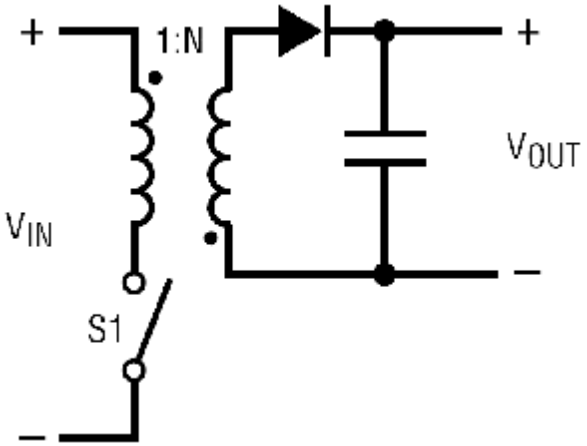
Buck-Boost Converter Achieving up to 97% Efficiency at 12V/5A from 4-32V Input

Linear Technology Corporation

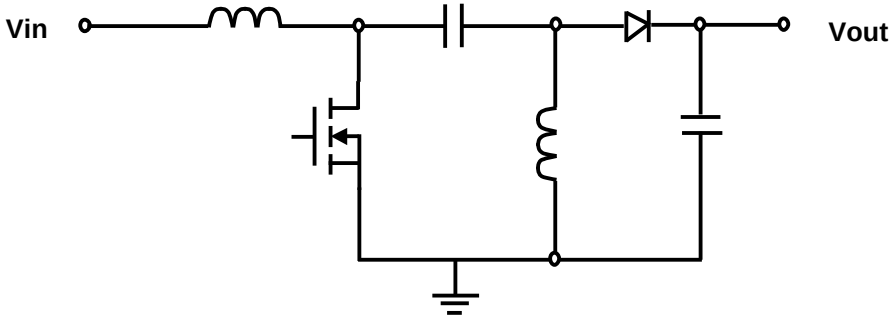
Where are the Vin, min<Vo<Vin, max Applications

- **Automotive:**
  - Vin=8-15V, Vo=12V
- **Telecom:**
  - Vin=36-72V, Vo=48V
- **Portable Equipments**
  - 1-4 cell Li-ion powered

Common Topologies for Buck-Boost Function



Flyback



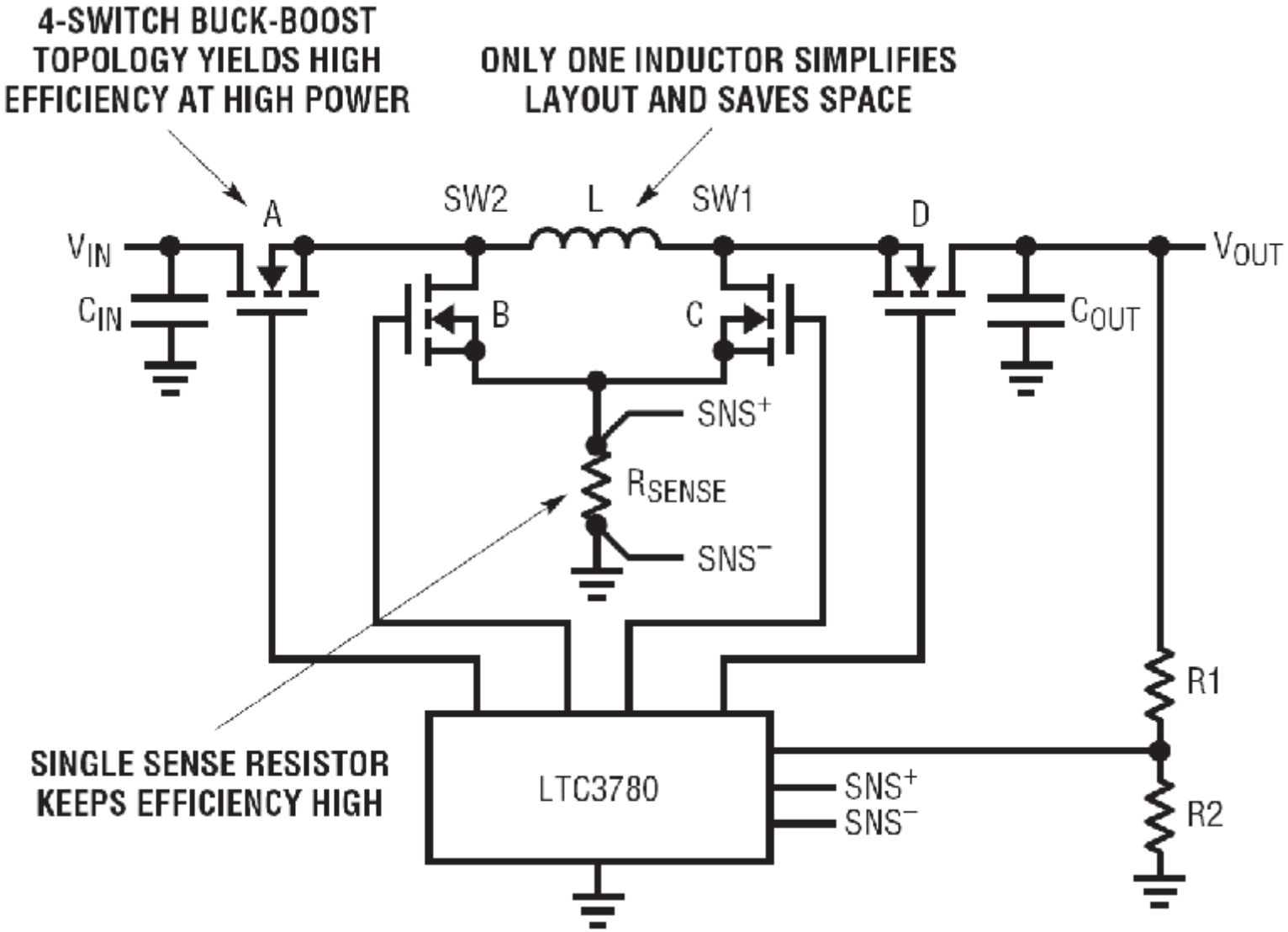
SEPIC

-2 inductors or a transformer

-High current stresses on switch

-Max achieved efficiency 90-92%

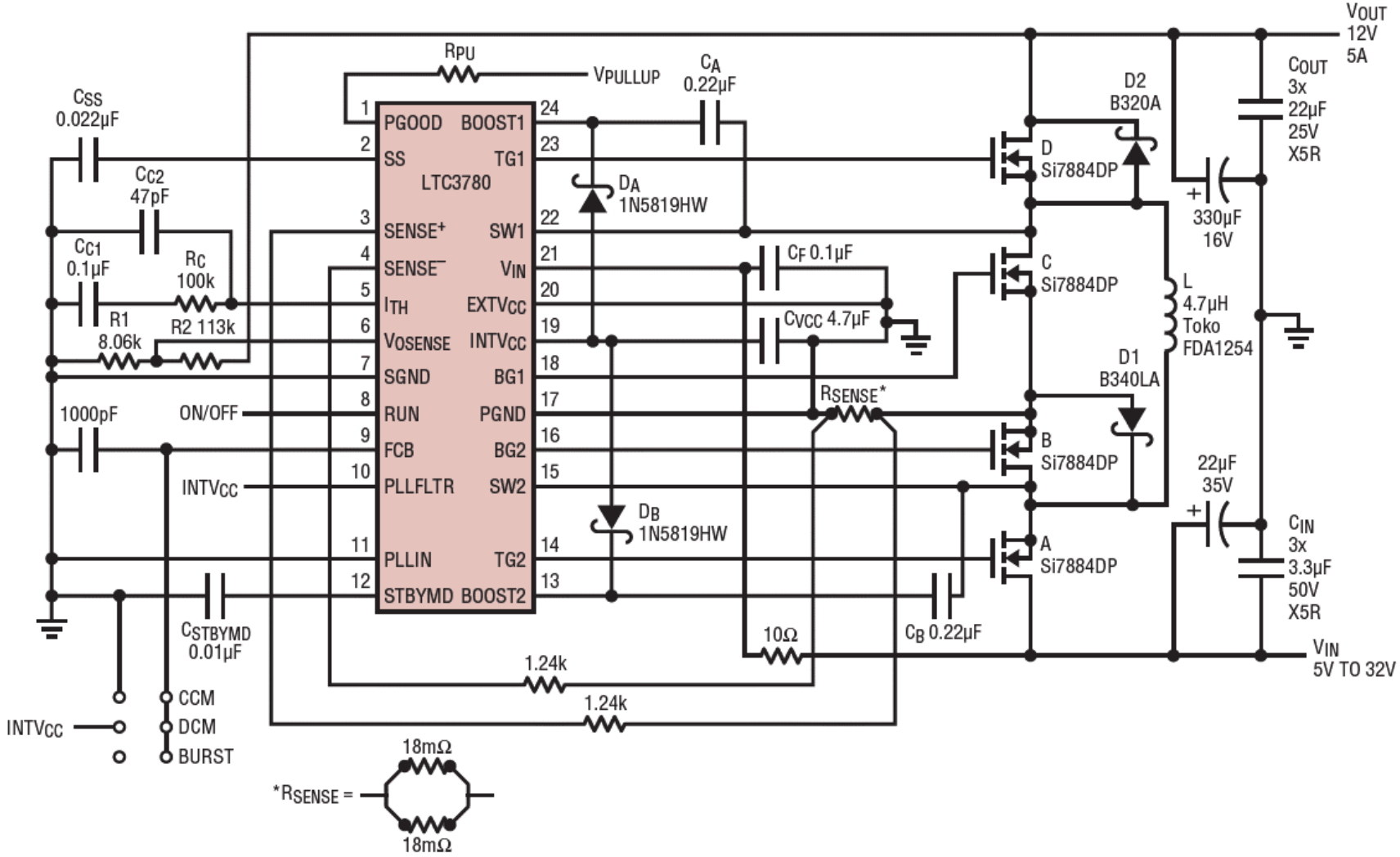
LTC3780-based Single Inductor Buck-Boost Converter



