Buck-Boost Converter
Achieving up to 97% Efficiency
at 12V/5A from 4-32V Input

Linear Technology Corporation
Where are the Vin, \( \text{min} < V_o < \text{Vin}, \text{ max } \) Applications

- **Automotive:**
  - \( \text{Vin}=8-15\text{V}, V_o=12\text{V} \)

- **Telecom:**
  - \( \text{Vin}=36-72\text{V}, V_o=48\text{V} \)

- **Portable Equipments**
  - 1-4 cell Li-ion powered
Common Topologies for Buck-Boost Function

Flyback
- 2 inductors or a transformer
- High current stresses on switch
- Max achieved efficiency 90-92%

SEPIC
LTC3780-based Single Inductor Buck-Boost Converter

4-Switch Buck-Boost Topology Yields High Efficiency at High Power

Only One Inductor Simplifies Layout and Saves Space

Single Sense Resistor Keeps Efficiency High

R1

R2
What does the Buck-Boost Achieve?

• Up to 97% efficiency at 12V/5A
• High light load efficiency
• Wide input range 8:1 (4V to 32V)
• Small single inductor
• Small converter size (2.5 in² PCB area)
• 1% output voltage accuracy
• Excellent load/line transient responses
• Internal LDO for MOSFET drive
• Over voltage/current protection
• Soft-start
The 12V/5A Buck-Boost Converter
Size and Efficiency

- <2.5 in\(^2\) total PCB area
- 97% Efficiency at 12V/5A
Load and Line Transient Responses

- **V_{IN} = 12V**
- **V_{OUT} = 12V**
- **LOAD STEP: 0A TO 5A**
- **CONTINUOUS MODE**

- **V_{IN} = 12V**
- **V_{OUT} = 12V**
- **LOAD STEP: 0A TO 5A**
- **DISCONTINUOUS CURRENT MODE**

- **V_{IN} = 12V**
- **V_{OUT} = 12V**
- **LOAD STEP: 0A TO 5A**
- **BURST MODE OPERATION**

---

**Line Transient**

- **V_{IN} = 12V**
- **V_{OUT} = 12V**
- **LOAD STEP: 7V TO 20V**
- **CONTINUOUS MODE**
SEPIC vs. Buck-Boost

- 2X inductor footprint and height
- Max 90% efficiency vs. 97%
How Does LTC3780 Achieve these?

More Details
How Does LTC3780 Achieve these?

- $D_{\text{min-BOOST}} = D_{\text{BUCK-BOOST}}$
- $D_{\text{max}_\text{BUCK}} = (1 - D_{\text{BUCK-BOOST}})$
- $D_{\text{BUCK-BOOST}} = 200\text{ns} \times F_s$
Constant Frequency Buck and Boost Operation

**Buck Mode (Vin>Vo)**

- valley current control
- (D always on, C always off
  A and B controlled as buck switch
  D shut off at zero load)

**Boost Mode (Vin<Vo)**

- peak current control
- (A always on, B always off
  C and D controlled as boost switch
  D shut off at zero load)
Valley Current Control vs. Peak Current Control

- **Valley-Current Control (Buck)**
  - \( D < 0.5 \);
  - Ramp needed;
  - Clock turn on bottom FETs;

- **Peak-Current Control (Boost)**
  - \( D > 0.5 \);
  - Ramp needed;
  - Clock turn on top FETs;
Valley-Peak Current Mode Control Transitions

- **Valley-Current Control (Buck)**
  
  \[ \text{Vin} > \text{Vo}, \text{ switch AD and BD} \]

- **Peak-Current Control (Boost)**
  
  \[ \text{Vin} < \text{Vo}, \text{ switch AC and AD} \]
Operation During Transition (Vin ≥ Vo)

Cycle start with switch B & D turn On
Operation During Transition (\(Vin \leq Vo\))

Cycle start with switch A & C turn On
For the battery powered device

Light load efficiency is critical

What does LTC3780 have?

