Presentation Content

- Power Market Overview
  - What is it?
  - Opportunities for Power Engineers
- NSC Power Management Portfolio
- DC-DC Conversion
  - Architectures
  - Linear Vs Switching
  - Synchronous Vs non-sync Vs multi-phase
- Web based design
  - Design a switching power supply
  - Circuit performance
  - Dynamic performance
  - Thermal performance

Power Management IC Market

18.2% CAGR (2000-2005)[1]

	2000	2001	2002	2003	2004
AC/DC Regulators	$.5B	$0.6B	$0.7B	$0.8	$0.9B
PFC Preregulators	83M	101M	119M	141M	168M
PWM/PFM Controllers	1.1B	1.4B	1.6B	1.9B	2.3B
DC/DC Regulators	0.8B	1.0B	1.1B	1.6B	1.9B
Linear Regulators	2.1B	2.5B	2.9B	3.4B	3.9B
Battery Charging/Mgt.	0.5B	.55B	.75B	.85B	1.1B
Total	**$5.2B**	**$6.2B**	**$7.2B**	**$8.5B**	**$10.1B**

[1] Venture Development Corp. 12/00

Applications

- **Line-Powered**
  - Computing systems
  - Automotive
  - Office automation
    - Printers
    - Scanners
    - Etc.
  - Consumer appliances
    - Set-Top Box
    - Audio-Video systems
  - Industrial applications
    - Process control
    - Data acquisition
    - Etc.

- **Battery-Powered**
  - Wireless
    - Mobile phones
    - Pagers
  - PDAs
    - Palm Pilots
    - Palm Computers
  - Cameras
  - Computing
  - Consumer appliances
    - Video recorders
    - MP3
    - DVD

Opportunities, Market Structure[1]

- Opportunities include helping customers sort out the inter-relationships among size, thermal transfer, efficiency, performance and cost of PACKAGES
- Market structure is efficient, competitive and fragmented market of 50 companies with non over 10% share

Power Management Market Drivers[1]

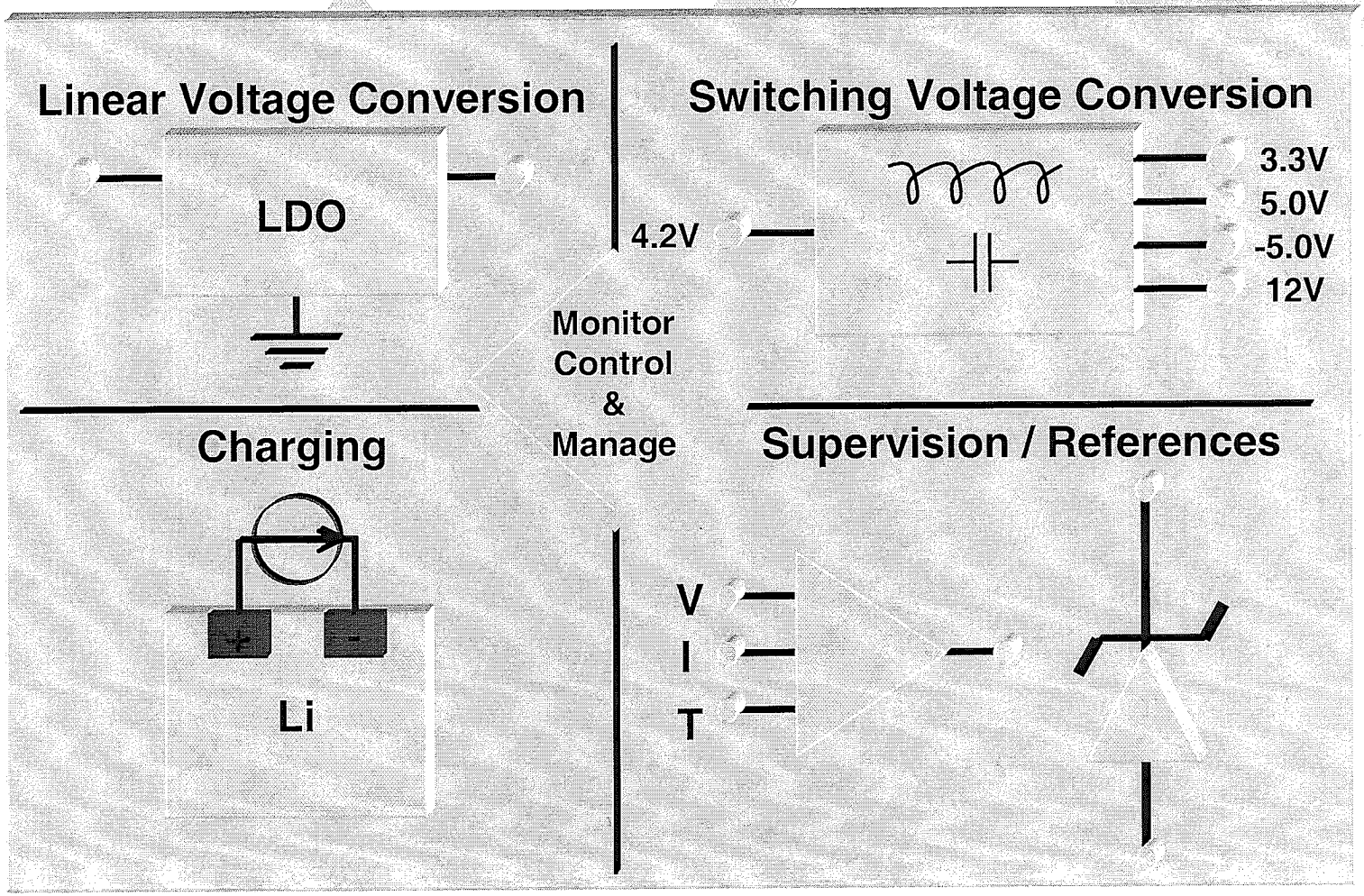
- **Growth Drivers**
  - 1. Demand for higher-efficiency portable electronics
  - ***2. 42V Automotive power***
  - 3. Need for greener products
  - 4. Adoption of power management standards
  - 5. Growth in telecom and computer applications
- **I.C. Technical/Feature Trends**
  - 1. Lower quiescent current
  - 2. Tighter tolerances
  - 3. Switchers will replace some linear solutions
  - 4. Integrated switchers will grow faster than controllers for <4A
  - Increased use of synchronous rectification

[1] **Venture Development Corp.**

What Does this Mean to You?

- Career Opportunity!
  - Per IEEE Power Electronics Society:
    - "Power Engineers are the single most difficult designer to hire." (New automotive standards driving demand for EEs)
  - Fastest growing segment in the industry
  - National, others building development centers!
    - Fort Collins, Tucson, Grass Valley, Boulder, Milano, Munich, Scotland, Santa Clara
  - STAY IN TOUCH!
    - john.d.perzow@nsc.com

NSC Power Management Portfolio:



Architectural Trade-Offs: When do you use--

- A linear solution?
  - Linear
  - LDO
  - Controller
- An inductive-based Switcher?
  - Controller
  - Synchronous
  - Asynchronous
  - Multi-phase
- A switched capacitor converter?

Architectural Trade-Offs: When do you use--

- **A linear solution?** (η<70%)
  - When simplicity and low-cost are key
  - When you have power to burn
    - Low currents
    - Low input V to output V differential
  - When you need noise isolation

Architectural Trade-Offs: When do you use--

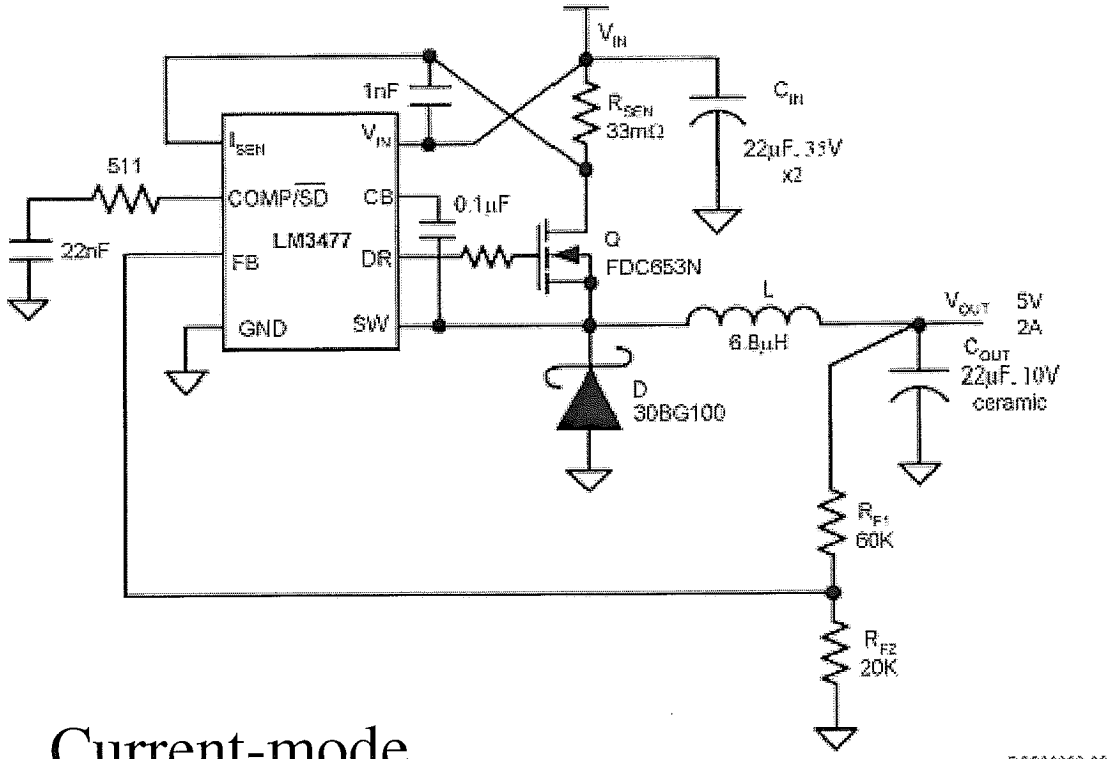
A switched capacitor converter? (η = ~80%)

- <300mA loads
- When noise and regulation are not important
- In battery-powered systems where PCB area is premium
- In thin packages
  - Hand-held appliances, for example.

