MIC23250 Evaluation Board

4MHz Dual 400mA Synchronous Buck Regulator with HyperLight Load™

General Description

The MIC23250 is a dual 400mA 4MHz switching regulator with HyperLight Load™ mode. The MIC23250 is highly efficient, consuming 33µA of quiescent current to operate both of its outputs. A Sub-1mm height solution is easily attainable using the tiny package (2mm x 2mm x 0.55mm) and only six external components. Small and fast, the MIC23250 can respond to a load transient at ultra-fast speed while reducing output peak-to-peak voltage.

The MIC23250 has two modes of operation that is automatically selected by the internal circuitry. Under light load conditions, the MIC23250 goes into HyperLight Load™ mode. The MIC23250 HyperLight Load™ uses a Pulse-Frequency Modulation (PFM) control scheme that controls the off time at light load. This allows the device to reduce the amount of switching needed at light load, thus reducing the switching losses. The MIC23250 can attain up to 85% efficiency at 1mA output load. At higher output currents of approximately 100mA, HyperLight Load™ mode automatically switches back to Pulse-Width Modulation (PWM) mode to ensure high efficiency up to 94% at higher load. The two modes of operation ensure that the MIC23250 maintains the highest efficiency throughout the entire load range.

The MIC23250 operates from a 2.7V to 5.5V input and features internal power MOSFETs that can supply up to 400mA of output current on each channel. It can operate with a maximum duty cycle of 90%.

Requirements

The MIC23250 evaluation board requires an input power source that is able to deliver greater than 800mA at 2.7V. The output loads can either be an active (electronic) or passive (resistive) load.

Getting Started

1. **Connect an external supply to the V_{IN} (J1) terminal**. Apply desired input voltage to the V_{IN} (J1) and ground (J2) terminal of the evaluation board, paying careful attention to polarity and supply voltage ($2.7V \leq V_{IN} \leq 5.5V$). An ammeter may be placed between the input supply and the V_{IN} (J1) terminal to the evaluation board. Be sure to monitor the supply voltage at the V_{IN} (J1) terminal, as the ammeter and/or power lead resistance can reduce the voltage supplied to the input.

2. **Connect a load to the V_O1 (J4) and V_O2 (J6) outputs and ground terminal (J7)**. The loads can be either passive (resistive) or active (electronic load). An ammeter can be placed between the load and the output terminal. Ensure that the output voltages are monitored at the V_O1 (J4) and V_O2 (J6) terminals.

3. **Enable the MIC23250 outputs**. The MIC23250 evaluation board has pre-installed pull-up resistors (R1 and R2) that enable the device as soon as input voltage is applied. These resistors are optional. To disable the device, apply a voltage below 0.5V to EN1 (J3) or EN2 (J5) terminals. Similarly, if the pull up resistors (R1 and R2) are not used the device may be enabled by applying a voltage greater than 1.2V to the EN1 (J3) or EN2 (J5) terminals. Be sure that the enable voltage never exceeds the input voltage.

Output Voltage

The MIC23250 evaluation board has fixed output voltage options available per the table below.

Ordering Information

Part Number	Description
MIC23250-C4YMT EV	1.2V / 1.0V Output Evaluation Board
MIC23250-G4YMT EV	1.2V / 1.8V Output Evaluation Board
MIC23250-S4YMT EV	1.2V / 3.3V Output Evaluation Board
MIC23250-AAYMT EV	Adjustable Output Evaluation Board

Note: Other voltage options available upon request. Contact Micrel.

HyperLight Load is a trademark of Micrel, Inc.

