Micro Linear

ML4771*

High Current Boost Regulator

GENERAL DESCRIPTION

The ML4771 is a continuous conduction boost regulator designed for DC to DC conversion in multiple cell battery powered systems. Continuous conduction allows the regulator to maximize output current for a given inductor. The maximum switching frequency can exceed 200kHz, allowing the use of small, low cost inductors. The ML4771 is capable of start-up with input voltages as low as 1.8V, and the output voltage can be set anywhere between 3.0V and 5.5V by an external resistor divider connected to the SENSE pin.
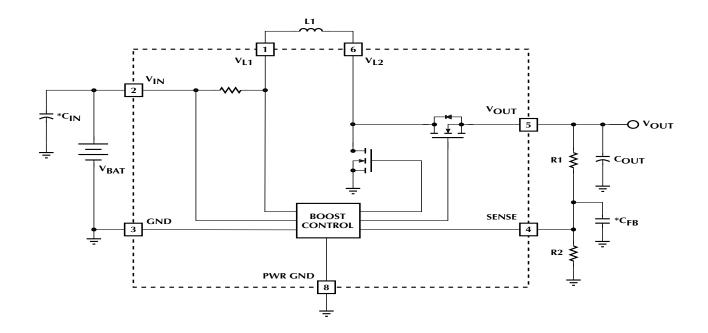
An integrated synchronous rectifier eliminates the need for an external Schottky diode and provides a lower forward voltage drop, resulting in higher conversion efficiency. In addition, low quiescent battery current and variable frequency operation result in high efficiency even at light loads. The ML4771 requires a minimum number of external components to build a very small regulator circuit capable of achieving conversion efficiencies exceeding 85%.

FEATURES

■ Guaranteed full load start-up and operation at 1.8V input

■ Continuous conduction mode for high output current

■ Very low supply current (20µA output referenced) for micropower operation

■ Pulse Frequency Modulation and Internal Synchronous Rectification for high efficiency

■ Maximum switching frequency > 200kHz

■ Minimum external components

■ Low ON resistance internal switching FETs

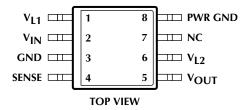■ Adjustable output voltage (3.0V to 5.5V)

(* Indicates Part is End Of Life as of July 1, 2000)

BLOCK DIAGRAM

ML4771

PIN CONFIGURATION

ML4771
8-Pin SOIC (S08)

V_{L1} [1]   [8] PWR GND
V_{IN} [2]   [7] NC
GND [3]   [6] V_{L2}
SENSE [4]   [5] V_{OUT}

TOP VIEW

PIN DESCRIPTION

PIN	NAME	FUNCTION
1	V_{L1}	Boost inductor connection
2	V_{IN}	Battery input voltage
3	GND	Ground
4	SENSE	Programming pin for setting the output voltage

PIN	NAME	FUNCTION
5	V_{OUT}	Output of the boost regulator
6	V_{L2}	Boost inductor connection
7	NC	No connection
8	PWR GND	Return for the NMOS output transistor

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ABSOLUTE MAXIMUM RATINGS

Absolute maximum ratings are those values beyond which the device could be permanently damaged. Absolute maximum ratings are stress ratings only and functional device operation is not implied.

V_{OUT} 7V
Voltage on any other pin ..... GND – 0.3V to V_{OUT} + 0.3V
Peak Switch Current (I_{PEAK}) 2A
Average Switch Current (I_{AVG}) 1A
Junction Temperature 150ºC
Storage Temperature Range .... –65ºC to 150ºC
Lead Temperature (Soldering 10 sec) 260ºC
Thermal Resistance (θ_{JA}) 160ºC/W

OPERATING CONDITIONS

Temperature Range
    ML4771CS .... 0ºC to 70ºC
    ML4771ES .... –20ºC to 70ºC
V_{IN} Operating Range
    ML4771CS .... 1.8V to V_{OUT} – 0.2V
    ML4771ES .... 2.0V to V_{OUT} – 0.2V
V_{OUT} Operating Range .... 3.0V to 5.5V

ELECTRICAL CHARACTERISTICS

Unless otherwise specified, V_{IN} = Operating Voltage Range, T_A = Operating Temperature Range (Note 1).