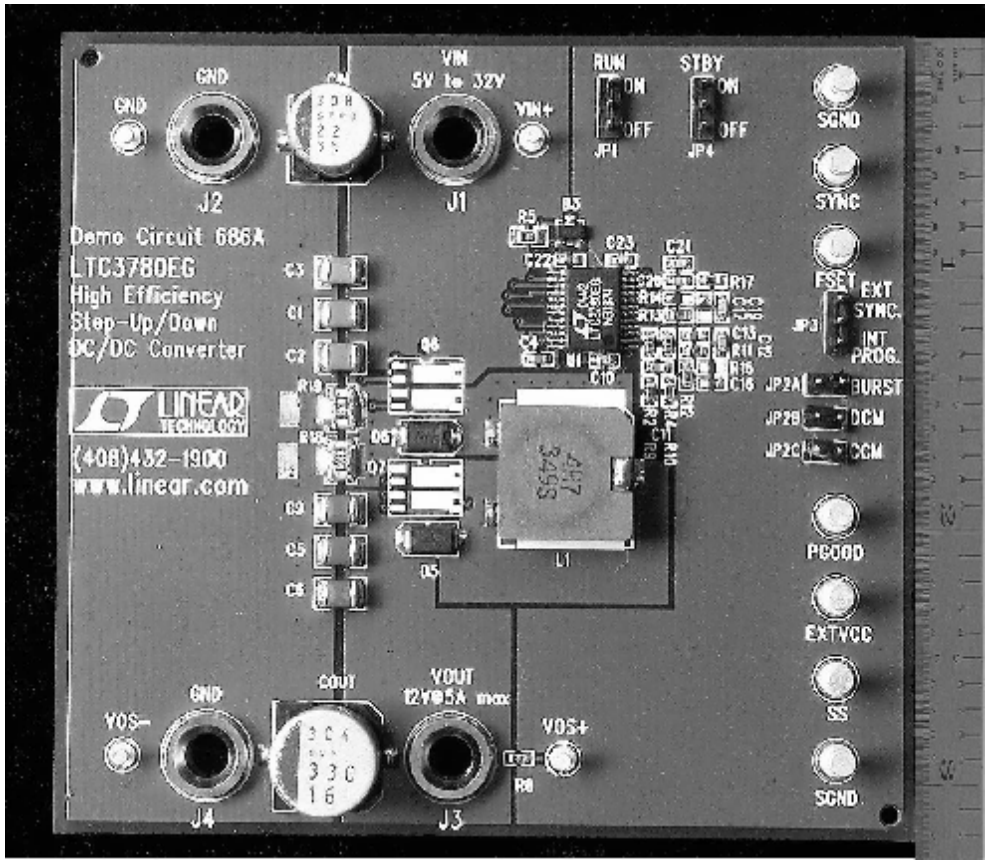
What does the Buck-Boost Achieve?

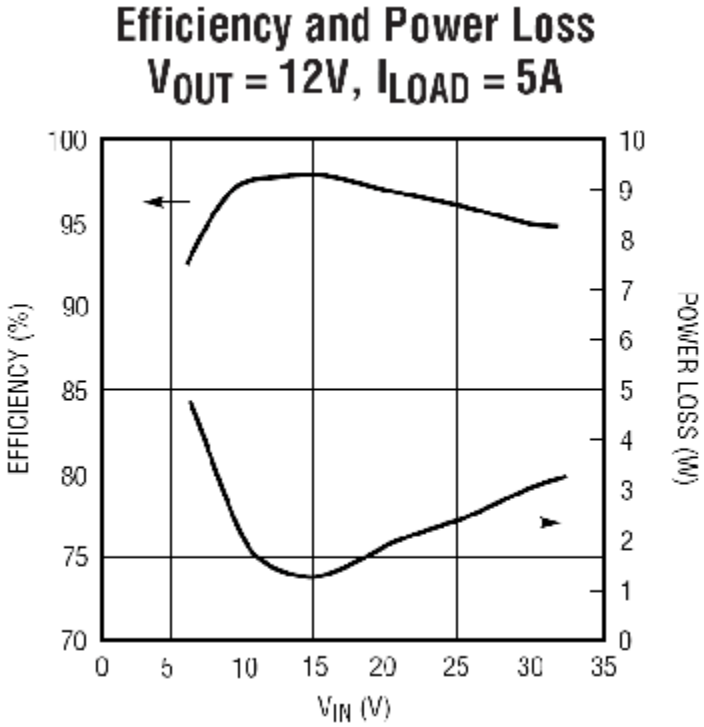
- Up to 97% efficiency at 12V/5A
- High light load efficiency
- Wide input range 8:1 (4V to 32V)
- Small single inductor
- Small converter size (2.5 in^2 PCB area)
- 1% output voltage accuracy
- Excellent load/line transient responses
- Internal LDO for MOSFET drive
- Over voltage/current protection
- Soft-start

The 12V/5A Buck-Boost Converter



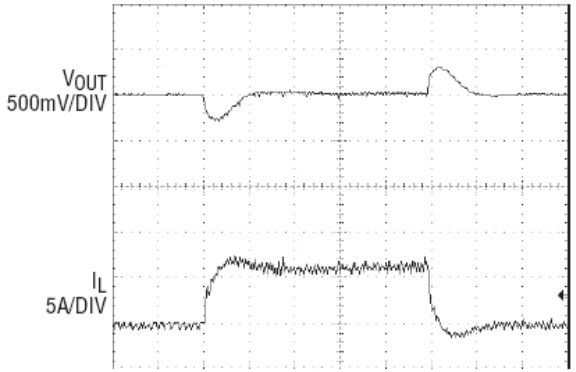
Size and Efficiency



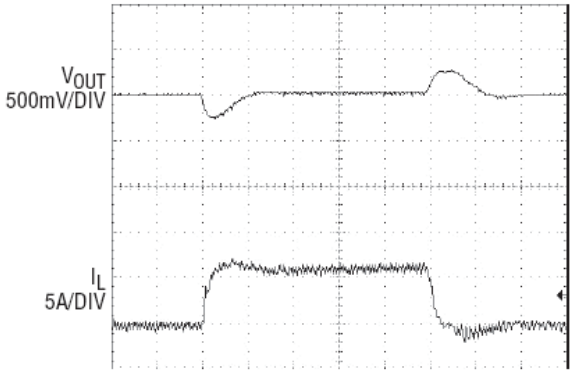


- **<2.5 in^2 total PCB area**
- **97% Efficiency at 12V/5A**

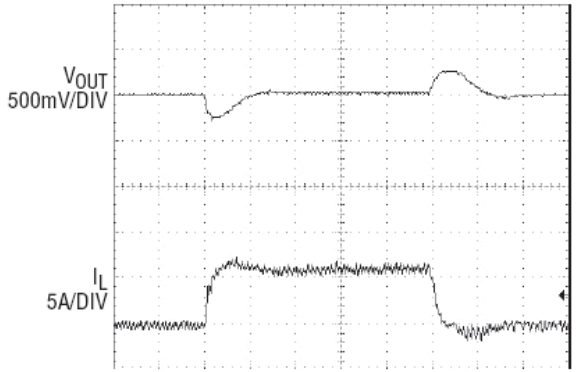
Load and Line Transient Responses



V_{IN} = 12V 200µs/DIV
V_{OUT} = 12V
LOAD STEP: 0A TO 5A
CONTINUOUS MODE

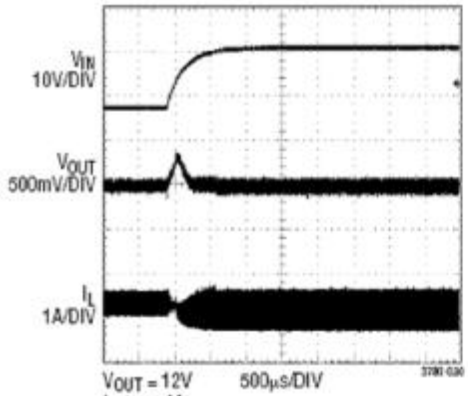


V_{IN} = 12V 200µs/DIV
V_{OUT} = 12V
LOAD STEP: 0A TO 5A
DISCONTINUOUS CURRENT MODE



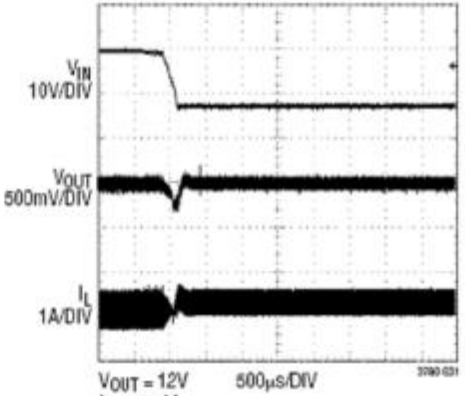
V_{IN} = 12V 200µs/DIV
V_{OUT} = 12V
LOAD STEP: 0A TO 5A
BURST MODE OPERATION