Architectural Trade-Offs: When do you use--

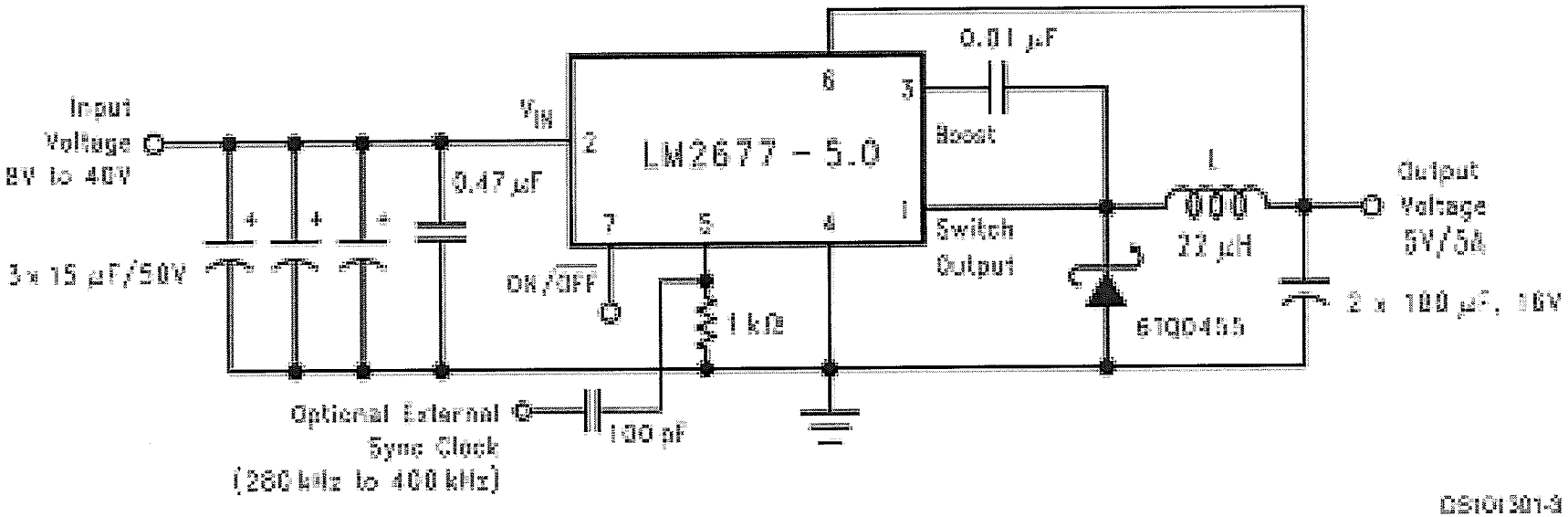
- **An inductive-based Switcher?** ($60\% < \eta < 97\%$)
  - When conversion efficiency is needed
    - Heat concerns
    - Battery life
    - System reliability
  - For maximum power density where $I > 1A$

Architectures: Controller-Based Buck for Flexibility



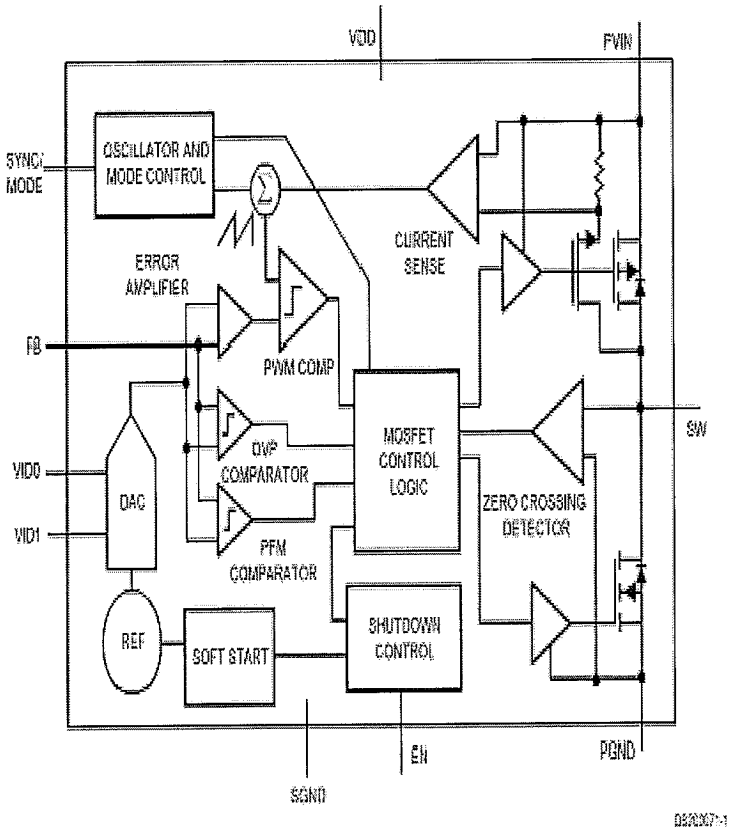
Current-mode buck controller

Architectures: Integrated Buck Regulator (non-synchronous)



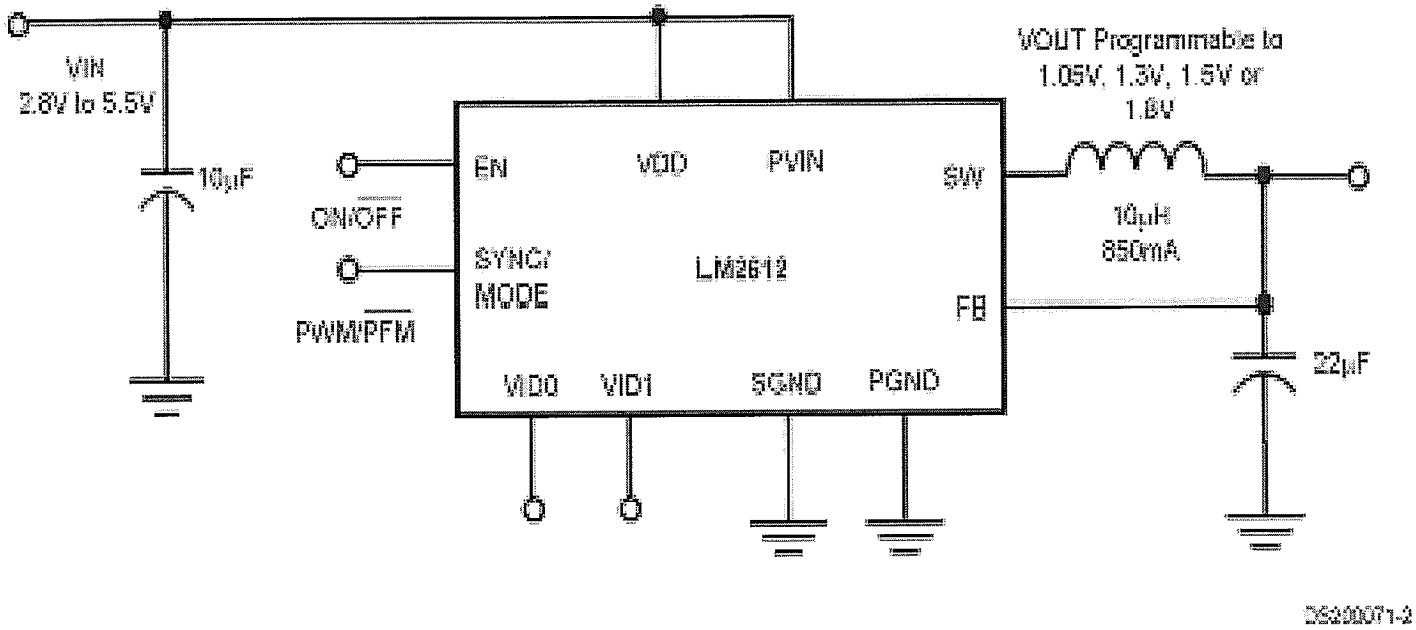
Buck w/ Synch Input
from external source