3 operation modes
## Achieving Light Load Efficiency

### Multi Operation Modes

<table>
<thead>
<tr>
<th>FCB Pin</th>
<th>BUCK Mode</th>
<th>BOOST Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>0V to 0.75V</td>
<td>Force continuous mode</td>
<td>Force continuous mode</td>
</tr>
<tr>
<td>0.85 to 5.0</td>
<td>Skip cycle mode</td>
<td>Burst mode</td>
</tr>
<tr>
<td>&gt; 5.3</td>
<td>DCM with constant freq</td>
<td>DCM with constant freq</td>
</tr>
</tbody>
</table>
Continuous Conduction Mode

\( (V_{\text{FCB}} = 0, \ V_{\text{OUT}} = 12V) \)

- **Vin** = 6V
- **Vin** = 12V
- **Vin** = 18V
Burst, SC Mode

($V_{FCB}$ floating, $V_{OUT} = 12V$)

VIN = 6V  VIN = 12V  VIN = 18V
DCM Mode

\( V_{FCB} = 6V, \ V_{OUT} = 12V \)

- **SW1**
- **SW2**
- **Vout**
- **IL**

- **VIN=6V**
- **VIN=12V**
- **VIN=18V**
Efficiency at Different Operation Modes

(VOUT = 12V, Fs = 200kHz)

\( \text{VIN} = 6V \) \hspace{1cm} \( \text{VIN} = 12V \) \hspace{1cm} \( \text{VIN} = 18V \)
Extending the Operation Voltage Range

Efficiency exceeds 92% most of time
Max efficiency 96.5%
Summary

• LTC3780 based Buck-Boost Converter achieves over 97% for 12V/5A output, 5-8% better than a comparable SEPIC converter.

• It has wide input range (8:1)

• It has all the desirable features in a DC/DC converter

• With external driver(s), the operation voltage range can be greatly extended

• An excellent converter for automotive, telecom, and portable applications
LTM®4600
10A Step Down DC/DC µModule™
LTM4600 μModule

• μModule™:
  
  - Complete step down switch mode power supply
  - As easy to design in as a linear regulator
LTM4600 Complete, Quick & Ready

- Discrete Design

20+ Components +
Design
Simulation
Layout
Debug

Expert Power Supply Designer
Purchase +
Assembly
Debug

Time-to-Market, Effort, $$

- LTM4600 µModule

- 40%-50% smaller solution
- Significant reduction in input/output capacitor size
- High power density
- Easy to use
LTM4600  What’s Inside?

√  All Linear Technology Silicon

Simplified Block Diagram

- Linear Technology’s DC/DC Controller & power MOSFETs
- On-board Inductor
- On-board bypass Capacitors
- On-board Compensation

F=800kHz
LTM4600 10A Step Down DC/DC Converter

• Features
  – Vin: 4.5V to 20V (28V for HV product)
  – Vout: 0.6V to 5V, adjustable with single resistor
  – -40°C to +85°C ambient operating temperature range
  – Up to 92% efficiency
  – 1.5% output regulation over temperature
  – Ultra-fast transient response
  – Integrated fault protection (OV/OC/UV)
  – Integrated soft start
    • Adjustable with capacitor
  – 15mm x 15mm x 2.8mm
    Land Grid Array (LGA) package
  \[ \theta_{JA} = 15^\circ \text{ C/W (4 layer PCB)} \]
LTM4600 More Power?

- Parallel 2 LTM4600 for 20A output

48V to V_{BUS}
LTC1950, LTC3723, LTC3722, LTC3900

5 / 12 / 24V_{BUS}
0.6V – 5V
0-10A

Battery or Adapter

OR

High Current PolyPhase™ DC/DC
LTC3728, 3729, 3731, 1778, 3778, 3708, 3733, 3738 etc

10 - 20A
10-200A
Questions and Discussion

Thank you for your time and interest in Linear Technology!

Instant 10A Power Supply

Complete, Quick & Ready.

Performance Driven.