Line Transient



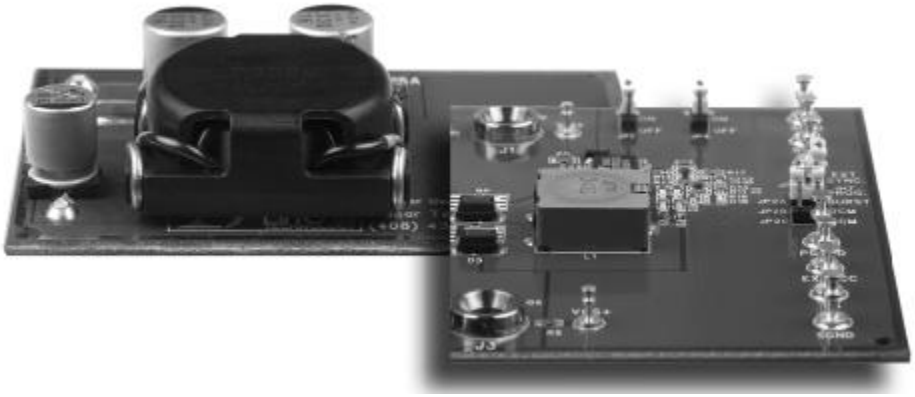
V_{OUT} = 12V 500µs/DIV
I_{LOAD} = 1A
V_{IN} STEP: 7V TO 20V
CONTINUOUS MODE

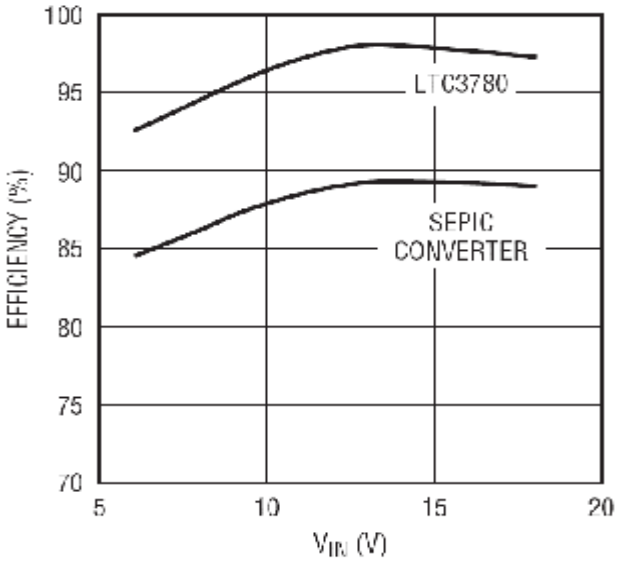
Line Transient



V_{OUT} = 12V 500µs/DIV
I_{LOAD} = 1A
V_{IN} STEP: 20V TO 7V
CONTINUOUS MODE

SEPIC vs. Buck-Boost



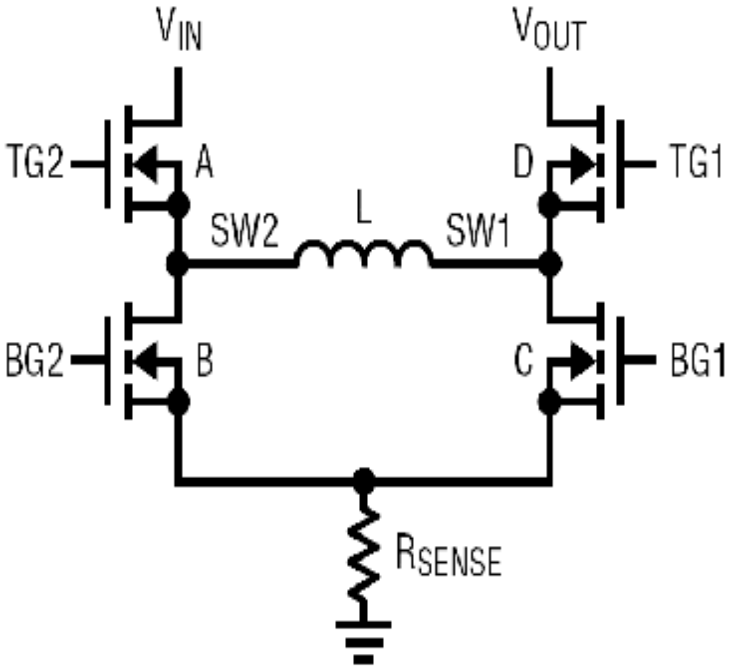


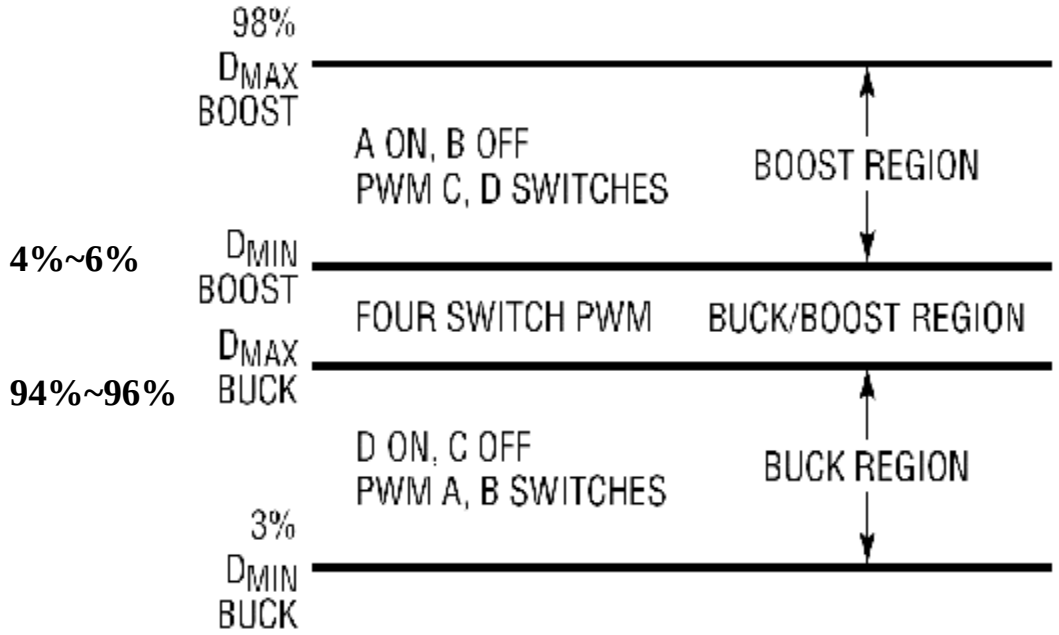
- **2X inductor foot print and height**
- **Max 90% efficiency vs. 97%**

How Does LTC3780 Achieve these?

More Details

How Does LTC3780 Achieve these?

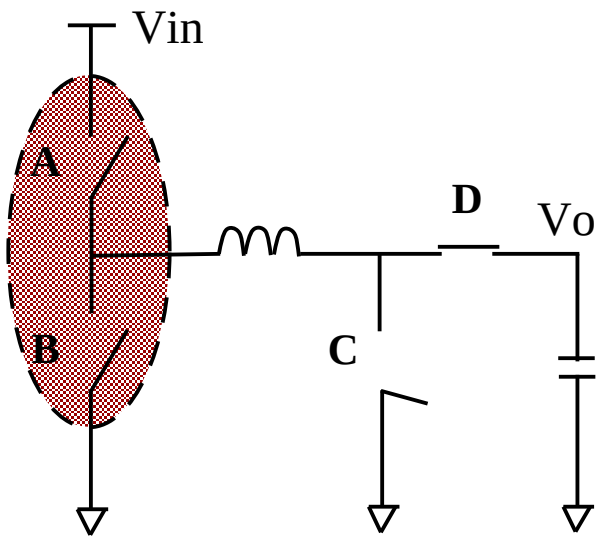




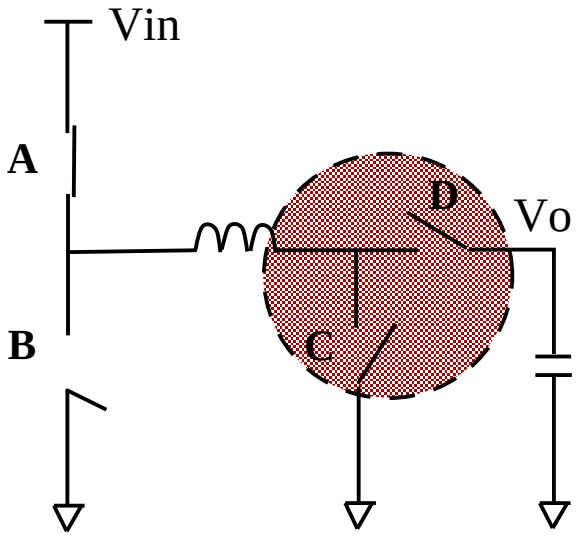
- $D_{min\text{-}BOOST}=D_{BUCK\text{-}BOOST}$
- $D_{max\_BUCK}=(1-D_{BUCK\text{-}BOOST})$
- $D_{BUCK\text{-}BOOST}=200ns*Fs$

Constant Frequency Buck and Boost Operation

Buck Mode (Vin>Vo)



Boost Mode (Vin<Vo)



- **Valley Current Control**

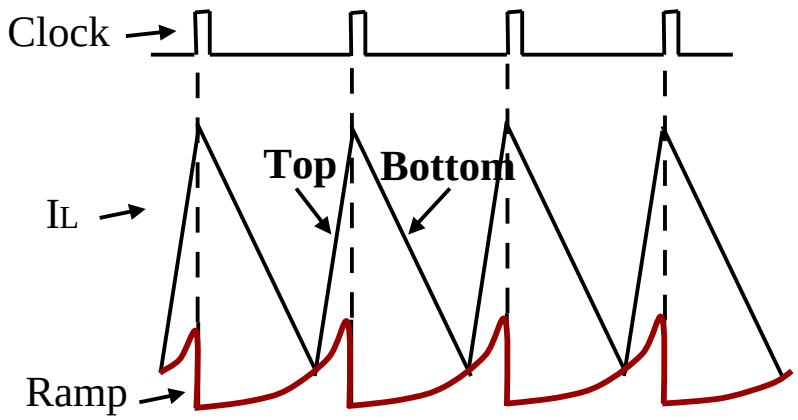
(D always on, C always off
A and B controlled as buck switch
D shut off at zero load)

