3MHz 2A High $\eta$ Step-Down Converter in DFN2x2-8L Package

DESCRIPTION

The ETA3410 is a high-efficiency, DC-to-DC step-down switching regulator, capable of delivering up to 2A of output current. The devices operate from an input voltage range of 2.6V to 5.5V and provide output voltages from 0.6V to VIN, making the ETA3410 ideal for low voltage power conversions. Running at a fixed frequency of 3MHz allows the use of small inductance value and low DCR inductors, thereby achieving higher efficiencies. Other external components, such as ceramic input and output caps, can also be small due to higher switching frequency, while maintaining exceptional low noise output voltages. Built-in EMI reduction circuitry makes this converter ideal power supply for RF applications. Internal soft-start control circuitry reduces inrush current. Short-circuit and thermal-overload protection improves design reliability. ETA3410 is housed in a tiny DFN2x2-8L package.

FEATURES

- $\eta$ up to 96%
- Up to 2A Max Output Current
- 3MHz Frequency
- Internal Compensation
- Clock Dithering
- Tiny DFN2x2-8L Package

APPLICATIONS

- USB ports/Hubs
- Hot Swaps
- Cellphones
- Tablet PC
- Set Top Boxes

ORDERING INFORMATION

<table>
<thead>
<tr>
<th>PART</th>
<th>PACKAGE PIN</th>
<th>TOP MARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETA3410D2I</td>
<td>DFN2x2-8</td>
<td>CEYW</td>
</tr>
</tbody>
</table>

TYPICAL APPLICATION

![1.8V/2A 3MHz Step-Down Converter](image)

![Efficiency Vs I_{OUT}](image)
ABSOLUTE MAXIMUM RATINGS
(Note: Exceeding these limits may damage the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.)

PVIN, AVIN, SW, FB, EN, MODE Voltage .......................... –0.3V to 6V
SW to ground current ............................................. Internally limited
Maximum Power Dissipation ..................................... 1300mW
Operating Temperature Range ................................. –40°C to 85°C
Storage Temperature Range ................................. –55°C to 150°C

ELECTRICAL CHARACTERISTICS
(VIN = 3.6V, unless otherwise specified. Typical values are at TA = 25°C.)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage Range</td>
<td></td>
<td>2.6</td>
<td>5.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Input UVLO</td>
<td>Rising, Hysteresis=200mV</td>
<td>2.1</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Input Supply Current</td>
<td>VIN =0.65V, MODE=GND</td>
<td>30</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Input Shutdown Current</td>
<td></td>
<td>0.1</td>
<td>1</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>FB Feedback Voltage</td>
<td>VIN =2.5 to 5.5V</td>
<td>0.588</td>
<td>0.6</td>
<td>0.612</td>
<td>V</td>
</tr>
<tr>
<td>FB Input Current</td>
<td></td>
<td>0.01</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Output Voltage Range</td>
<td>VIN</td>
<td>0.6</td>
<td>VIN</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Load Regulation</td>
<td>VIN =2.7 to 5.5V</td>
<td>0.15</td>
<td></td>
<td></td>
<td>%/A</td>
</tr>
<tr>
<td>Line Regulation</td>
<td>VIN =2.7 to 5.5V</td>
<td>0.04</td>
<td></td>
<td></td>
<td>%/V</td>
</tr>
<tr>
<td>Switching Frequency</td>
<td>VIN =2.7 to 5.5V</td>
<td>2.4</td>
<td>3</td>
<td>3.6</td>
<td>MHz</td>
</tr>
<tr>
<td>NMOS Switch On Resistance</td>
<td>ISW =200mAx</td>
<td>100</td>
<td>150</td>
<td></td>
<td>mΩ</td>
</tr>
<tr>
<td>PMOS Switch On Resistance</td>
<td>ISW =200mAx</td>
<td>80</td>
<td>120</td>
<td></td>
<td>mΩ</td>
</tr>
<tr>
<td>PMOS Switch Current Limit</td>
<td></td>
<td>2.5</td>
<td>3</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>SW Leakage Current</td>
<td>VOUT=5.5V, VIN=0 or 5.5V, EN= GND</td>
<td>10</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>EN, MODE Input Current</td>
<td>EN=MODE=GND</td>
<td>0.4</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>EN, MODE Input Low Voltage</td>
<td></td>
<td>1.5</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Thermal Shutdown</td>
<td>Rising, Hysteresis =15°C</td>
<td></td>
<td>160</td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>