Fully-Integrated Synchronous Buck Regulator



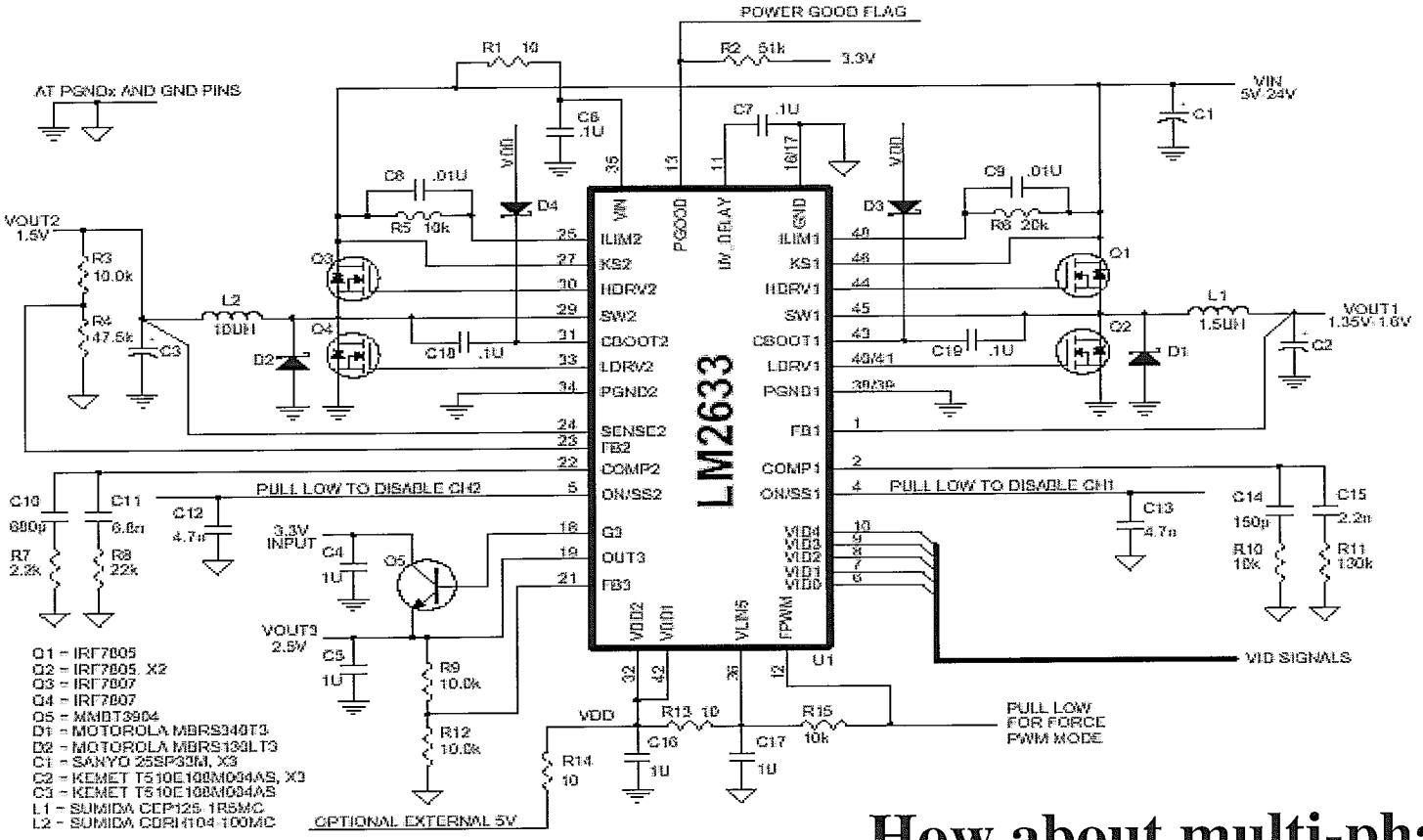
- Freq: 500-1000KHz
- PWM or PFM Selectable
  - PWM (EMI) PFM (load i)
- Vin:2.8-5.5V
- Iout: 400mA
- Vout: 1.8,1.5,1.3,1.05V
- Synchronizable
- uSMD-10
  - 1/3 the size of other solutions

Architectures: Integrated for Simplicity



Synchronous converter with only 3 external components

Triple Controller:
2 Synchronous + Linear



How about multi-phase?

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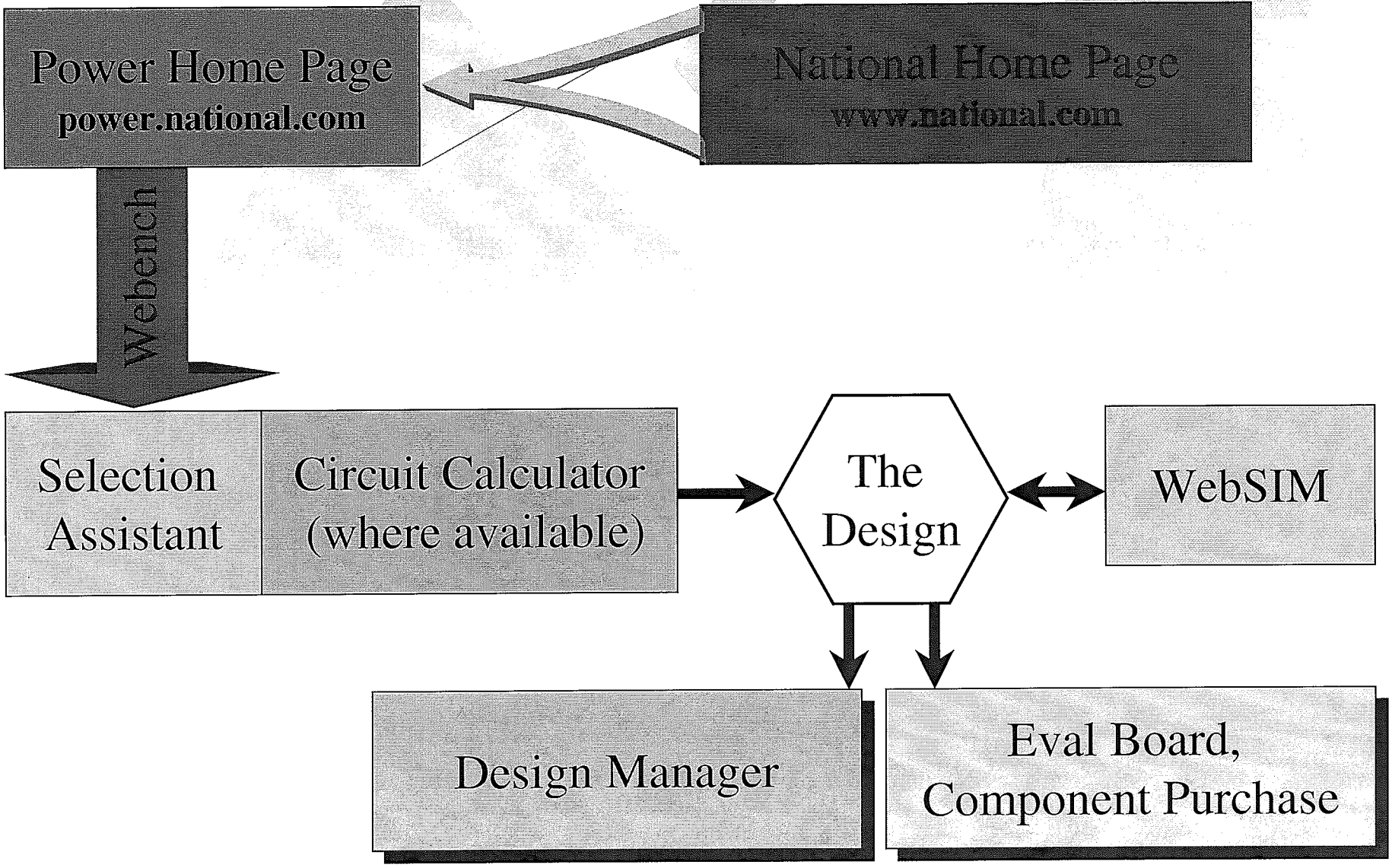
Let's Design a Switching Power Supply

- Problem:
  - Input V = 10V-14V
  - Output requirement = 5V
  - Load current = 2A
- Linear or Switcher?
- Synchronous or non-synchronous?

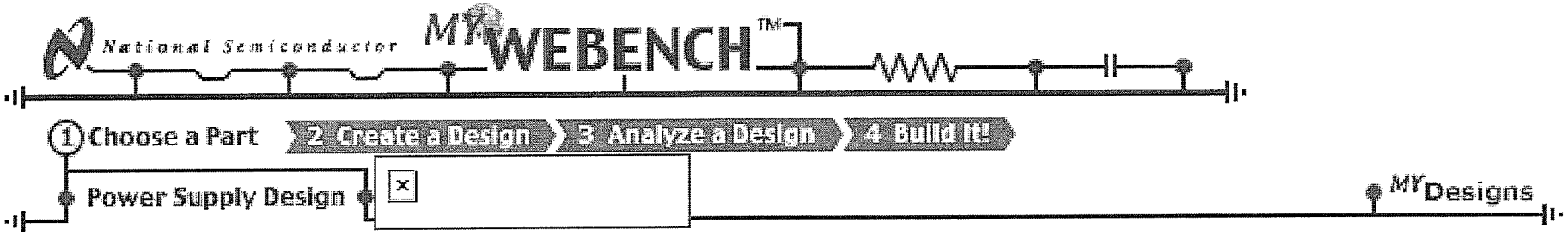
National Power Goals

- Simplify the design process
- Shorten the design cycle
  - Design Development/ Simulation / Eval Brds
- Assure success in power design from the beginner to the expert

Online Design Flow – Webench 2000



Design Assistant Analyzes Requirements



Enter your power supply design requirements.