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
SUPPLY						
I_{IN}	V_{IN} Current	V_{IN} = V_{OUT} – 0.2V		2	5	µA
$I_{OUT(Q)}$	V_{OUT} Quiescent Current			25	35	µA
$I_{L(Q)}$	V_L Quiescent Current				1	µA
PFM REGULATOR						
	I_L Peak Current		1.2	1.4	1.7	A
V_{SENSE}	SENSE Comparator Threshold Voltage		2.52	2.57	2.62	V
V_{OUT}	Output Voltage	See Figure 1, I_{OUT} = 0	4.95	5.05	5.15	V
	Load Regulation	See Figure 1, V_{IN} = 2.4V, I_{OUT} = 220mA	4.85	4.95	5.15	V

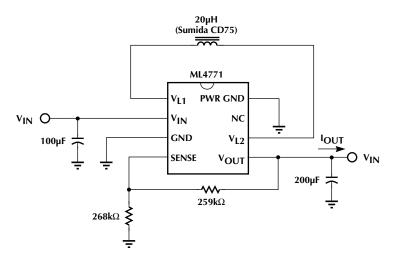Note 1:   Limits are guaranteed by 100% testing, sampling or correlation with worst case test conditions.
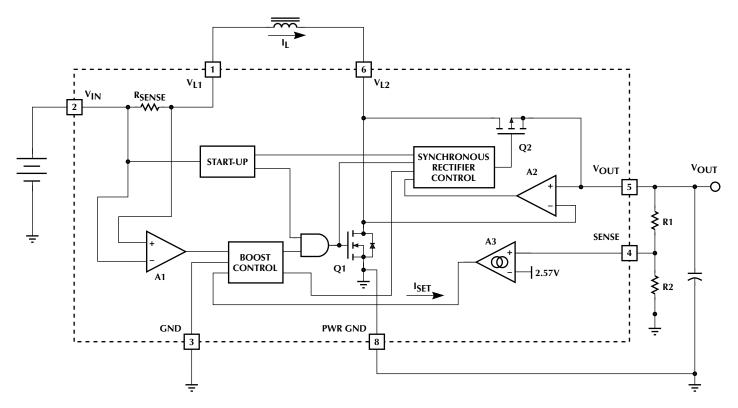
Figure 1. Application Test Circuit.
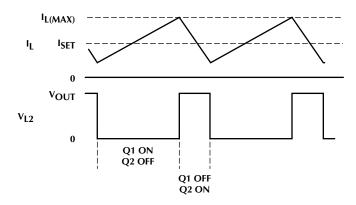

Figure 2. PFM Regulator Block Diagram.

Figure 3. Inductor Current and Voltage Waveforms.

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FUNCTIONAL DESCRIPTION

The ML4771 combines a unique form of current mode control with a synchronous rectifier to create a boost converter that can deliver high currents while maintaining high efficiency. Current mode control allows the use of a very small, high frequency inductor and output capacitor. Synchronous rectification replaces the conventional external Schottky diode with an on-chip PMOS FET to reduce losses and eliminate an external component. Also included on-chip are an NMOS switch and current sense resistor, further reducing the number of external components, which makes the ML4771 very easy to use.

REGULATOR OPERATION

The ML4771 is a variable frequency, current mode switching regulator. Its unique control scheme converts efficiently over more than three decades of load current. A block diagram of the boost converter is shown in Figure 2.

Error amp A3 converts deviations in the desired output voltage to a small current, I_{SET}. The inductor current is measured through a 50mΩ resistor which is amplified by A1. The boost control block matches the average inductor current to a multiple of the I_{SET} current by switching Q1 on and off. The peak inductor current is limited by the controller to about 1.5A.

At light loads, I_{SET} will momentarily reach zero after an inductor discharge cycle , causing Q1 to stop switching. Depending on the load, this idle time can extend to tenths of seconds. While the circuit is not switching, only 20µA of supply current is drawn from the output. This allows the part to remain efficient even when the load current drops below 200µA.

Amplifier A2 and the PMOS transistor Q2 work together to form a low drop diode. When transistor Q1 turns off, the current flowing in the inductor causes pin 6 to go high. As the voltage on V_{L2} rises above V_{OUT}, amplifier A2 allows the PMOS transistor Q2 to turn on. In discontinuous operation, (where I_L always returns to zero), A2 uses the resistive drop across the PMOS switch Q2 to sense zero inductor current and turns the PMOS switch off. In continuous operation, the PMOS turn off is independent of A2, and is determined by the boost control circuitry.

Typical inductor current and voltage waveforms are shown in Figure 3.