- **Peak Current Control**

(A always on, B always off
C and D controlled as boost switch
D shut off at zero load)

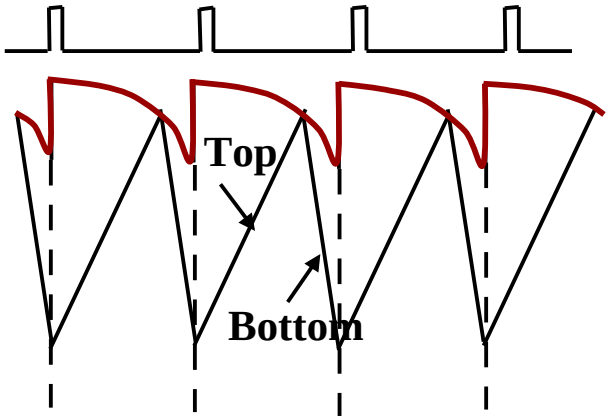
Valley Current Control vs. Peak Current Control

- **Valley-Current Control (Buck)**



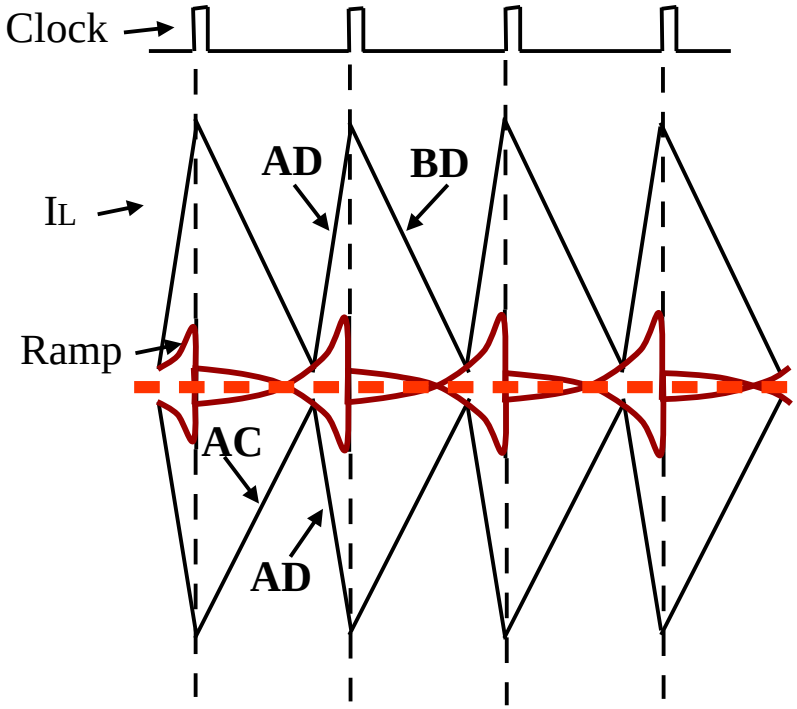
- **D < 0.5;**
- **Ramp needed;**
- **Clock turn on bottom FETs;**

- **Peak-Current Control (Boost)**



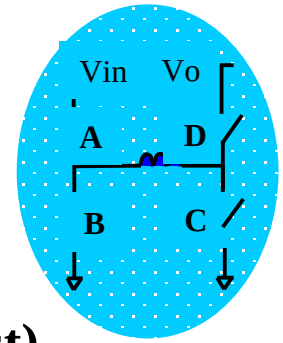
- **D > 0.5;**
- **Ramp needed;**
- **Clock turn on top FETs;**

Valley-Peak Current Mode Control Transitions



- **Valley-Current Control (Buck)**

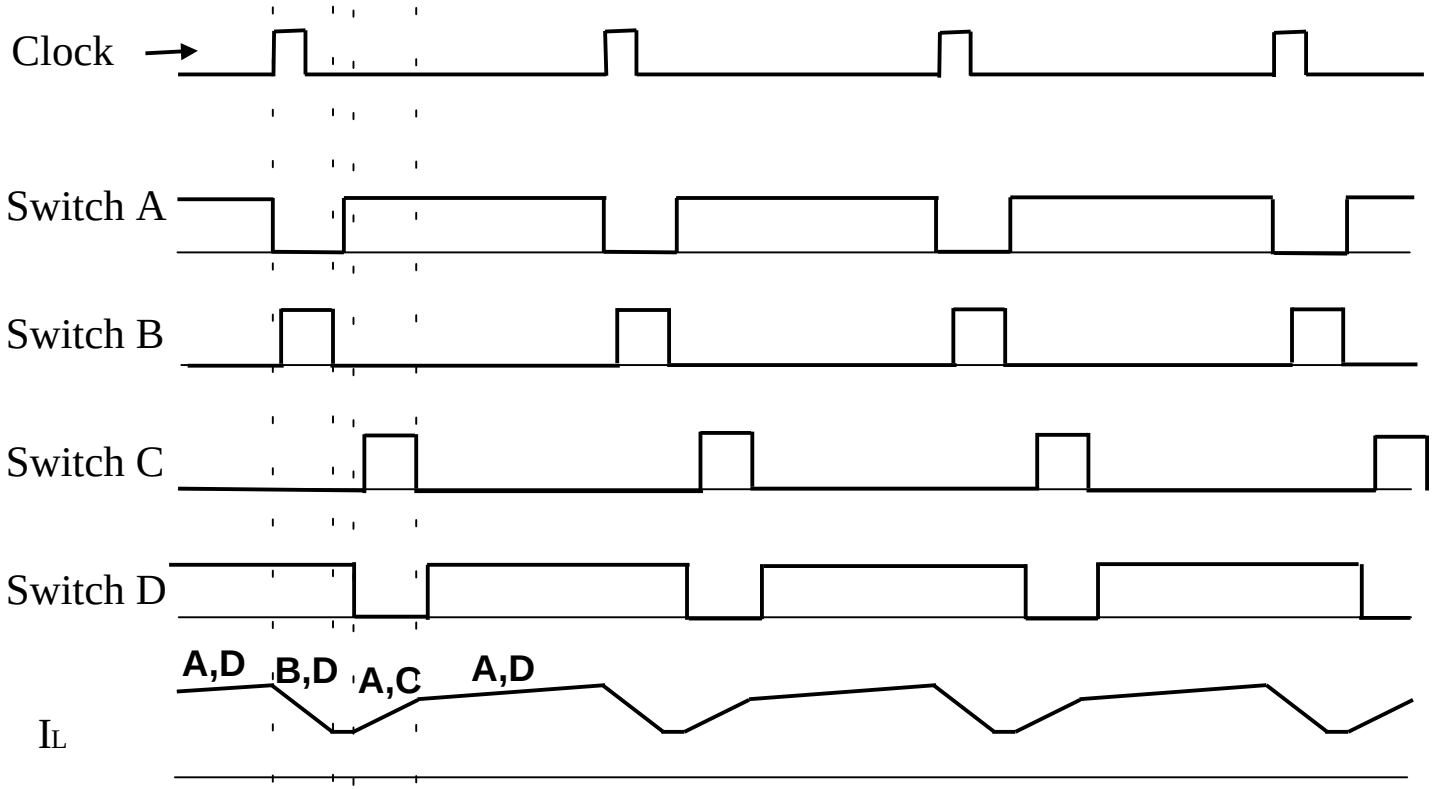
  Vin>Vo, switch AD and BD

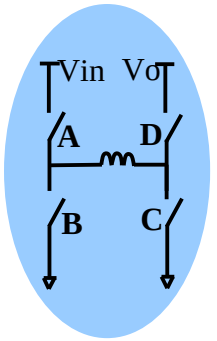


- **Peak-Current Control (Boost)**

  Vin<Vo, switch AC and AD

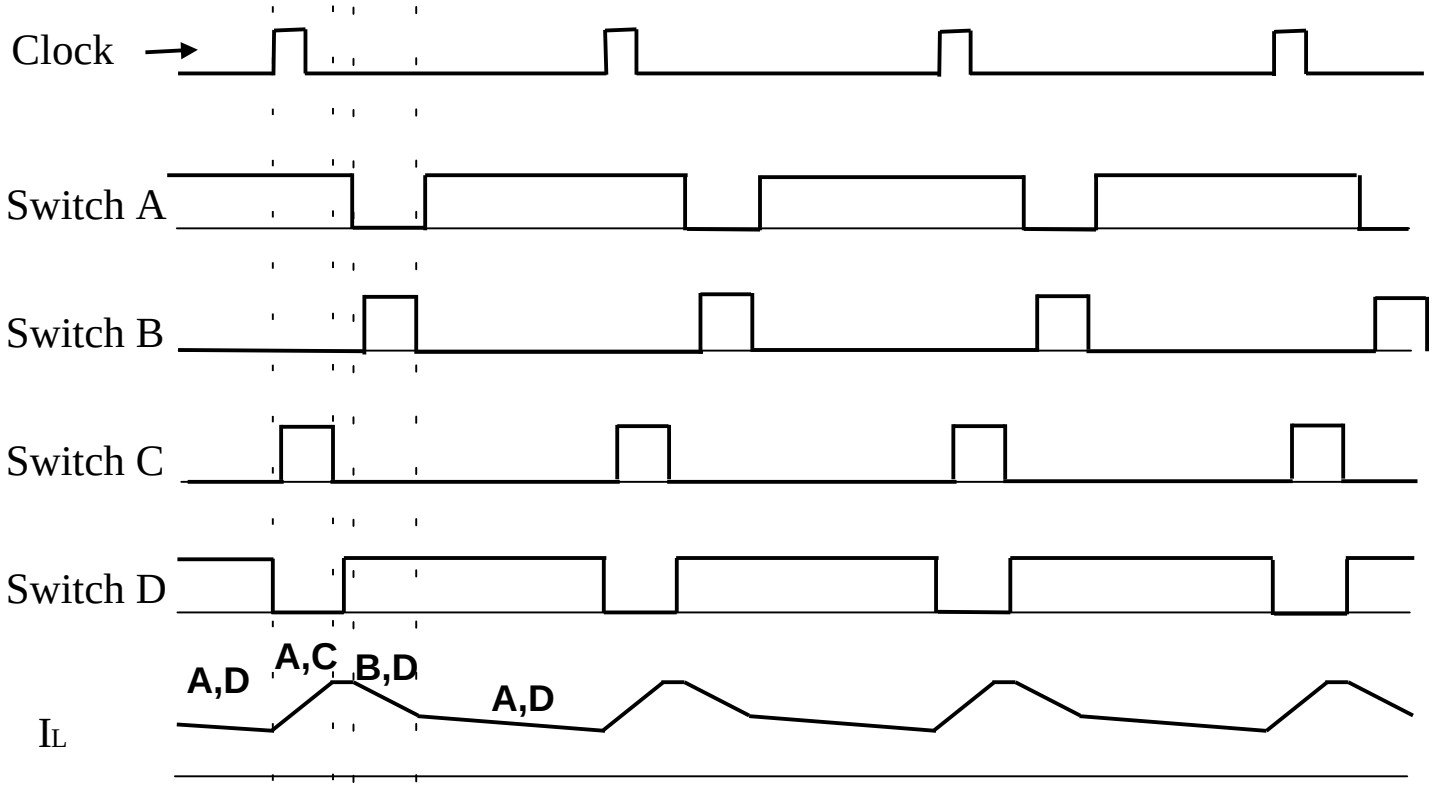
Operation During Transition (Vin ³ Vo)