Basic Selections

Vin Min 14 V
Vin Max 22 V

Output Voltage 3.3 Volts

	V out	I out
Output #1	3.3 V	1 A

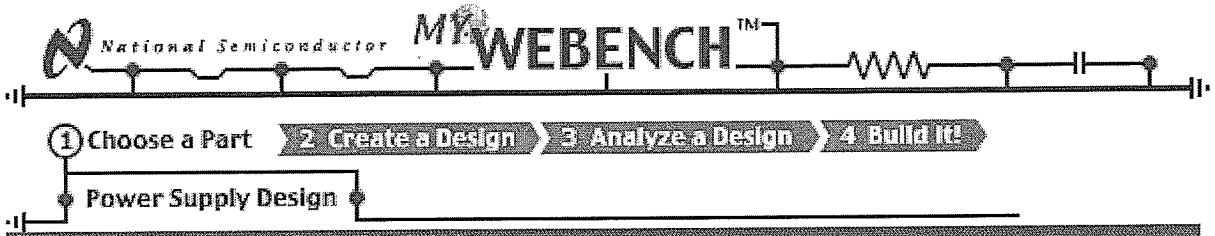
Choose Additional features (Optional)

On/Off Pin	○ No	○ Yes	◉ Ignore
Error Flag	○ No	○ Yes	◉ Ignore
Sync Pin	○ No	○ Yes	◉ Ignore

	V out	I out
Output 2	V	A
Output 3	V	A

Show Recommended Power Management ICs

List Shows Suitable Devices Which Meet the Power Supply Requirements



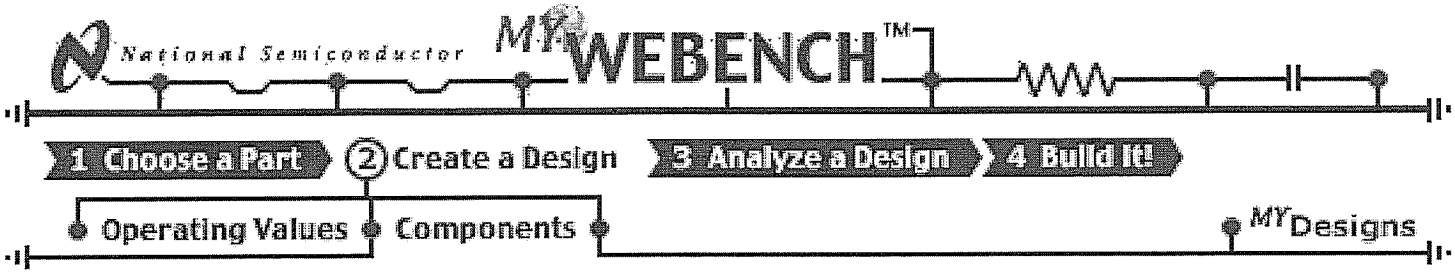
Your Design Specifications

VinMin: 14.0V VinMax: 22.0V	Output #1 Vout= 3.3 V Iout= 1.0 A

Suggested Switching Regulators

Product Folder	Webench Tools	Top-ology	Max Curr.	Typ. Eff.	On/ Off	Err. Pin	Other Features	Freq.	Est. Price
LM2595-3.3	Create a Design	Buck	1.0A	78%	Y	N		150.0kHz	$1.86
LM2595-ADJ	Create a Design	Buck	1.0A	78%	Y	N	Adj. Vout	150.0kHz	$1.86
LM2596-3.3	Create a Design	Buck	1.0A	73%	Y	N		150.0kHz	$2.61
LM2596-ADJ	Create a Design	Buck	1.0A	73%	Y	N	Adj. Vout	150.0kHz	$2.61
LM2598-3.3	Create a Design	Buck	1.0A	78%	Y	Y	SoftStart	150.0kHz	$2.18
LM2598-ADJ	Create a Design	Buck	1.0A	78%	Y	Y	SoftStart, Adj. Vout	150.0kHz	$2.18
LM2599-3.3	Create a Design	Buck	1.0A	73%	Y	Y	SoftStart	150.0kHz	$2.91

Design Includes IC, External Components



Design: UNKNOWN
Device: LM2595S Thu Jun 1 17:45:04 2000 ID: 87632_3

Design Requirements Output # 1

VinMin = 14.00 V Vout= 3.30 V

VinMax = 22.00 V Iout= 1.00 A

Choose Operation

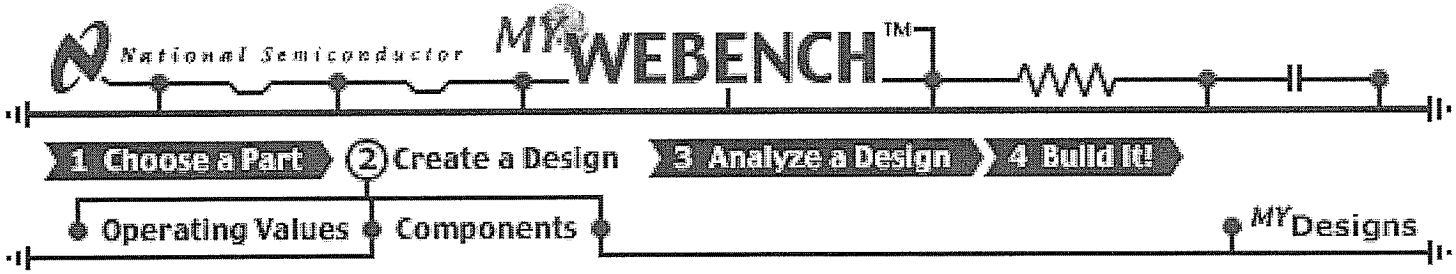
View Components
View Operating Values
Simulate, Delete
Rename, Add Notes
Save As, Print

Components

Part	Manufacture	Part#	Attributes	
D1	General Semiconductor	SS24	0.500	Select Alternate Part
IC	National Semiconductor	LM2595	3.3,Buck	Select Alternate
L1	Coiltronics	UP4T-680	68.00,0.102	Select Alternate Part
Cin	Nichicon	UPL1V121MPH	0.140,120.0	Select Alternate Part
Cout	Nichicon	UPL1V181MPH	180.0,0.100	Select Alternate Part

For SIMPLE SWITCHER converters, component selection and Operating Values calculations are done with "Switchers Made Simple" code

User can Choose Other Recommended Parts

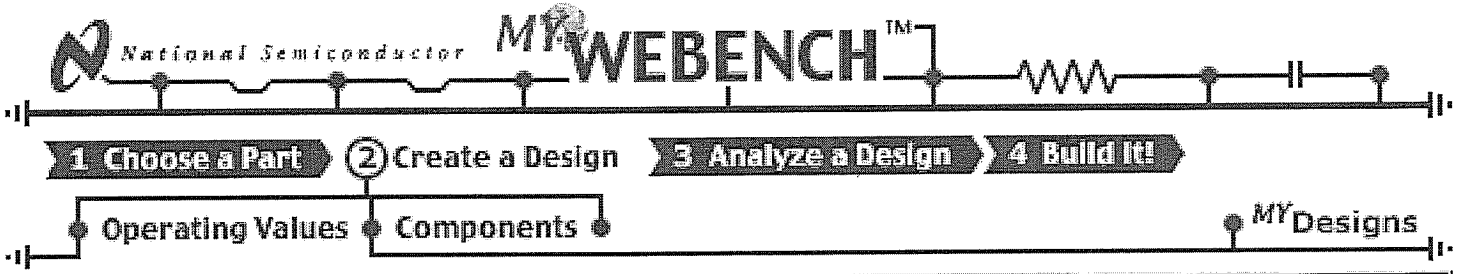


Select Alternative

Alternates	Part #Name	Inductance(uH)	DC Resistance (Ohms)
Custom ○			
1 ◉	UP4T-680 Coiltronics	68.00	0.103
2 ○	PE-54038 Pulse Engineering	68.00	0.100
3 ○	RL-5471-5 Renco Electronics	68.00	0.055
4 ○	DO5022P-683 Coilcraft Inc.	68.00	0.108
5 ○	UP4B-680 Coiltronics	68.00	0.103
6 ○	PE-54038S Pulse Engineering	68.00	0.080

Continue

Operating Values Show Calculated Performance



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Design Requirements Output # 1

VinMin = 14.00 V Vout= 3.30 V

VinMax = 22.00 V Iout= 1.00 A

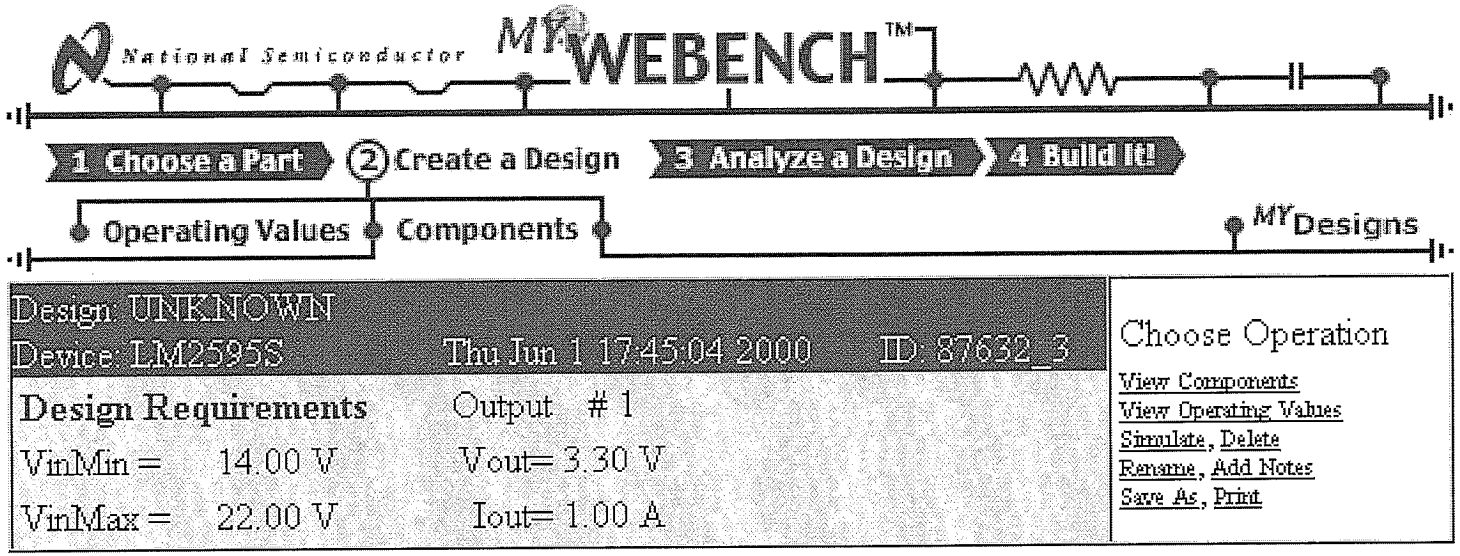
Choose Operation

View Components
View Operating Values
Simulate, Delete
Rename, Add Notes
Save As, Print

Operating Values

#	Description	Parameter	Value
1	Bode Plot Phase Margin, should be positive for stability generally 20° is good target	Phase Marg	46.56 Deg
2	Bode Plot Crossover Frequency, indication of bandwidth of supply	Cross Freq	15.68 kHz
3	Diode Power Dissipation	Diode Pd	0.35 W
4		Vout p-p	26.85 mV
5	Average input current	Iin Avg	0.31 A
6	Inductor Power Dissipation	L Pd	0.11 W
7	IC Power Dissipation	IC Pd	0.55 W
8	Continuous or Discontinuous Conduction mode, inductor current goes to zero in Discontinuous Conduction	Mode	Cont

Designs can be Renamed, Saved, Printed, refined...