Feedback Resistor Selection (Adjustable Only)

The feedback pins (FB1/FB2) are two extra pins that can only be found on the MIC23250-AAYMT devices. It allows the regulated output voltage to be set by applying an external resistor network. The internal reference voltage is 0.72V and the recommended value of R_{BOTTOM} is within 10% of 442kΩ. The R_{TOP} resistor is the resistor from the FB pin to the output of the device and R_{BOTTOM} is the resistor from the FB pin to ground. The output voltage is calculated from the equation below.

$$V_{OUT} = 0.72V\left(\frac{R_{TOP}}{R_{BOTTOM}} + 1\right)$$

Compensation

The MIC23250 is designed to be stable with a 0.47µH to 4.7µH inductor with a minimum of 2.2µF ceramic (X5R) output capacitor. For the adjustable MIC23250, the total feedback resistance should be kept as high as possible to reduce current loss down the feedback resistor network. This helps to improve efficiency. A feed-forward capacitor (CFF) of 120pF must be used in conjunction with the external feedback resistors to reduce the effects of parasitic capacitance that is inherent of most circuit board layouts. Figure 1 and Table 1 shows the recommended feedback resistor values along with the recommended feed-forward capacitor for the MIC23250 adjustable device.

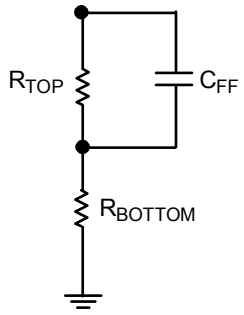


Figure 1. Feedback Resistor Network

For V_O1 the feedback components are: R_{TOP} = R3, R_{BOTTOM} = R4, C_{FF} = C5. For V_O2 the feedback components are: R_{TOP} = R5, R_{BOTTOM} = R6, C_{FF} = C6.

V_{OUT} (V)	R_{TOP} (kΩ)	R_{BOTTOM} (kΩ)	CFF (pF)
0.8	49	442	120
0.9	111	442	120
1	172	442	120
1.1	233	442	120
1.2	295	442	120
1.3	356	442	120
1.4	417	442	120
1.5	479	442	120
1.6	540	442	120
1.7	602	442	120
1.8	663	442	120
1.9	724	442	120
2	786	442	120
2.1	847	442	120
2.2	909	442	120
2.3	970	442	120
2.4	1031	442	120
2.5	1093	442	120
2.6	1154	442	120
2.7	1216	442	120
2.8	1277	442	120
2.9	1338	442	120
3	1400	442	120
3.1	1461	442	120
3.2	1522	442	120
3.3	1584	442	120

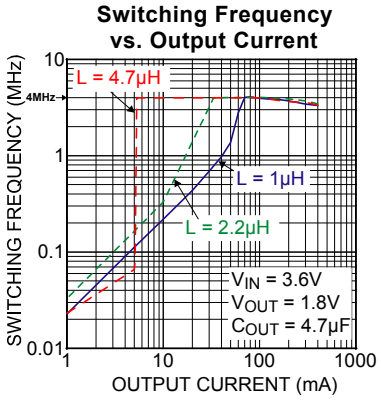
Table 1. Recommended Feedback Component Values