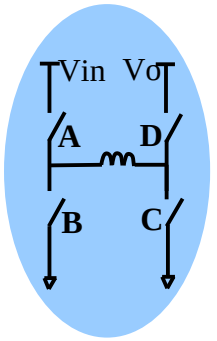




Cycle start with switch B & D turn On

Operation During Transition (Vin£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

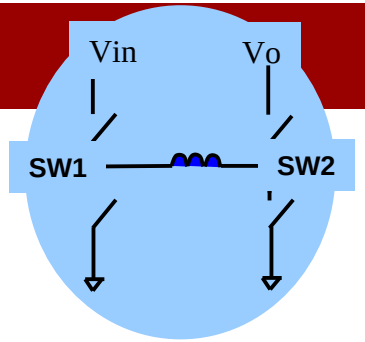
Achieving Light Load Efficiency

Multi Operation Modes

FCB Pin	BUCK Mode	BOOST Mode
0V to 0.75V	Force continuous mode	Force continuous mode
0.85 to 5.0	Skip cycle mode	Burst mode
> 5.3	DCM with constant freq	DCM with constant freq

Continuous Conduction Mode

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

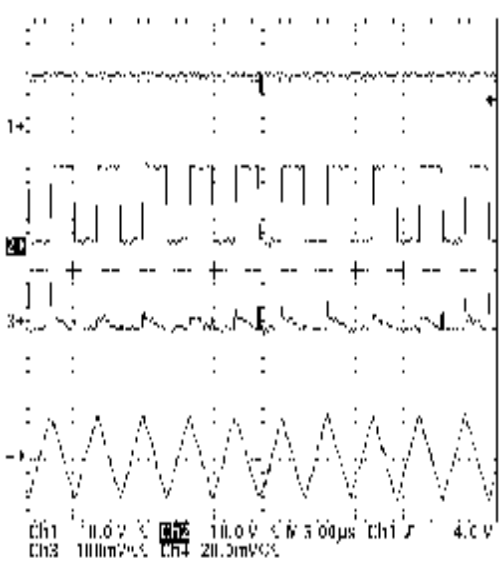


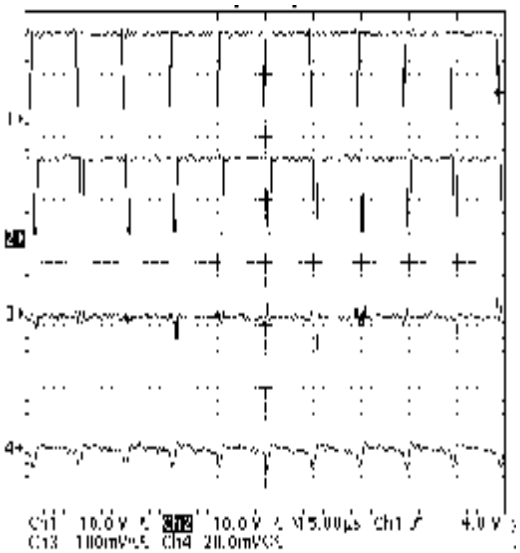
SW1

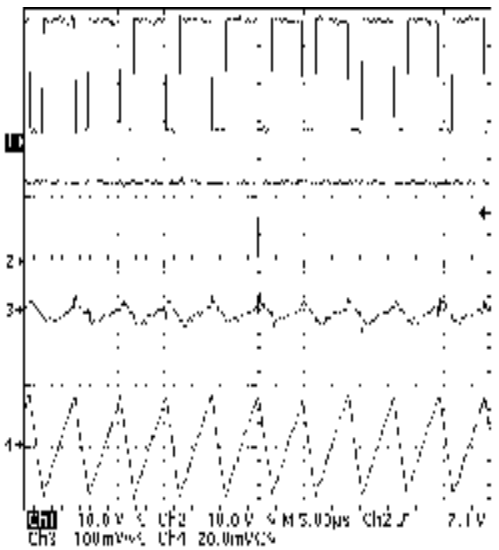
SW2

Vout

I_L







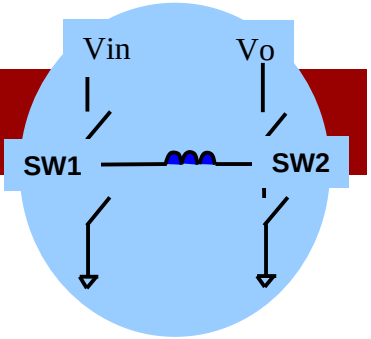