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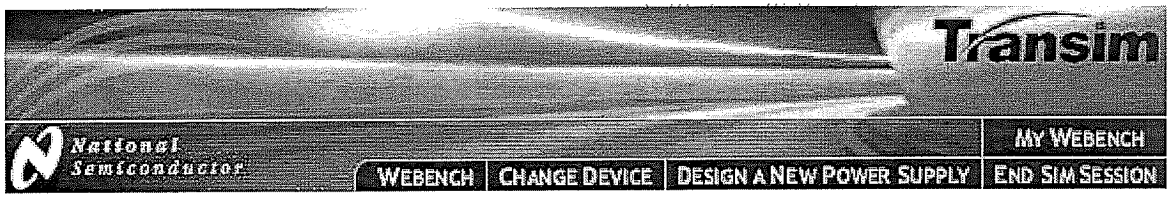
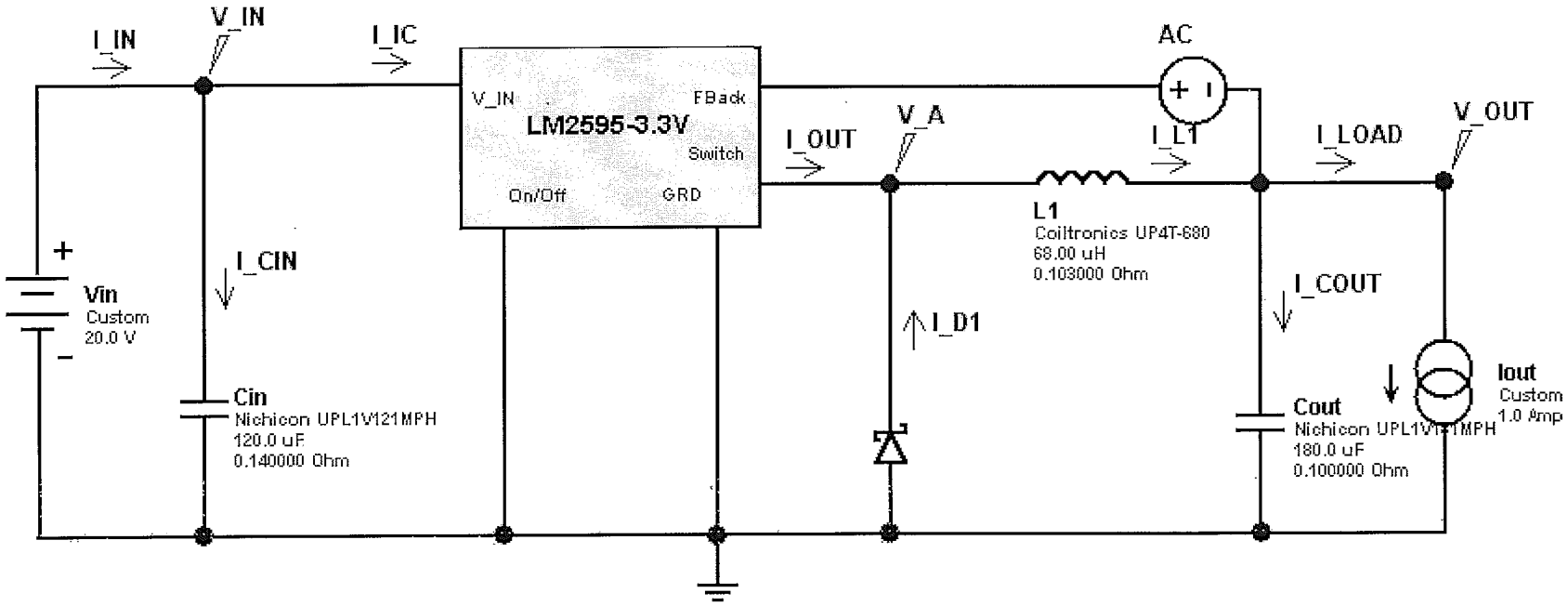
"Analyze Design" Brings User's Design into WebSIM





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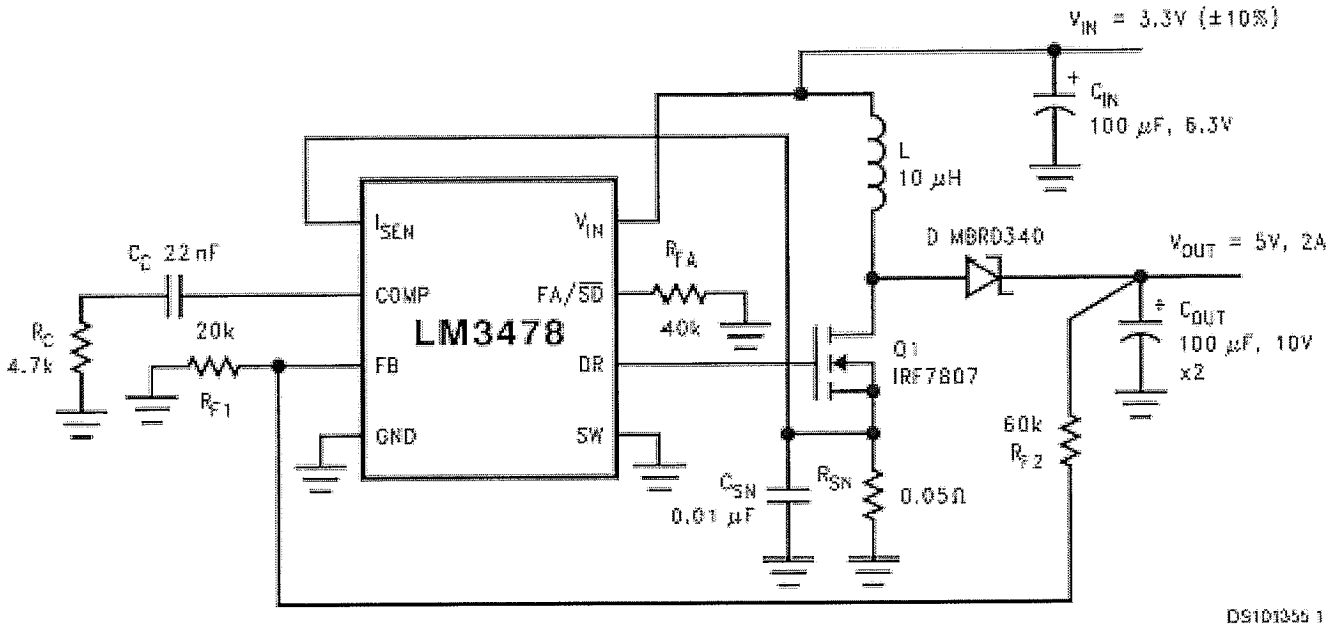
Let's Do It!

Additional Material

- Other switching topologies
- Other power management functions
  - USB switches
  - References
  - Supervisory products
- Semiconductor packaging trends

Inductive Boost Controller



Typical Boost

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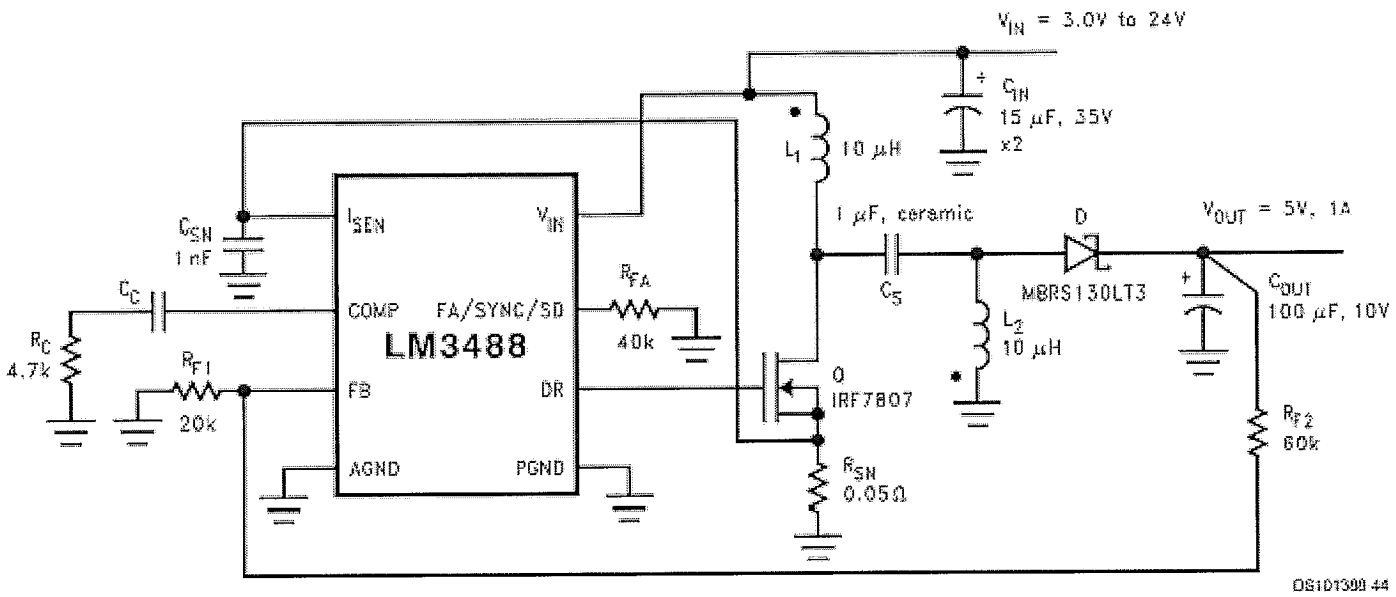
SEPIC