HyperLight Load Mode™

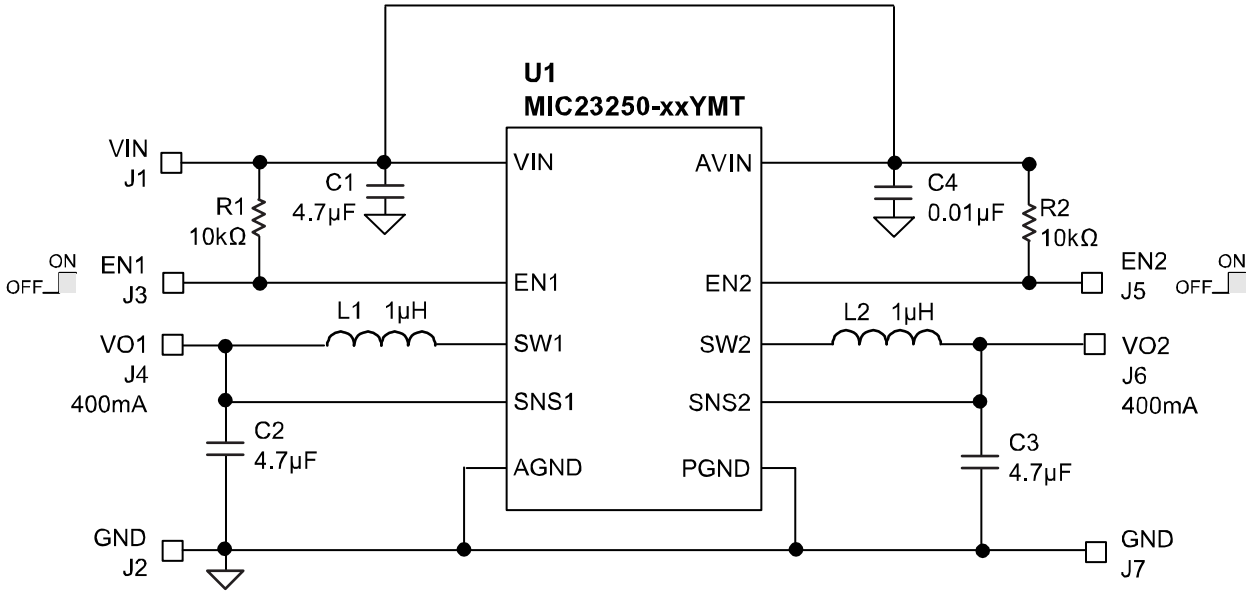
MIC23250 uses a minimum on and off time proprietary control loop (patented by Micrel). When the output voltage falls below the regulation threshold, the error comparator begins a switching cycle that turns the PMOS on and keeps it on for the duration of the minimum-on-time. This increases the output voltage. If the output voltage is over the regulation threshold, then the error comparator turns the PMOS off for a minimum-off-time until the output drops below the threshold. The NMOS acts as an ideal rectifier that conducts when the PMOS is off. Using a NMOS switch instead of a diode allows for lower voltage drop across the switching device when it is on. The asynchronous switching combination between the PMOS and the NMOS allows the control loop to work in discontinuous mode for light load operations. In discontinuous mode, the MIC23250 works in pulse frequency modulation (PFM) to regulate the output. As the output current increases, the off-time decreases, thus provides more energy to the output. This switching scheme improves the efficiency of MIC23250 during light load currents by only switching when it is needed. As the load current increases, the MIC23250 goes into continuous conduction mode (CCM) and switches at a frequency centered at 4MHz. The equation to calculate the load when the MIC23250 goes into continuous conduction mode may be approximated by the following formula:

$$I_{LOAD} = \left(\frac{V_{IN} - V_{OUT} \times D}{2L \times f} \right)$$

As shown in the previous equation, the load at which MIC23250 transitions from HyperLight Load™ mode to PWM mode is a function of the input voltage (V_{IN}), output voltage (V_{OUT}), duty cycle (D), inductance (L) and frequency (f). This is illustrated in the graph below. Since the inductance range of MIC23250 is from 0.47µH to 4.7µH, the device may then be tailored to enter HyperLight Load™ mode or PWM mode at a specific load current by selecting the appropriate inductance. For example in the graph below, when the inductance is 4.7µH the MIC23250 will transition into PWM mode at a load of approximately 4mA. Under the same condition, when the inductance is 1µH, the MIC23250 will transition into PWM mode at approximately 70mA.



MIC23250 Evaluation Board Schematic (Fixed Output)