V_{IN} = 6V

V_{IN} = 12V

V_{IN} = 18V

Burst, SC Mode

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

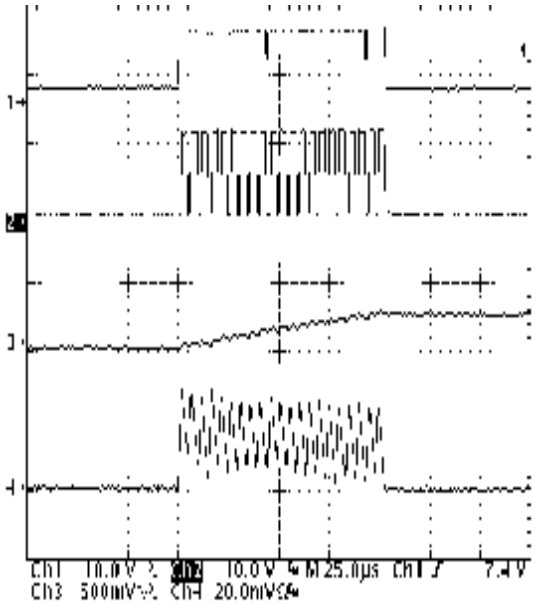


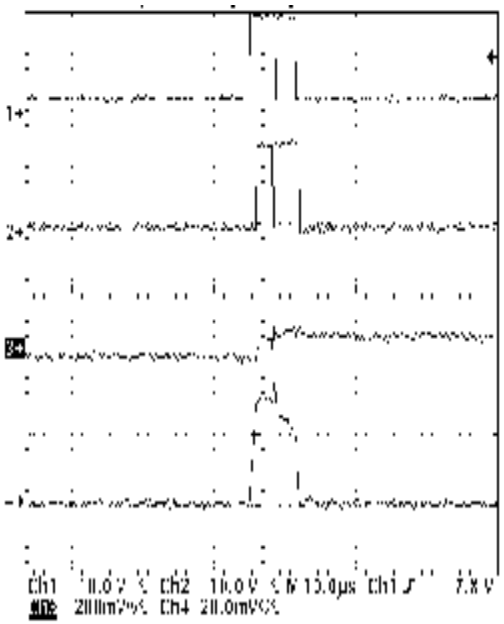
SW1

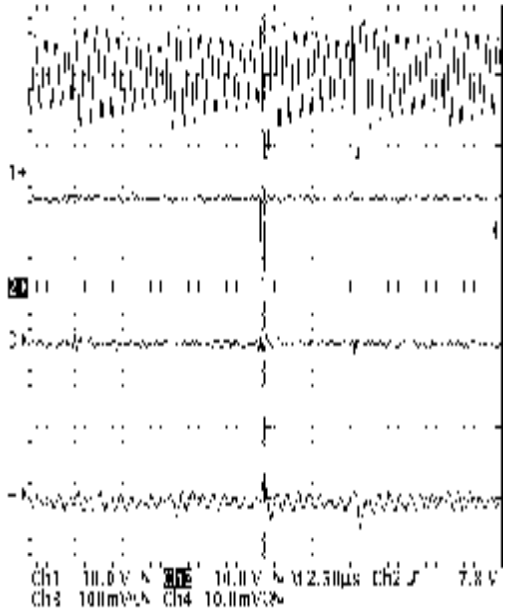
SW2

Vout

I_L







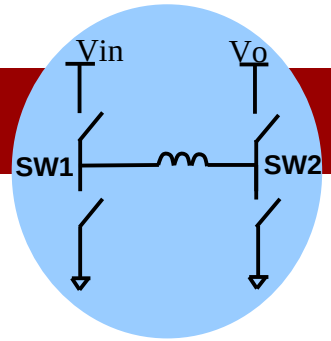
V_{IN} = 6V

V_{IN} = 12V

V_{IN} = 18V

DCM Mode

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

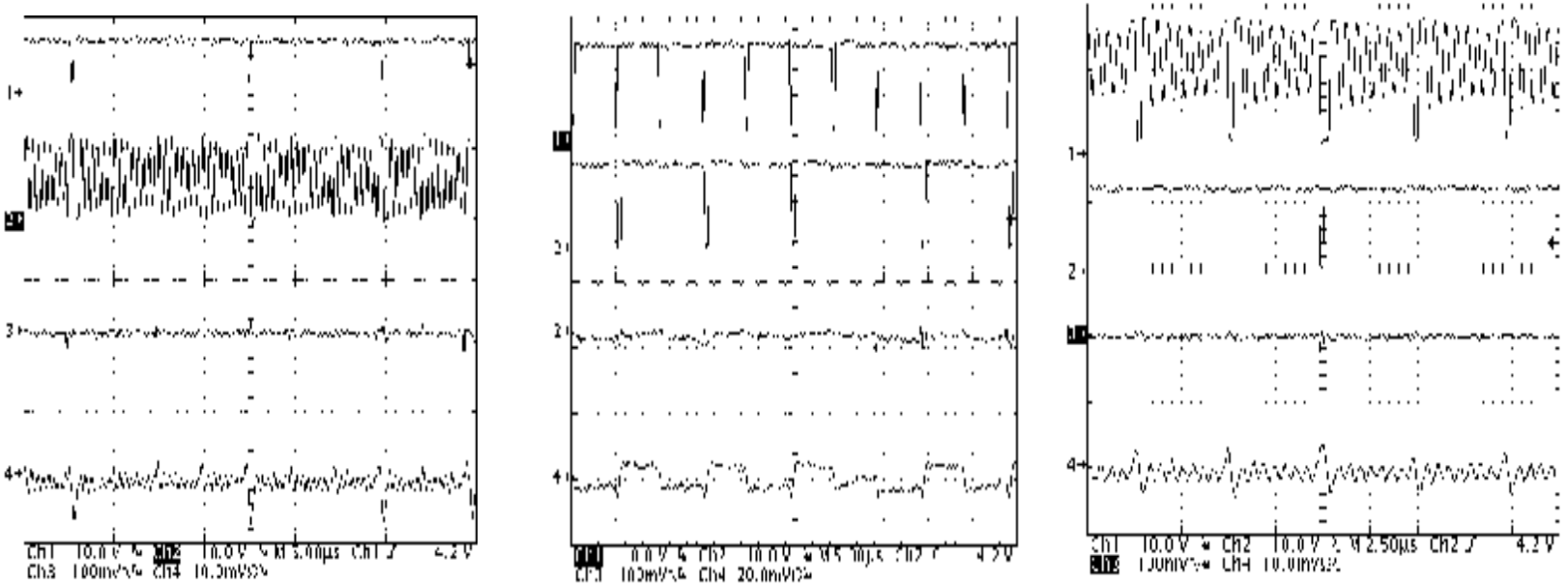


SW1

SW2

Vout

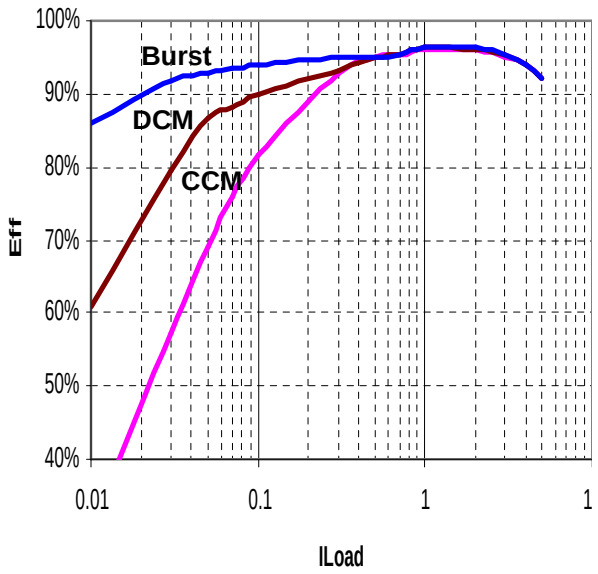
I_L



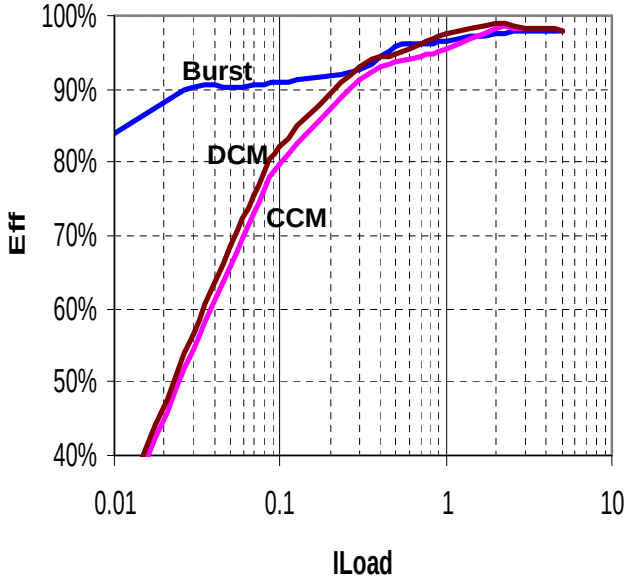
V_{IN}=6V V_{IN}=12V V_{IN}=18V

Efficiency at Different Operation Modes

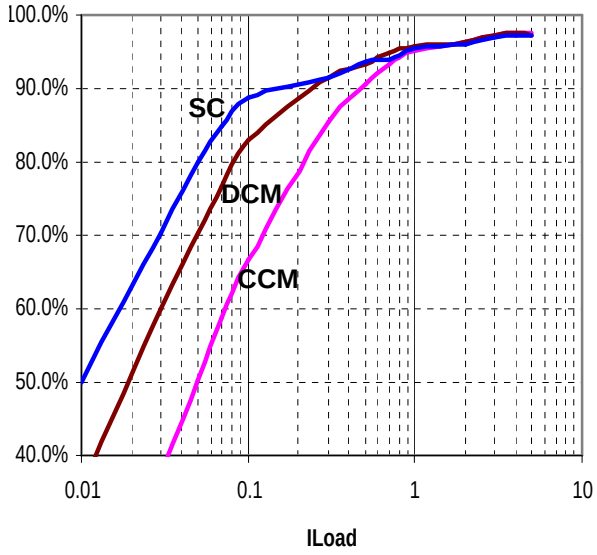
(VOUT = 12V, Fs = 200kHz)