DESIGN CONSIDERATIONS

OUTPUT CURRENT CAPABILITY

The maximum current available at the output of the regulator is related to the maximum inductor current by the ratio of the input to output voltage and the full load efficiency. The maximum inductor current is approximately 1.25A and the full load efficiency may be as low as 70%. The maximum output current can be determined by using the typical performance curves shown in Figures 4 and 5, or by calculation using the following equation:

$$I_{OUT(MAX)} = 1.25 \times \left(\frac{V_{IN(MIN)}}{V_{OUT}} \right) \times 0.7A \qquad (1)$$

INDUCTOR SELECTION

The ML4771 is able to operate over a wide range of inductor values. A value of 10µH is a good choice, but any value between 5µH and 33µH is acceptable. As the inductor value is changed the control circuitry will automatically adjust to keep the inductor current under control. Choosing an inductance value of less than 10µH will reduce the component's footprint, but the efficiency and maximum output current may drop.

It is important to use an inductor that is rated to handle 1.5A peak currents without saturating. Also look for an inductor with low winding resistance. A good rule of thumb is to allow 5 to 10mΩ of resistance for each µH of inductance.

The final selection of the inductor will be based on trade-offs between size, cost and efficiency. Inductor tolerance, core and copper loss will vary with the type of inductor selected and should be evaluated with a ML4771 under worst case conditions to determine its suitability.

Several manufacturers supply standard inductance values in surface mount packages:

Coilcraft	(847) 639-6400
Coiltronics	(561) 241-7876
Dale	(605) 665-9301
Sumida	(847) 956-0666

DESIGN CONSIDERATIONS (Continued)

OUTPUT CAPACITOR

The output capacitor filters the pulses of current from the switching regulator. Since the switching frequency will vary with inductance, the minimum output capacitance required to reduce the output ripple to an acceptable level will be a function of the inductor used. Therefore, to maintain an output voltage with less than 100mV of ripple at full load current, use the following equation:

$$C_{OUT} = \frac{44 \times L}{V_{OUT}} \qquad (2)$$

The output capacitor's Equivalent Series Resistance (ESR) and Equivalent Series Inductance (ESL), also contribute to the ripple. Just after the NMOS transistor, Q1, turns off, the current in the output capacitor ramps quickly to between

0.5A and 1.5A. This fast change in current through the capacitor's ESL causes a high frequency (5ns) spike to appear on the output. After the ESL spike settles, the output still has a ripple component equal to the inductor discharge current times the ESR. To minimize these effects, choose an output capacitor with less than 10nH of ESL and 100mΩ of ESR.

Suitable tantalum capacitors can be obtained from the following vendors:

AVX   (207) 282-5111
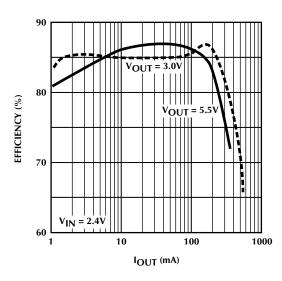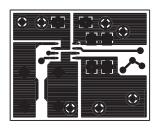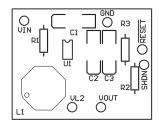
Kemet   (846) 963-6300

Sprague   (207) 324-4140

Figure 4. I_{OUT} vs. VIN Using the Circuit of Figure 8

Figure 5. Efficiency vs. I_{OUT} Using the Circuit of Figure 8

Figure 6. No Load Input Current vs. V_{IN}

Figure 7. Sample PC Board Layout

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ML4771
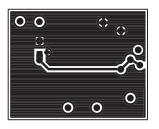
DESIGN CONSIDERATIONS (Continued)

INPUT CAPACITOR

Due to the high input current drawn at startup and possibly during operation, it is recommended to decouple the input with a capacitor with a value of 47µF to 100µF. This filtering prevents the input ripple from affecting the ML4771 control circuitry, and also improves the efficiency by reducing the I squared R losses during the charge cycle of the inductor. Again, a low ESR capacitor (such as tantalum) is recommended.

It is also recommended that low source impedance batteries be used. Otherwise, the voltage drop across the source impedance during high input current situations will cause the ML4771 to fail to start-up or to operate unreliably. In general, for two cell applications the source impedance should be less than 200mΩ, which means that small alkaline cells should be avoided.