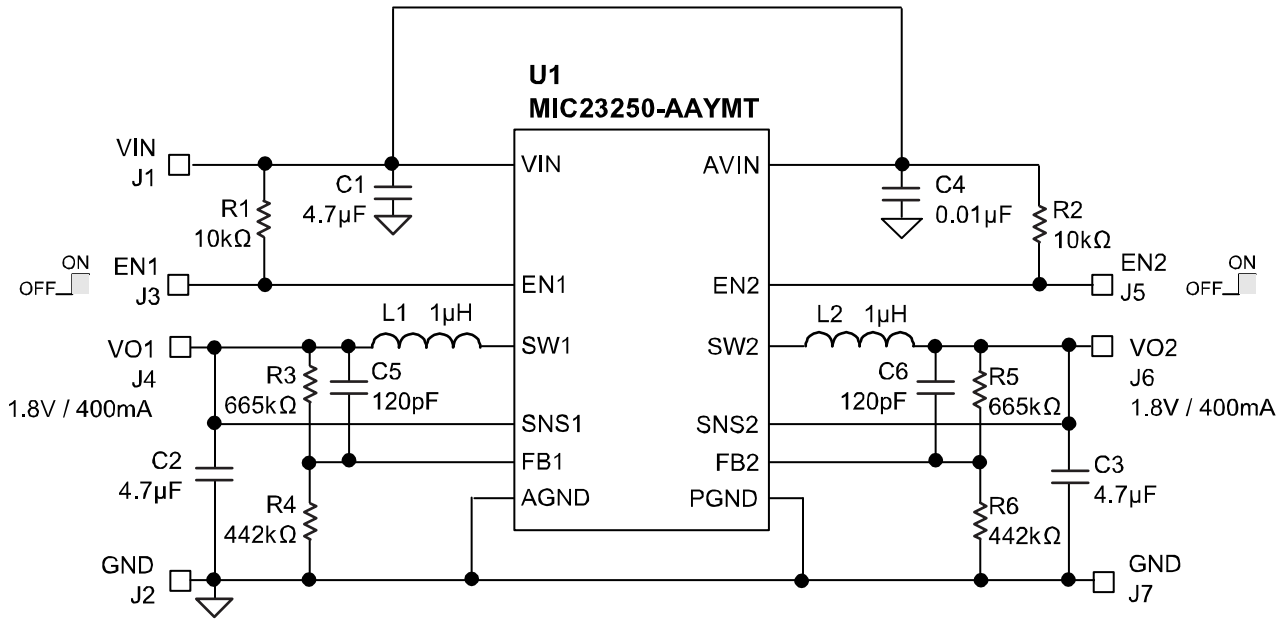
Bill of Materials

Item	Part Number	Manufacturer	Description	Qty
C1, C2, C3	C1608X5R0J475K	TDK[1]	4.7µF Ceramic Capacitor, 6.3V, X5R, Size 0603	3
C4	VJ0603Y103KXXAT	Vishay[2]	0.01µF Ceramic Capacitor, 25V, X7R, Size 0603	1
R1, R2	CRCW060310K0FKEA	Vishay[2]	10kΩ Resistor, 1%, 1/16W, Size 0603	Optional
L1, L2	LQM21PN1R0M00	Murata[3]	1µH, 0.8A, 190mΩ, L2mm x W1.25mm x H0.5mm	2
	LQH32CNR1R0M33	Murata[3]	1µH, 1A, 60mΩ, L3.2mm x W2.5mm x H2.0mm	
	LQM31P1R0M00	Murata[3]	1µH, 1.2A, 120mΩ, L3.2mm x W1.6mm x H0.95mm	
	GLF251812T1R0M	TDK[1]	1µH, 0.8A, 100mΩ, L2.5mm x W1.8mm x H1.35mm	
	LQM31PNR47M00	Murata[3]	0.47µH, 1.4A, 80mΩ, L3.2mm x W1.6mm x H0.85mm	
	MIPF2520D1R5	FDK[4]	1.5µH, 1.5A, 70mΩ, L2.5mm x W2mm x H1.0mm	
U1	**MIC23250-xxYMT**	**Micrel, Inc.[5]**	**4MHz Dual 400mA Buck Regulator with HyperLight Load™ Mode**	**1**

Notes:

1. TDK: www.tdk.com
2. Vishay: www.vishay.com
3. Murata: www.murata.com
4. FDK: www.fdk.co.jp
5. **Micrel, Inc: www.micrel.com**

MIC23250 Evaluation Board Schematic (Adjustable Output)



