERATURE PROTECTION**

If an over temperature fault occurs, the DC-DC converter will stop switching and the SW# outputs will become high impedance. Note that the temperature fault occurs at a die temperature of approximately 160°C. When the IC cools down, it will attempt to resume switching. If a POR is activated as a result of the OT situation, restart will be subject to the soft start/sequencing routine and will not occur until the OT condition has been corrected.

The device junction temperature is a function of the device's total power dissipation, the junction to ambient thermal resistance, and the ambient temperature:

$$T_J = T_A + (P_{TOTAL} \times \theta_{JA})$$

The total power dissipated by the LX13088 device,  $P_{TOTAL}$ , will be comprised of the power dissipated by the RMS current flowing through the internal high-side FET during the duty cycle D time, by the RMS current flowing through the synchronous rectifier during 1-D time, by the switching or transitioning of the FET, and of the power dissipated by the device supply current.

**INDUCTOR SELECTION**

A 3.3μH ±20% inductor is suggested as the internal compensation has been optimized around this inductor value. A 3.3μH is a good compromise, since for an output voltage ranging from  $V_{OUT} = 1V$  to  $V_{OUT} = 4V$ , loaded at 1A, the LIR or the ratio of inductor ripple current to output load will range from about 20% to 30%, assuming  $V_{IN} = 5V$  and the converter switching at 1.3MHz.

**OUTPUT CAPACITOR**

To ensure stability and good load transient response, use at least a 10μF output capacitor for converter 1, and a 20μF or greater for converter 2. Output ceramics capacitors with low ESR are suitable.

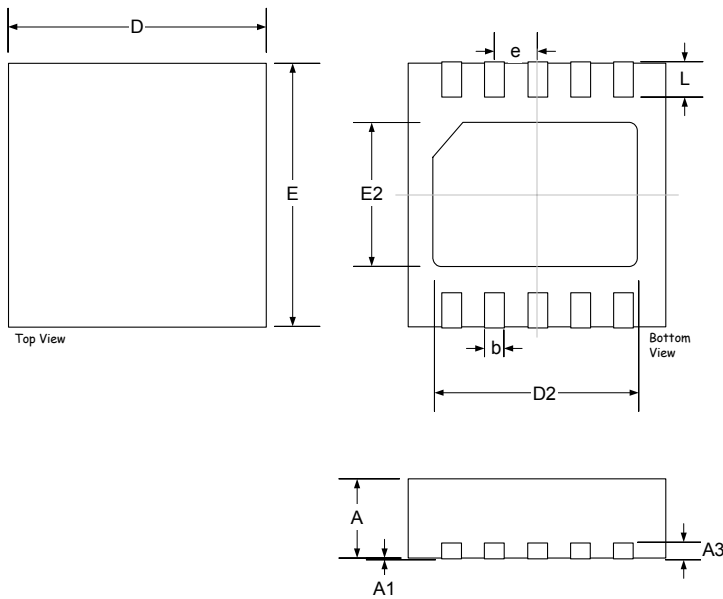
**SETTING THE OUTPUT VOLTAGE**

The LX13088 converter's maximum duty cycle is approximately 90%. For a 5V input, 90% duty cycle will be achieved for an output voltage of about 4V loaded at 1A.

To set the output voltage, connect a resistive divider from the output to the FBx pin to signal ground. Note that the feedback voltage is 1.0V. For the desired output voltage  $V_{OUT}$ , the upper resistor from  $V_{OUT}$  to FB ( $R_{UPPER}$ ) is calculated by the following equation:

$$R_{UPPER} = R_{LOWER} \times \left( \frac{V_{OUT}}{V_{FB}} - 1 \right)$$

$R_{LOWER}$ , or the resistor from FBx pin to ground, is selected to be 20kΩ.  $V_{FB} = 1V$ , and  $V_{OUT}$  is chosen by the designer for the given application.

**PACKAGE DIMENSIONS**
**LD 10-Pin Plastic MLP Dual Exposed Pad**


Dim	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	0.80	1.00	0.0315	0.0394
A1	0	0.05	0	0.0019
A3	0.20 REF		0.0079 REF	
b	0.18	0.30	0.0071	0.0118
D	3.00 BSC		0.1181 BSC	
D2	2.23	2.48	0.0878	0.0976
e	0.50 BSC		0.0197 BSC	
E	3.00 BSC		0.1181 BSC	
E2	1.49	1.74	0.0587	0.0685
L	0.30	0.50	0.0071	0.0197

**Note:**

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

PRODUCTION DATA – Information contained in this document is proprietary to Microsemi and is current as of publication date. This document may not be modified in any way without the express written consent of Microsemi. Product processing does not necessarily include testing of all parameters. Microsemi reserves the right to change the configuration and performance of the product and to discontinue product at any time.