VIN=6V

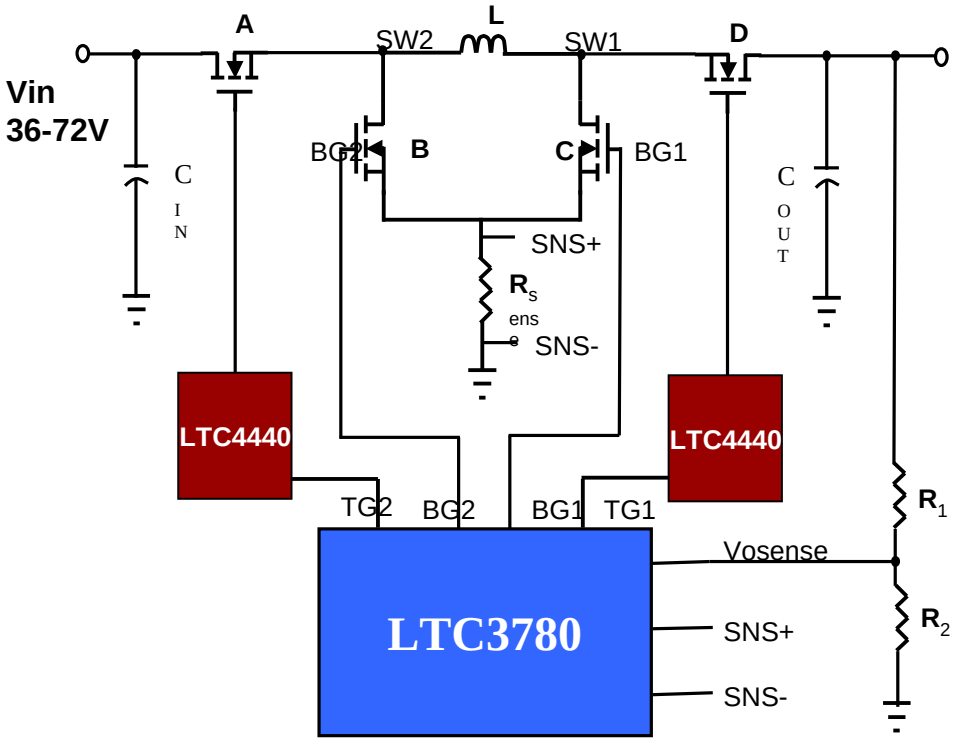


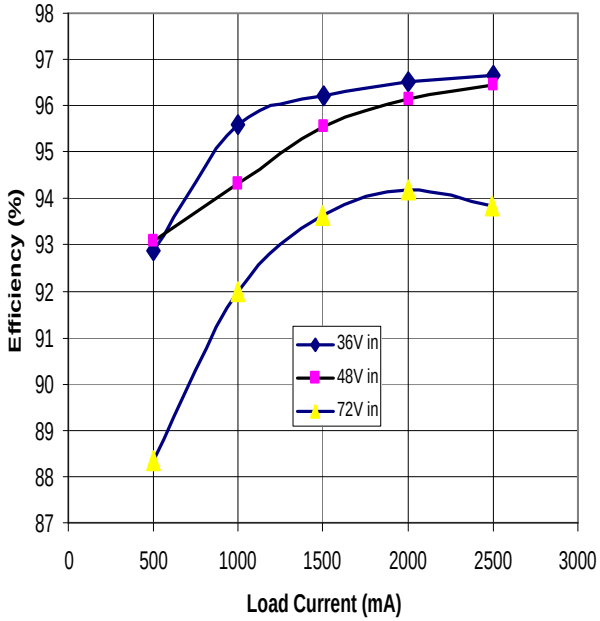
VIN=12V



VIN=18V

Extending the Operation Voltage Range



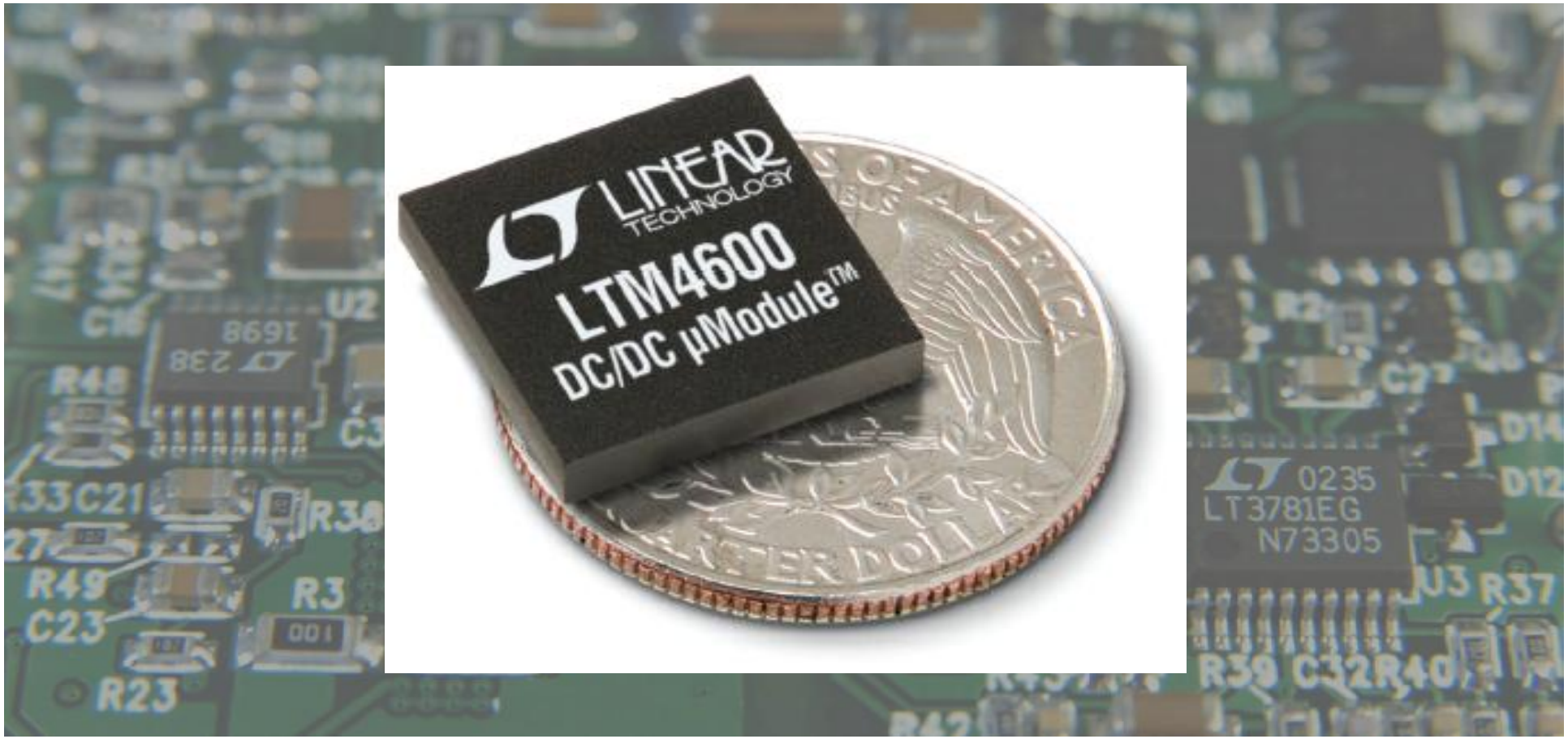


Efficiency exceeds 92% most of time

Max efficiency 96.5%

Summary

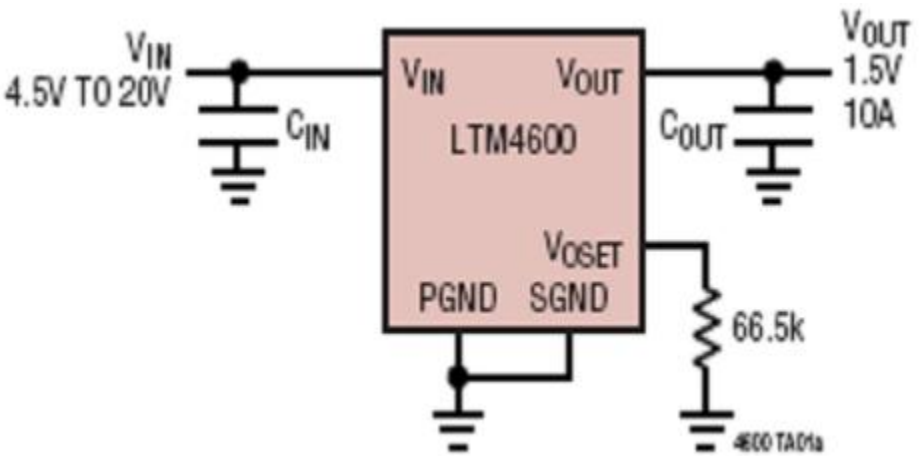
- **LTC3780 based Buck-Boost Converter achieves over 97% for 12V/5A output, 5-8% better than a comparable SEPIC converter.**
- **It has wide input range (8:1)**
- **It has all the desirable features in a DC/DC converter**
- **With external driver(s), the operation voltage range can be greatly extended**
- **An excellent converter for automotive, telecom, and portable applications**

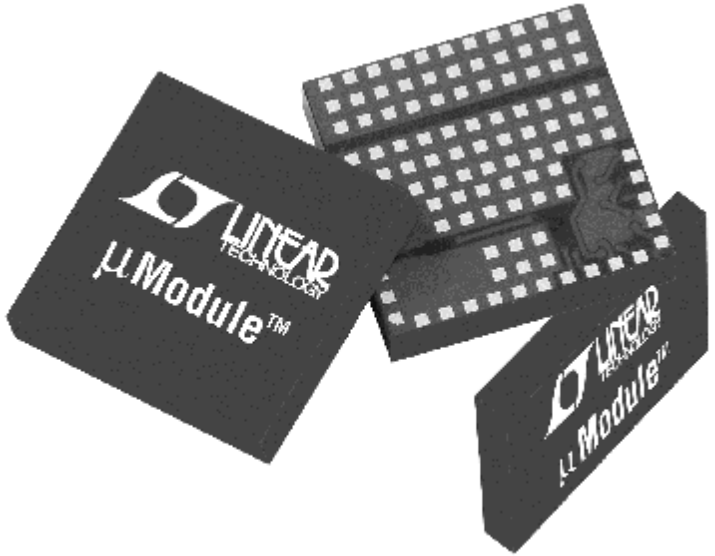


LTM®4600
10A Step Down DC/DC µModule™

LTM4600 µModule

- **µModule™:**

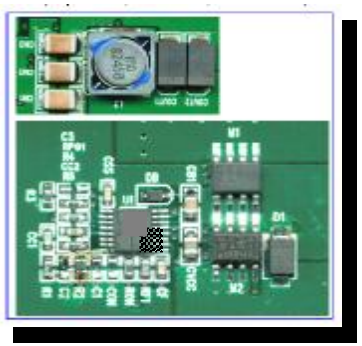




- **Complete step down switch mode power supply**
- **As easy to design in as a linear regulator**

LTM4600 Complete, Quick & Ready

- **Discrete Design**



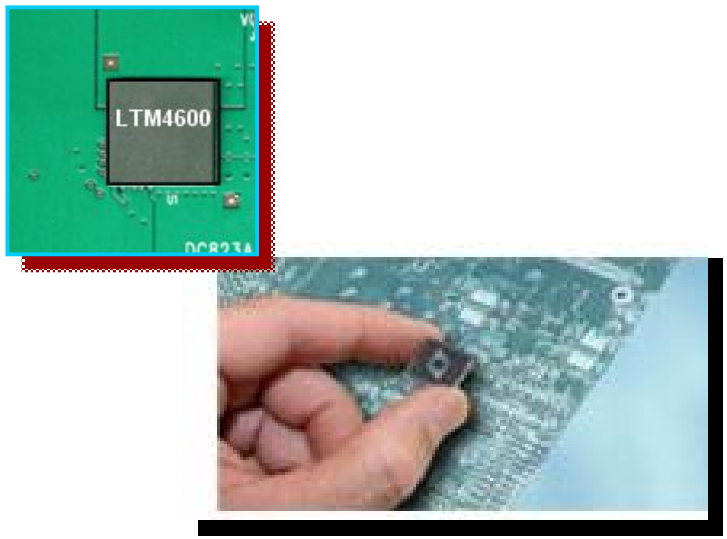
20+ Components +
Design
Simulation
Layout
Debug