Single **E**nded **P**rimary **I**nductance **C**onverter:

Performs like a flyback but without the transformer

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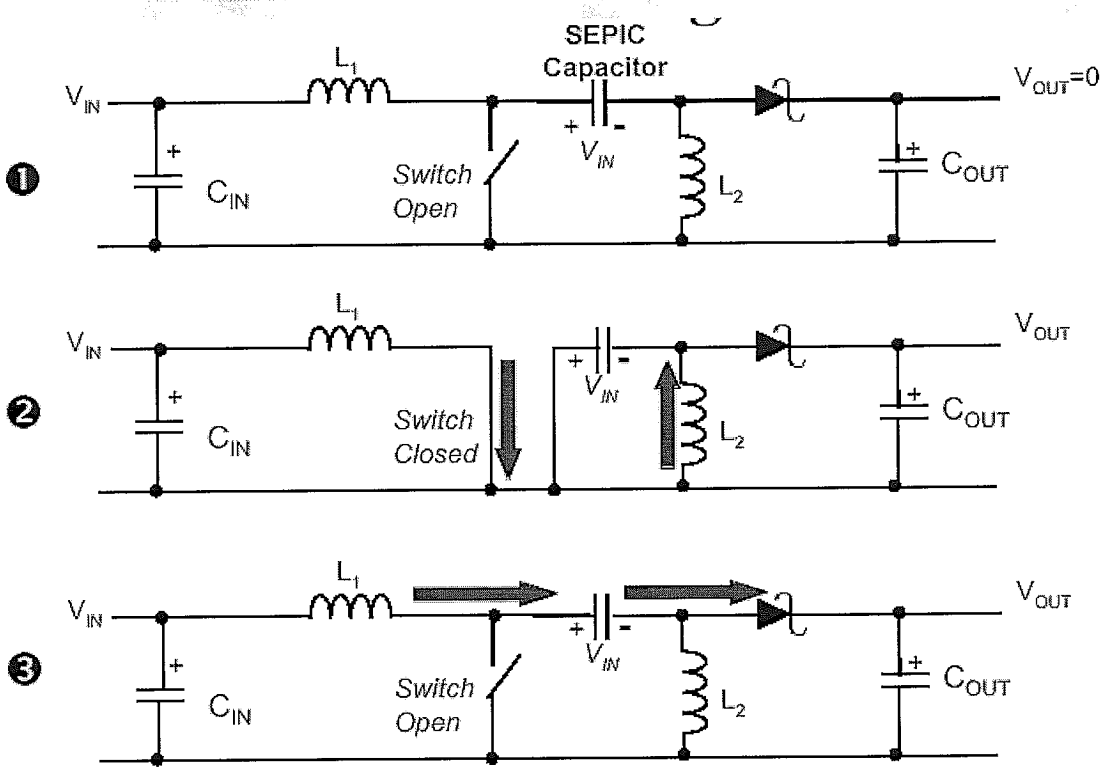
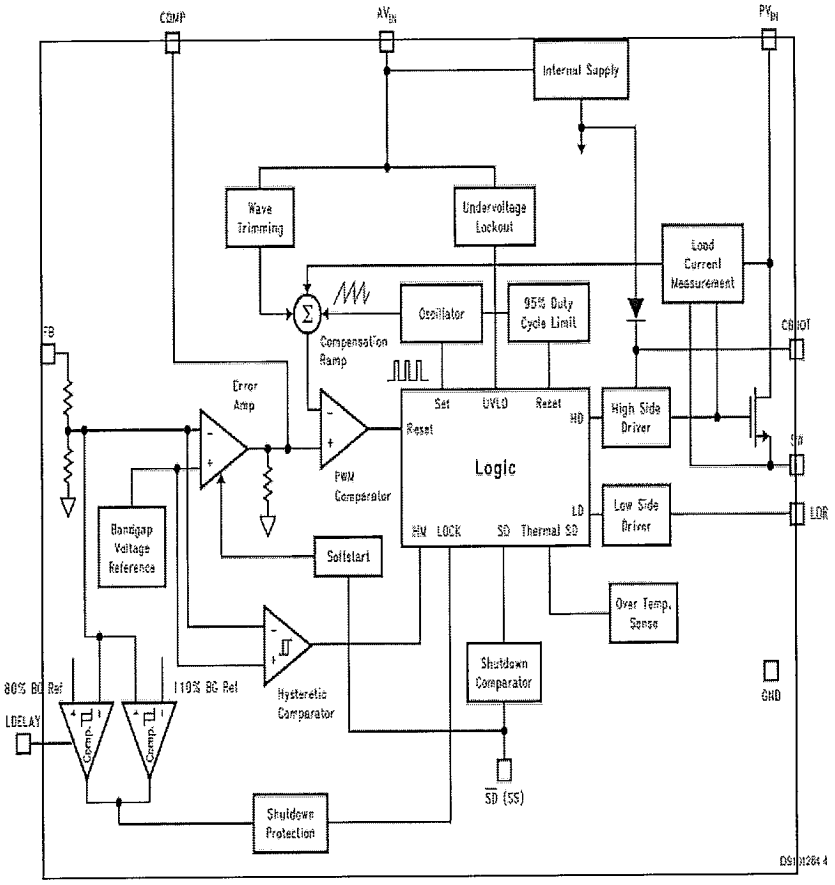
SEPIC



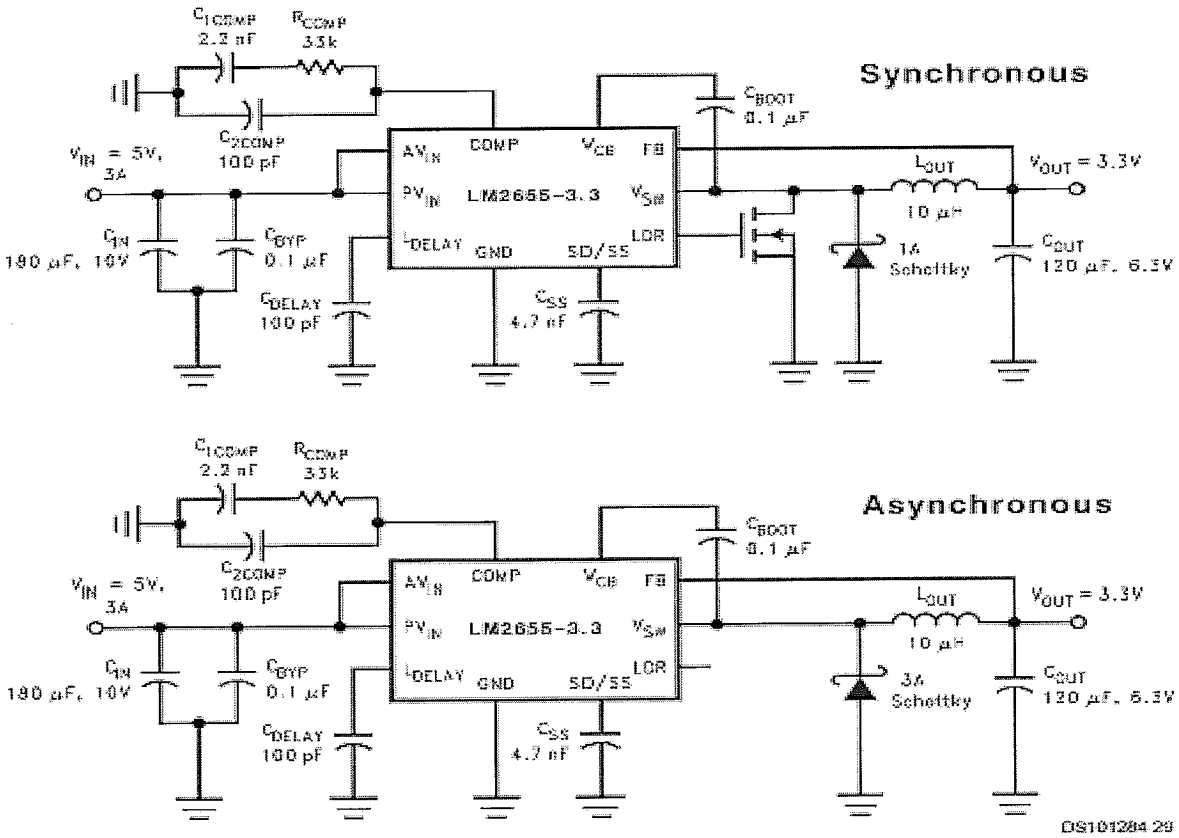
Single Ended Primary Inductance Converter - Operation

Portable Buck



- 300KHz Pulse Width Modulation with Hysteretic Control
- Current Controlled
- **Vin: 4.0-14V** (1-2 cell Li+)
- Iout: 2.5A
- TSSOP-16
- Software in Development