PIN DESCRIPTION

<table>
<thead>
<tr>
<th>PIN #</th>
<th>NAME</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PGND</td>
<td>Power Ground. Bypass with a 10μF ceramic capacitor to PVIN</td>
</tr>
<tr>
<td>2</td>
<td>SW</td>
<td>Inductor Connection. Connect an inductor Between SW and the regulator output.</td>
</tr>
<tr>
<td>3</td>
<td>AGND</td>
<td>Analog Ground. Connect to PGND</td>
</tr>
<tr>
<td>4</td>
<td>FB</td>
<td>Feedback Input. Connect an external resistor divider from the output to FB and GND to set the output to a voltage between 0.6V and VIN</td>
</tr>
<tr>
<td>5</td>
<td>EN</td>
<td>Enable pin for the IC. Drive this pin to high to enable the part, low to disable.</td>
</tr>
</tbody>
</table>

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### TYPICAL CHARACTERISTICS

(Typical values are at TA = 25°C unless otherwise specified.)

- **Mode**
  - When forced high, the device operates in fixed frequency PWM mode. When forced low, it enables the Power Save Mode with automatic transition from PFM mode to fixed frequency PWM mode. This pin must be terminated.

- **AVIN**
  - Analog Power. Short externally to PVIN

- **PVIN**
  - Supply Voltage. Bypass with a 10μF ceramic capacitor to PGND
TYPICAL CHARACTERISTICS
(Typical values are at TA = 25°C unless otherwise specified.)

SWITCHING WAVEFORMS
Light Load 20mA Mode=VIN

SWITCHING WAVEFORMS
Light Load 20mA Mode=GND

SWITCHING WAVEFORMS
Medium Load 0.5A

Load Transient
VOUT=1.2V 0.2A to 1.0A

Load Transient
VOUT=1.8V 0.2A to 1.5A

Short-Circuit Recovery

Start-Up Waveform
No Load

Start-Up Waveform
IZS=1A

Shutdown Waveform
IZS=1A

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Outperform with Efficiency

Proprietary Information DO NOT Distribute
ETA3410

FUNCTION DESCRIPTION
The ETA3410 high efficiency switching regulator is a small, simple, DC-to-DC step-down converter capable of delivering up to 2A of output current. The device operates in pulse-width modulation (PWM) at 3MHz from a 2.6V to 5.5V input voltage and provides an output voltage from 0.6V to VIN, making the ETA3410 ideal for on-board post-regulation applications. An internal synchronous rectifier improves efficiency and eliminates the typical Schottky free-wheeling diode. Using the on resistance of the internal high-side MOSFET to sense switching currents eliminates current-sense resistors, further improving efficiency and cost.

Loop Operation
ETA3410 uses a PWM current-mode control scheme. An open-loop comparator compares the integrated voltage-feedback signal against the sum of the amplified current-sense signal and the slope compensation ramp. At each rising edge of the internal clock, the internal high-side MOSFET turns on until the PWM comparator terminates the on cycle. During this on-time, current ramps up through the inductor, sourcing current to the output and storing energy in the inductor. The current mode feedback system regulates the peak inductor current as a function of the output voltage error signal. During the off cycle, the internal high-side P-channel MOSFET turns off, and the internal low-side N-channel MOSFET turns on. The inductor releases the stored energy as its current ramps down while still providing current to the output.

Current Sense
An internal current-sense amplifier senses the current through the high-side MOSFET during on time and produces a proportional current signal, which is used to sum with the slope compensation signal. The summed signal then is compared with the error amplifier output by the PWM comparator to terminate the on cycle.

Current Limit
There is a cycle-by-cycle current limit on the high-side MOSFET. When the current flowing out of SW exceeds this limit, the high-side MOSFET turns off and the synchronous rectifier turns on. ETA3410 utilizes a frequency fold-back mode to prevent overheating during short-circuit output conditions. The device enters frequency fold-back mode when the FB voltage drops below 200mV, limiting the current to \( I_{PEAK} \) and reducing power dissipation. Normal operation resumes upon removal of the short-circuit condition.

Soft-start
ETA3410 has an internal soft-start circuitry to reduce supply inrush current during startup conditions. When the device exits under-voltage lockout (UVLO), shutdown mode, or restarts following a thermal-overload event, the soft-start circuitry slowly ramps up current available at SW.

UVLO and Thermal Shutdown
If \( PVIN/AVIN \) drops below 1.9V, the UVLO circuit inhibits switching. Once \( PVIN/AVIN \) rises above 2.1V, the UVLO clears, and the soft-start sequence activates. Thermal-overload protection limits total power dissipation in the device. When the junction temperature exceeds \( T_J = +160^\circ C \), a thermal sensor forces the device into shutdown, allowing the die to cool. The thermal sensor turns the device on again after the junction temperature cools by 15°C, resulting in a pulsed output during continuous overload conditions. Following a thermal-shutdown condition, the soft-start sequence begins.