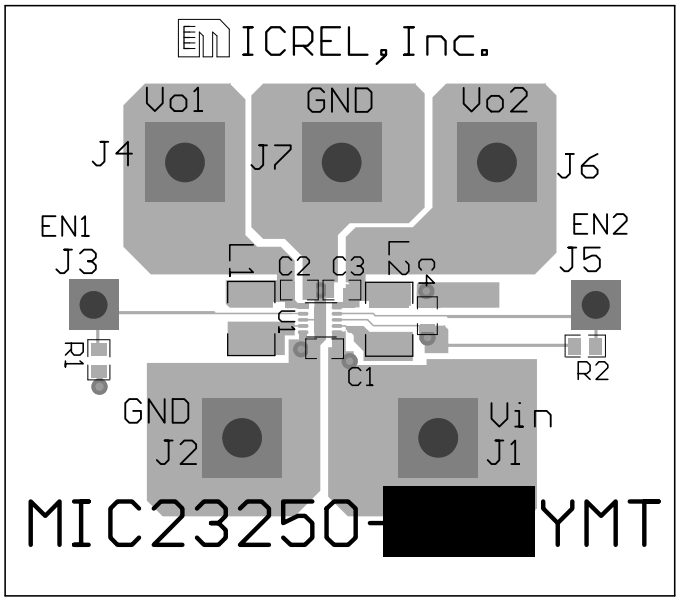
Bill of Materials

Item	Part Number	Manufacturer	Description	Qty
C1, C2, C3	C1608X5R0J475K	TDK[1]	4.7µF Ceramic Capacitor, 6.3V, X5R, Size 0603	3
C4	VJ0603Y103KXXAT	Vishay[2]	0.01µF Ceramic Capacitor, 25V, X7R, Size 0603	1
C5, C6	VJ0603Y121KXAAT	Vishay[2]	120pF Ceramic Capacitor, 50V, X7R, Size 0603	2
R1, R2	CRCW06031002FKEA	Vishay[2]	10kΩ, 1%, 1/16W, Size 0603	Optional
R3, R5	CRCW06036653FKEA	Vishay[2]	665kΩ, 1%, 1/16W, Size 0603	2
R4, R6	CRCW06034423FKEA	Vishay[2]	442kΩ, 1%, 1/16W, Size 0603	2
L1, L2	LQM21PN1R0M00	Murata[3]	1µH, 0.8A, 190mΩ, L2mm x W1.25mm x H0.5mm	2
	LQH32CN1R0M33	Murata[3]	1µH, 1A, 60mΩ, L3.2mm x W2.5mm x H2.0mm	
	LQM31P1R0M00	Murata[3]	1µH, 1.2A, 120mΩ, L3.2mm x W1.6mm x H0.95mm	
	GLF251812T1R0M	TDK[1]	1µH, 0.8A, 100mΩ, L2.5mm x W1.8mm x H1.35mm	
	LQM31PNR47M00	Murata[3]	0.47µH, 1.4A, 80mΩ, L3.2mm x W1.6mm x H0.85mm	
	MIPF2520D1R5	FDK[4]	1.5µH, 1.5A, 70mΩ, L2.5mm x W2mm x H1.0mm	
	EPL2010-102	Coilcraft[5]	1.0µH, 1.0A, 86mΩ, L2.0mm x W1.8mm x H1.0mm	
U1	**MIC23250-AAYMT**	**Micrel, Inc.[6]**	**4MHz Dual 400mA Adjustable Output Buck Regulator with HyperLight Load™ Mode**	**1**

Notes:

1. TDK: www.tdk.com
2. Vishay: www.vishay.com
3. Murata: www.murata.com
4. FDK: www.fdk.co.jp
5. Coilcraft: www.coilcraft.com
6. **Micrel, Inc: www.micrel.com**

PCB Layout Recommendations (Fixed Output)