Portable Buck



Typical Application circuits

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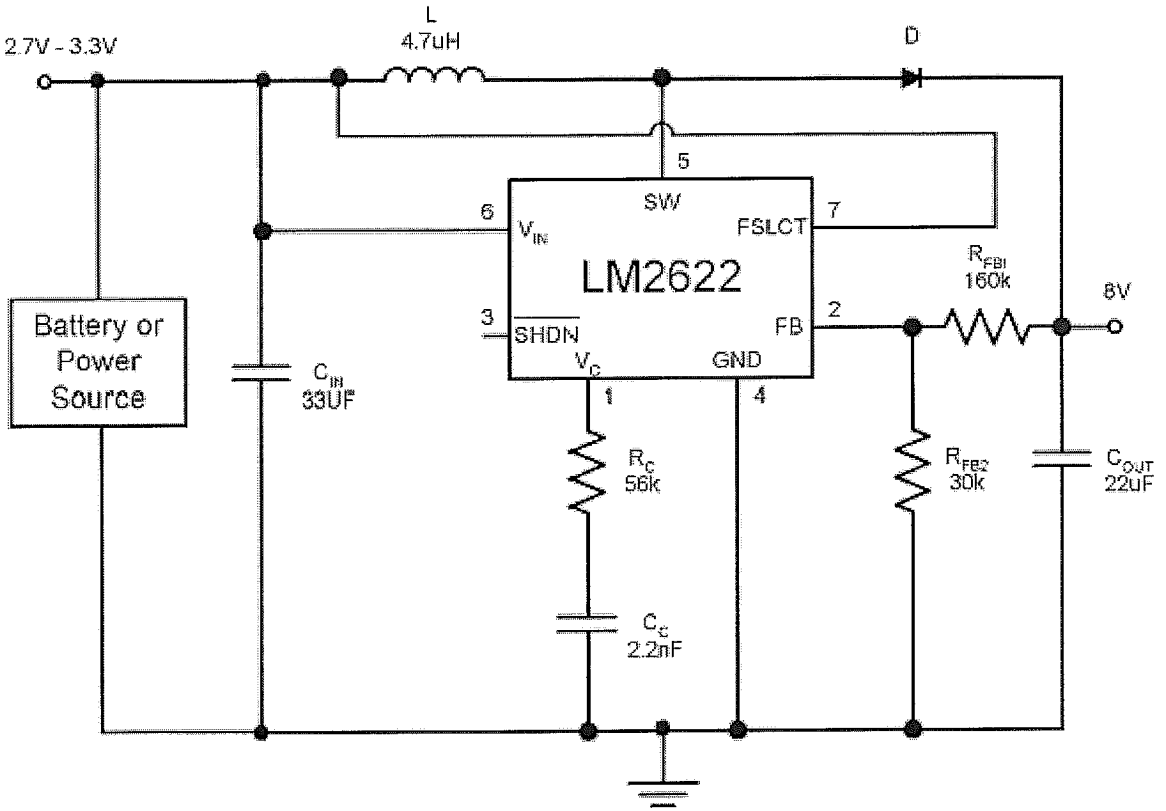
High-Frequency Boost: Integrated Regulator



Boost @ 1.3MHz = tiny external components

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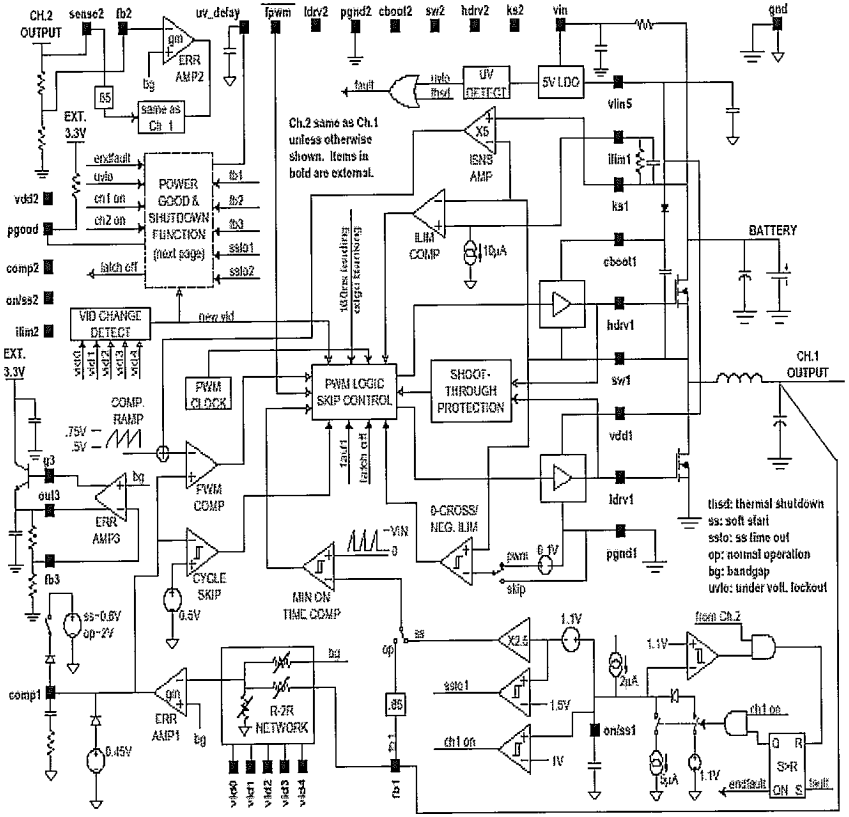
LM2633 - Triple Controller

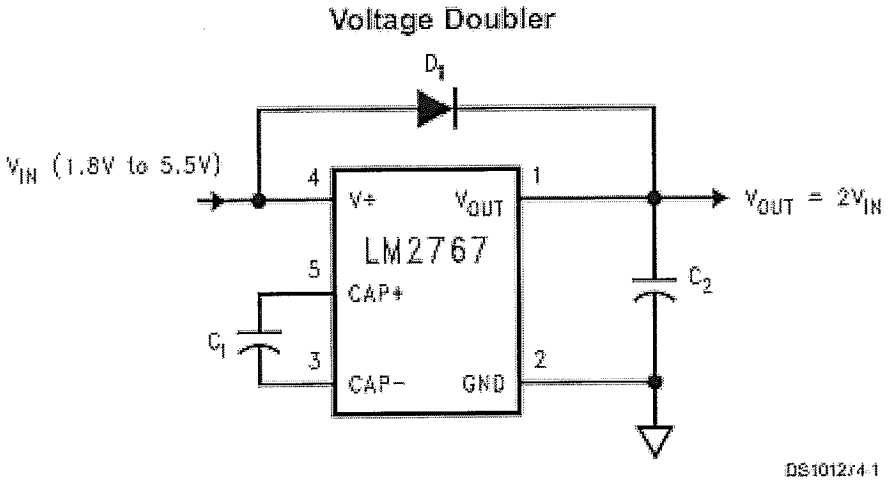


- Freq: 250KHz
- Dual Out of Phase Switcher plus LDO cont.
  - Smaller input caps
- Vin:5.0-30V (4.5V split)
- Iout: Flexible
- Vout:
  - V1=0.925-2.0V (DAC Codes)
  - V2=1.3-6.0V Adjustable
  - V3 LDO=5.0-1.5V
- Synchronous
- TSSOP-48 Package

Why Sync to an External Clock?

- What applications use the synchronize feature?
  - One Example: DSL Modems & Base Stations
    - Move the band and harmonics away from the data carrier (shift between up/down stream data or out band)
    - Move the band and harmonics away from the radio
  - Achieve consistent frequency device to device thereby allowing for minimum output ripple on all supplies

Switched Capacitor Converter



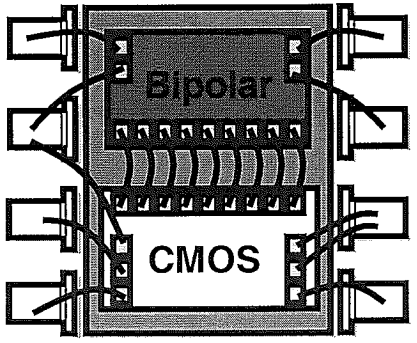
- Vin: 1.8-5.5V
- Vout: Twice Input Voltage
- LM2765 - 40mA Continuous
  - Doubler
  - 50kHz, 20 Ohm
- LM2766 - 40mA Continuous
  - Doubler
  - 200kHz, 20 Ohm
- LM2767 - 30mA Continuous
  - Doubler
  - 11kHz, 30 Ohm
- Package: SOT23-5

Precision References

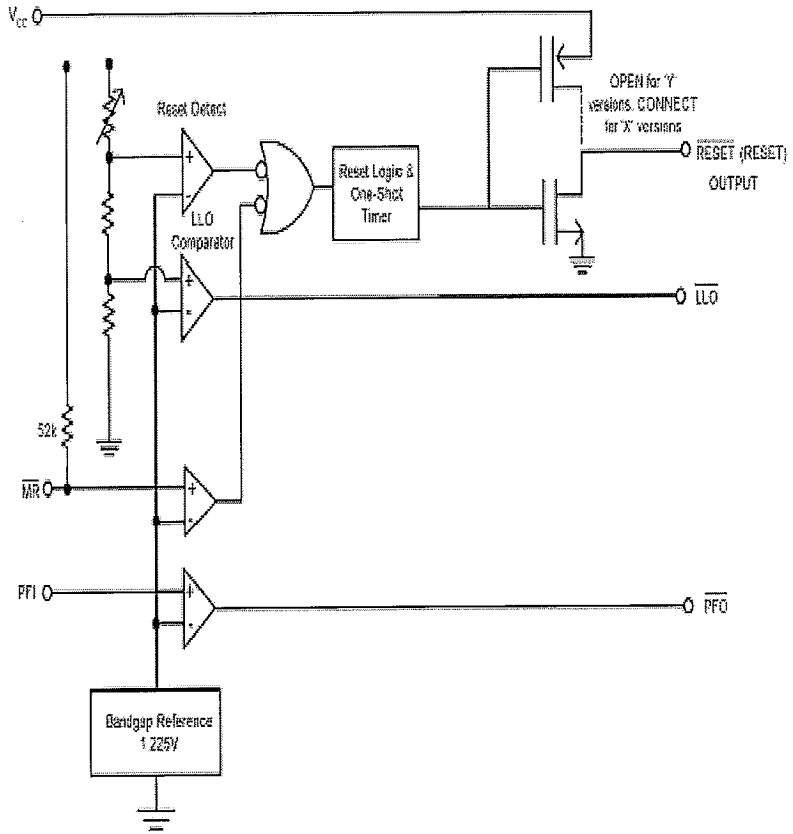
LM4050/1 - Shunt Reference

- LM4120- CMOS Series Reference
- LM4130 -
  - World's first 10ppm/C reference in a SOT23 package
  - Our first high precision series reference using CMOS
- LM4140 -CMOS/BiPolar **dual** Die
  - First sub-bandgap voltage reference (lower than 1.2V)
  - "Ultra high precision series reference, smallest of the kind"
  - "very low noise and best accuracy"
  - 6 ppm/C Tempco, 0.1% initial accuracy