Expert Power Supply Designer

Purchase +
Assembly
Debug

Time-to-Market, Effort, $$

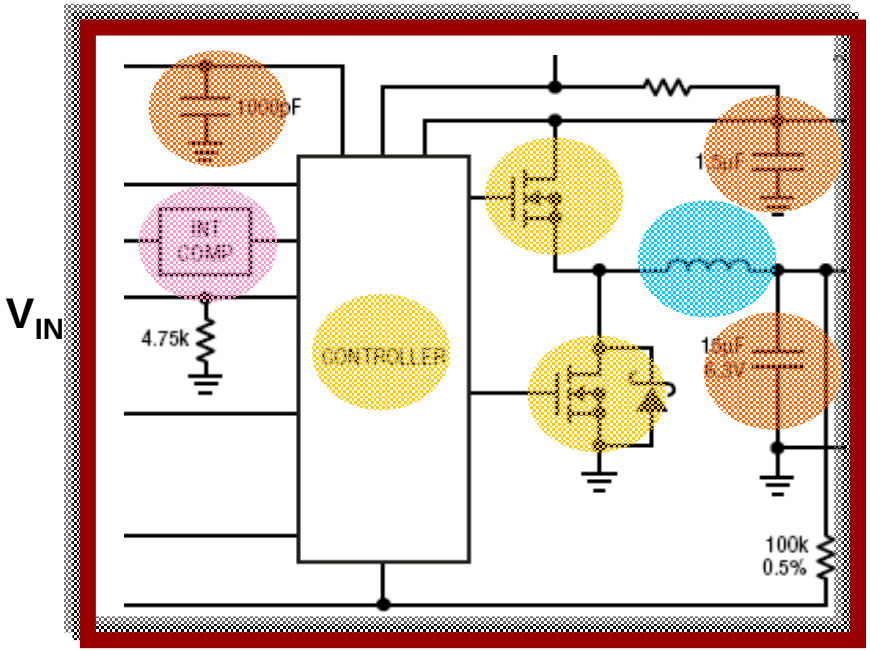
- **LTM4600 µModule**



- **40%-50% smaller solution**
- **Significant reduction in input/output capacitor size**
- **High power density**
- **Easy to use**

LTM4600 What's Inside?

Ö **All Linear Technology Silicon**



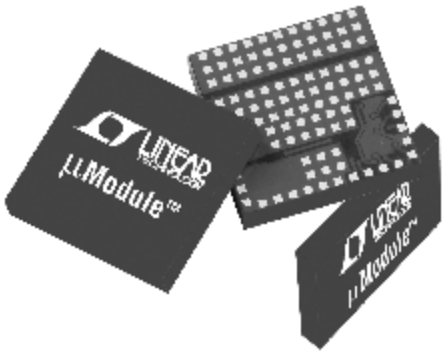
Simplified Block Diagram

- **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

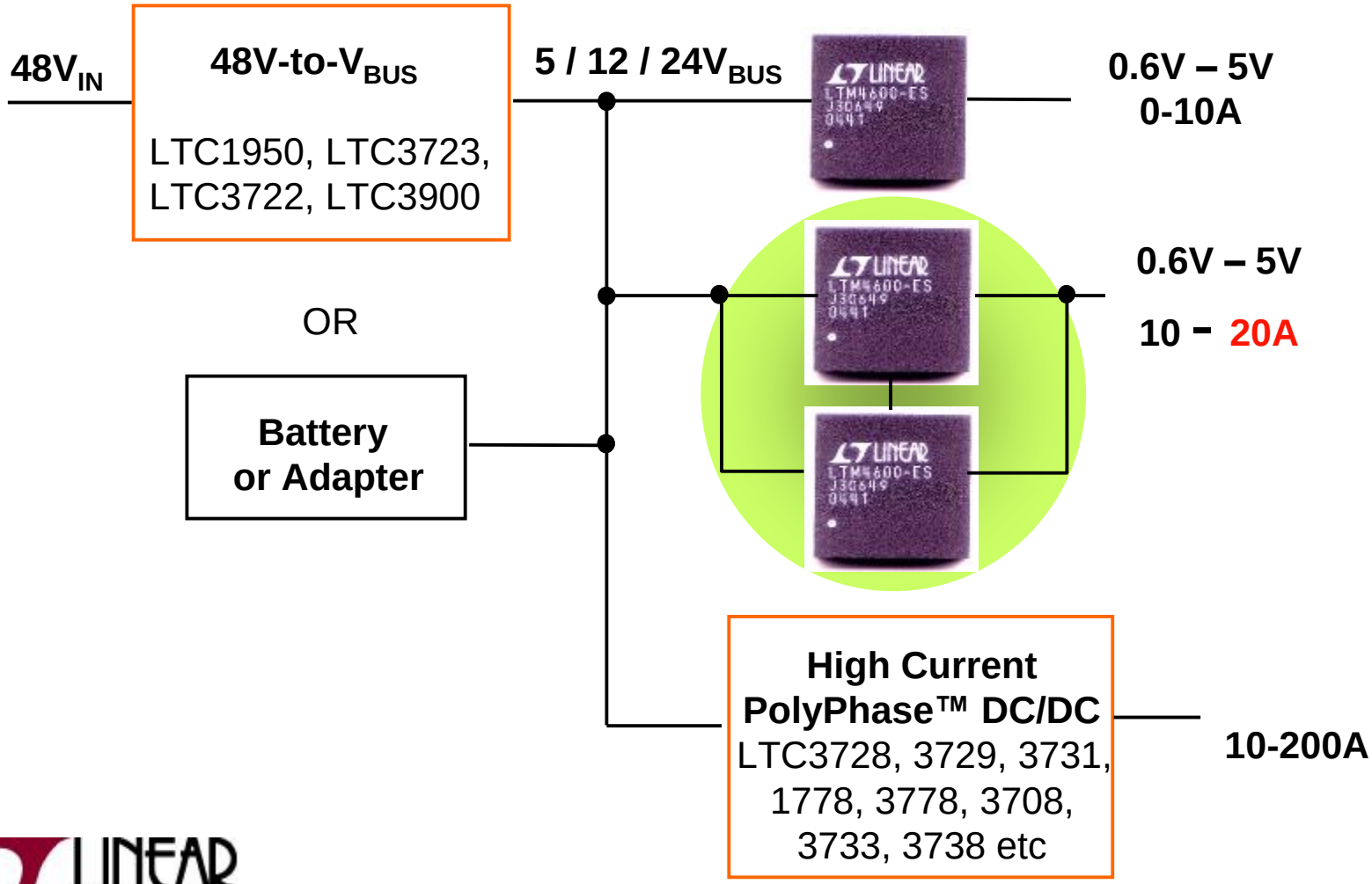
- **Features**
  - **Vin: 4.5V to 20V (28V for HV product)**
  - **Vout: 0.6V to 5V, adjustable with single resistor**
  - **-40° C to +85° C ambient operating temperature range**
  - **Up to 92% efficiency**
  - **1.5% output regulation over temperature**
  - **Ultra-fast transient response**
  - **Integrated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



RoHS Compliant Pb-Free

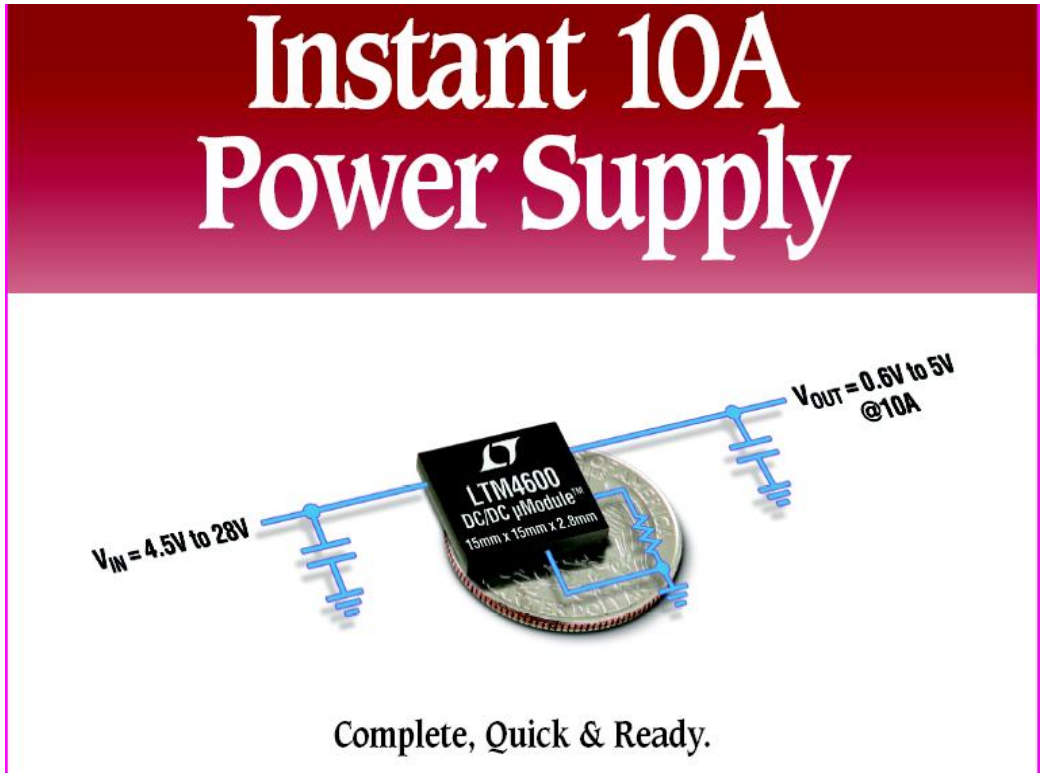
LTM4600 More Power?

- **Parallel 2 LTM4600 for 20A output**



Questions and Discussion

Thank you for your time and interest in Linear Technology!



Performance Driven.