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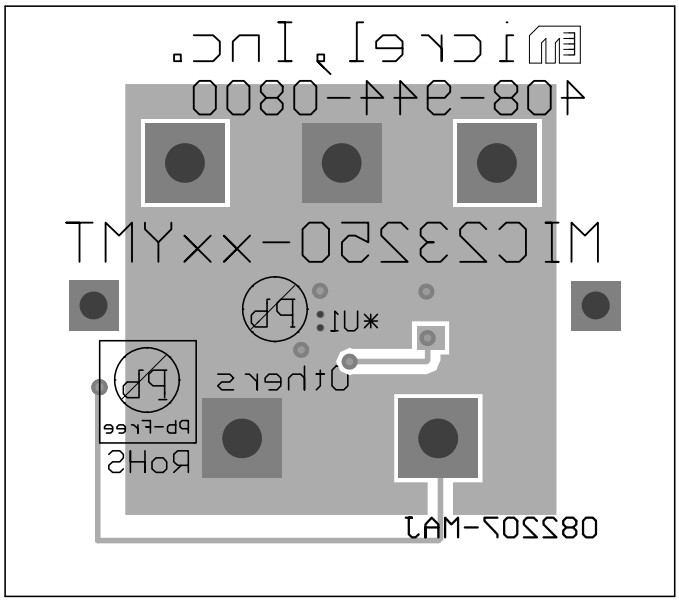

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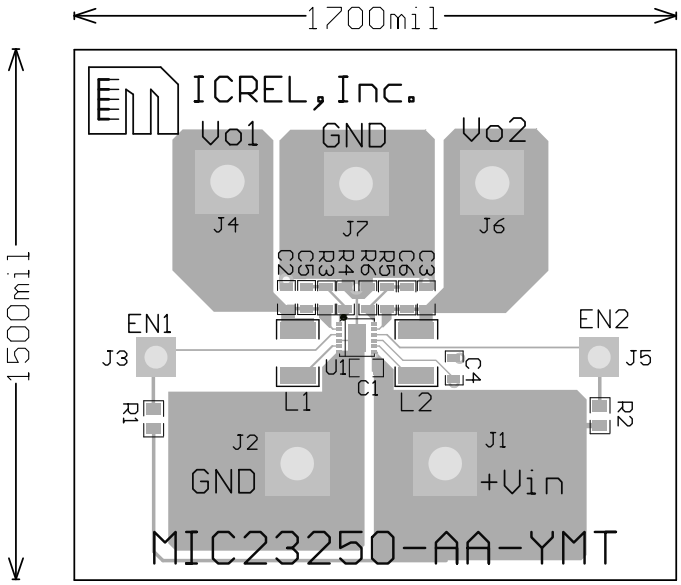
PCB Layout Recommendations (Adjustable Output)



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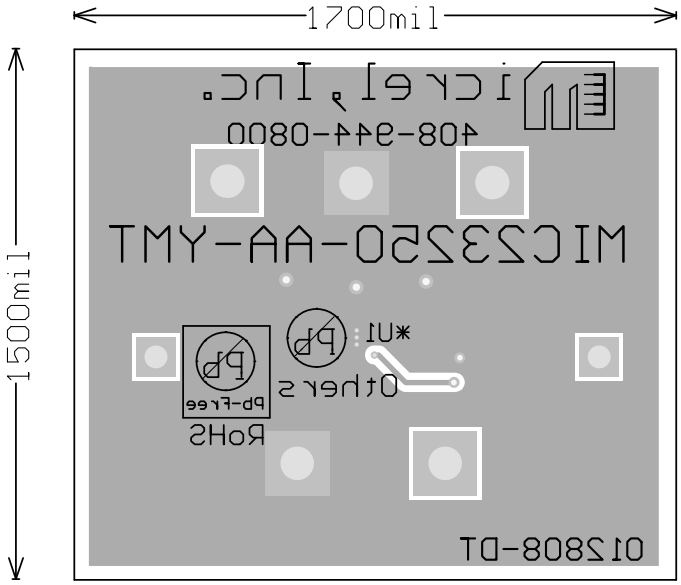

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