Design Procedure

Setting Output Voltages
Output voltages are set by external resistors. The FB threshold is 0.6V.
\[
R_{TOP} = R_{BOTTOM} \times \left(\frac{V_{OUT}}{0.6} - 1\right)
\]

Inductor Selection
The peak-to-peak ripple is limited to 30% of the maximum output current. This places the peak current far enough from the minimum overcurrent trip level to ensure reliable operation while providing enough current ripples for the current mode converter to operate stably. In this case, for 2A maximum output current, the maximum inductor ripple current is 667mA. The inductor size is estimated as following equation:
\[
L_{IDEAL} = \frac{(V_{IN(MAX)} - V_{OUT})}{V_{RIPPLE} \times D \times \frac{1}{f_{OSC}}}
\]
Therefore, for \( V_{OUT}=1.8V \),

The inductor values is calculated to be \( L = 0.60\mu H \).
Choose 1 μH
For $V_{OUT} = 1.2V$,
The inductor values is calculated to be $L = 0.469 \mu H$.
Choose 0.47 μH
The resulting ripple is
$$I_{RIPPLE} = \frac{(V_{IN(MAX)} - V_{OUT})}{L_{ACTUAL} \times D_{MIN}} \times \frac{1}{f_{OSC}}$$
When,
$V_{OUT} = 1.8V$, $I_{RIPPLE} = 403mA$
$V_{OUT} = 1.2V$, $I_{RIPPLE} = 665mA$

Output Capacitor Selection

For most applications a nominal 10μF or 22μF capacitor is suitable. The ETA3410 internal compensation is designed for a fixed corner frequency that is equal to
$$f_C = \frac{1}{2 \pi \sqrt{C_{OUT} \times L}} = 50Khz$$
For example, for $V_{OUT} = 1.8V$, $L = 1\mu H$, $C_{OUT} = 10\mu F$, for $V_{OUT} = 1.2V$, $L = 0.47\mu H$, $C_{OUT} = 22\mu F$
The output capacitor keeps output ripple small and ensures control-loop stability. The output capacitor must also have

Input Capacitor Selection

The input capacitor in a DC-to-DC converter reduces current peaks drawn from the battery or other input power source and reduces switching noise in the controller. The impedance of the input capacitor at the switching frequency should be

low impedance at the switching frequency. Ceramic, polymer, and tantalum capacitors are suitable, with ceramic exhibiting the lowest ESR and high-frequency impedance. Output ripple with a ceramic output capacitor is approximately as follows:
$$V_{RIPPLE} = I_{L(PEAK)} \times \frac{1}{(2 \pi x f_{OSC} \times C_{OUT})}$$
If the capacitor has significant ESR, the output ripple component due to capacitor ESR is as follows:
$$V_{RIPPLE(ESR)} = I_{L(PEAK)} \times ESR$$

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**BLOCK DIAGRAM**

![Block Diagram](image)
TYPICAL APPLICATION

1.2V/2A 3MHz Step-Down Converter

PCB LAYOUT

PACKAGE OUTLINE
DFN2X2-8L PACKAGE OUTLINE AND DIMENSIONS

TOP VIEW

SIDE VIEW

BOTTOM VIEW

<table>
<thead>
<tr>
<th>PIN</th>
<th>REF.</th>
<th>MIN.</th>
<th>NOM.</th>
<th>MAX.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>0.70</td>
<td>0.75</td>
<td>0.80</td>
</tr>
<tr>
<td>A1</td>
<td></td>
<td>0.60</td>
<td>-</td>
<td>0.03</td>
</tr>
<tr>
<td>A2</td>
<td></td>
<td>0.2</td>
<td>-</td>
<td>0.03</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>0.85</td>
<td>0.80</td>
<td>2.05</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>0.90</td>
<td>0.80</td>
<td>2.05</td>
</tr>
<tr>
<td>G</td>
<td></td>
<td>0.20</td>
<td>0.20</td>
<td>0.40</td>
</tr>
<tr>
<td>L</td>
<td></td>
<td>0.20</td>
<td>0.40</td>
<td>2.05</td>
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<tr>
<td>DF</td>
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<td>1.45</td>
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<td>0.90</td>
<td>1.00</td>
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<tr>
<td>e</td>
<td></td>
<td>0.50</td>
<td>R50</td>
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