SETTING THE OUTPUT VOLTAGE

The adjustable output of the ML4771 requires an external feedback resistor divider to set V_{OUT}. The output voltage can be determined from the following equation:

$$V_{OUT} = 2.57 \times \frac{(R_1 + R_2)}{R_2} \qquad (3)$$

where R1 and R2 are connected as shown in Figure 2. The value of R2 should be 250kΩ or less to minimize bias current errors. Choose an appropriate value for R2 and calculate R1.

LAYOUT

Good layout practices will ensure the proper operation of the ML4771. Some layout guidelines follow:

- Use adequate ground and power traces or planes

- Keep components as close as possible to the ML4771

- Use short trace lengths from the inductor to the V_{L1} and V_{L2} pins and from the output capacitor to the V_{OUT} pin

- Use a single point ground for the ML4771 ground pin, and the input and output capacitors

- Separate the ground for the converter circuitry from the ground of the load circuitry and connect at a single point

A sample layout is shown in Figure 7.

DESIGN EXAMPLE

In order to design a boost converter using the ML4871, it is necessary to define a few parameters. For this example, assume that V_{IN} = 3.0V to 3.6V, V_{OUT} = 5.0V, and $I_{OUT(MAX)}$ = 500mA.

First, it must be determined whether the ML4871 is capable of delivering the output current. This is done using Equation 1:

$$I_{OUT(MAX)} = 1.25 \times \left(\frac{3.0V}{5.0V} \right) \times 0.7A = 0.53A$$

Next, select an inductor. As previously mentioned, the recommended inductance is 10µH. Make sure that the peak current rating of the inductor is at least 1.5A, and that the DC resistance of the inductor is in the range of 50 to 100mΩ.

Then, the value of the output capacitor is determined using Equation 2:

$$C_{OUT} = \frac{44 \times 10µH}{5.0V} = 88µF$$

The closest standard value would be a 100µF capacitor with an ESR rating of 100mΩ. If such a low ESR value cannot be found, two 47µF capacitors in parallel could also be used.

Finally, the values of R1 and R2 are calculated using equation 3, assuming that R2 = 250kΩ:

$$R_1 = \left(\frac{5.0}{2.57} \times 250k\Omega \right) - 250k\Omega = 236k\Omega$$

The complete circuit is shown in Figure 8. As mentioned previously, the use of an input supply bypass capacitor is highly recommended.
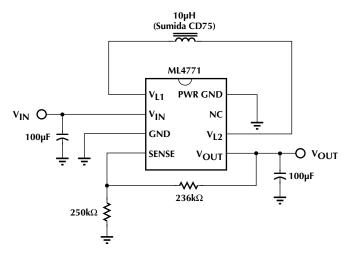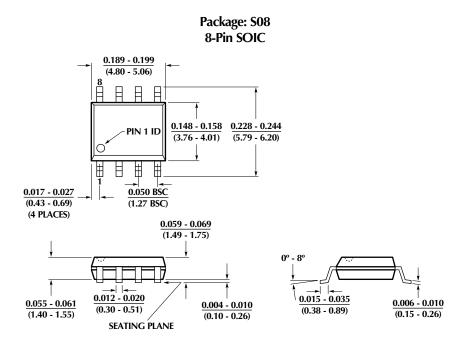

Figure 8. Typical Application Circuit

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PHYSICAL DIMENSIONS inches (millimeters)

Package: S08
8-Pin SOIC

0.189 - 0.199
(4.80 - 5.06)

8

PIN 1 ID

0.148 - 0.158
(3.76 - 4.01)

0.228 - 0.244
(5.79 - 6.20)

1

0.017 - 0.027
(0.43 - 0.69)
(4 PLACES)

0.050 BSC
(1.27 BSC)

0.059 - 0.069
(1.49 - 1.75)

0° - 8°

0.055 - 0.061
(1.40 - 1.55)

0.012 - 0.020
(0.30 - 0.51)

0.004 - 0.010
(0.10 - 0.26)

SEATING PLANE

0.015 - 0.035
(0.38 - 0.89)

0.006 - 0.010
(0.15 - 0.26)

ORDERING INFORMATION

PART NUMBER	TEMPERATURE RANGE	PACKAGE
ML4771CS (End Of Life)	0ºC to 70ºC	8-Pin SOIC (S08)
ML4771ES (Obsolete)	−20ºC to 70ºC	8-Pin SOIC (S08)

2092 Concourse Drive
San Jose, CA 95131
Tel: 408/433-5200
Fax: 408/432-0295
www.microlinear.com

DS4771-01

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