LM4140

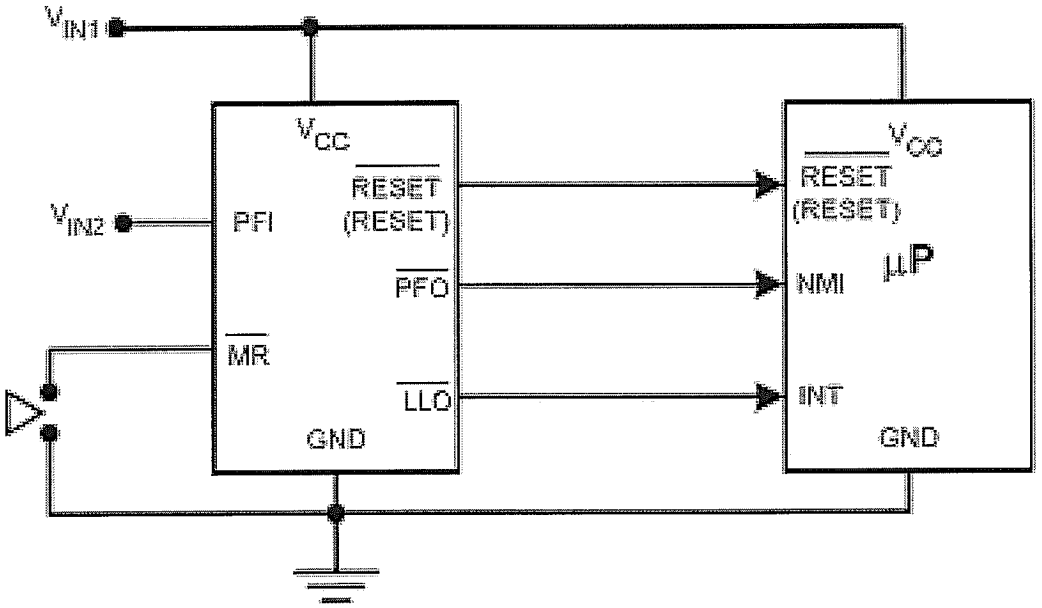


Supervisory Function



- CMOS for Programmability
  - (EEProm)
- Vin: 1.2-5.5V
- Thresholds: 1st standard 3.08V
  - 2.2-5.0V (10mV steps)
- Manual Reset for Ext. Switch
- Power Failure - 2nd Reset
- Low Line: Early Warning 2%
- Factory reset timeout duration
- No external components
- MSOP-10, uSMD-10

LM3700 Family of Supervisors



Typical Application

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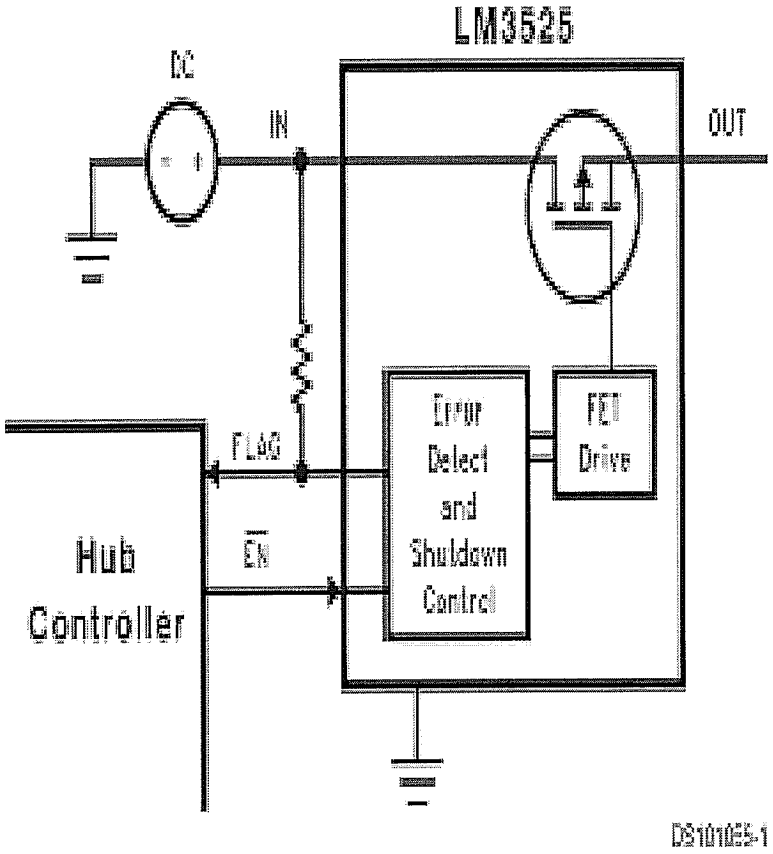
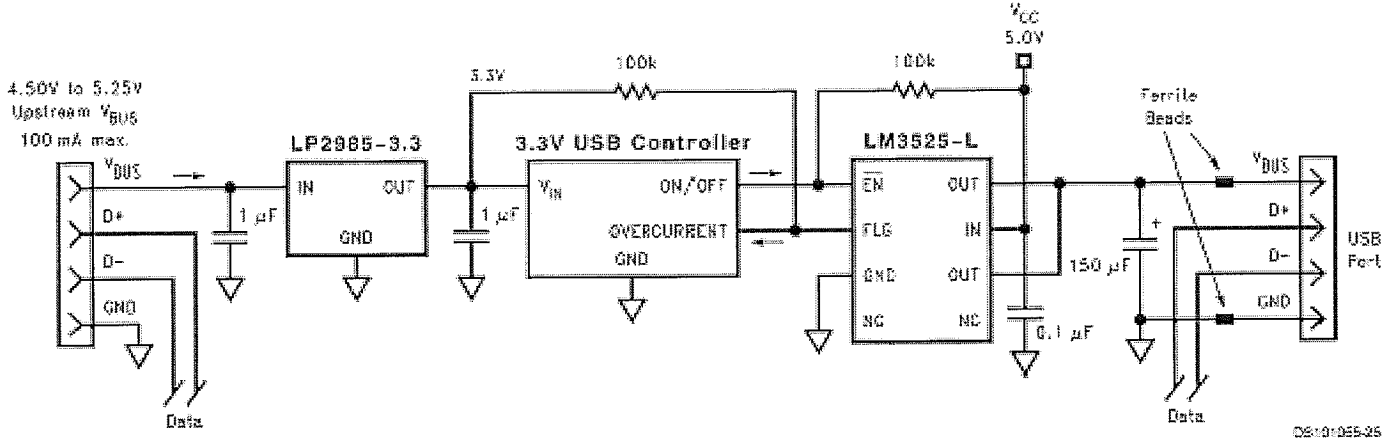
USB Switch



- Single USB protection Switch
  - Replaces Raychem & Thermister solutions
- Vin: 2.7-5.5V
- Fault Flag
- Iout load: 0.5A continuous
- Fault over 0.5 to 1.5A
- Built in Thermal shut down for short circuit protection
- Under voltage lock out
- Highside and Lowside versions

USB Switch: Typical Application

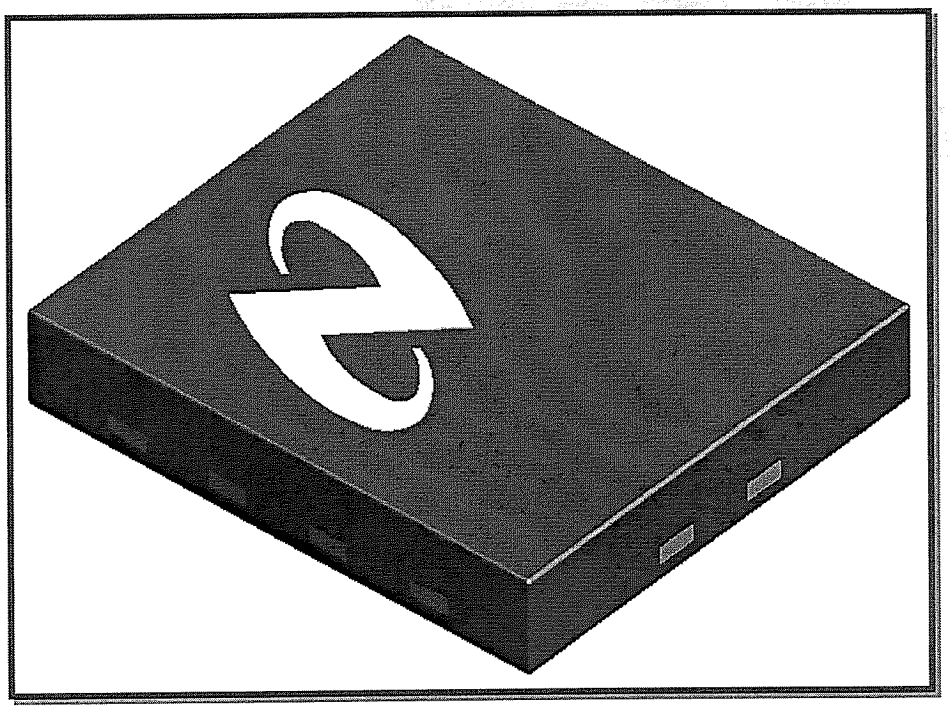


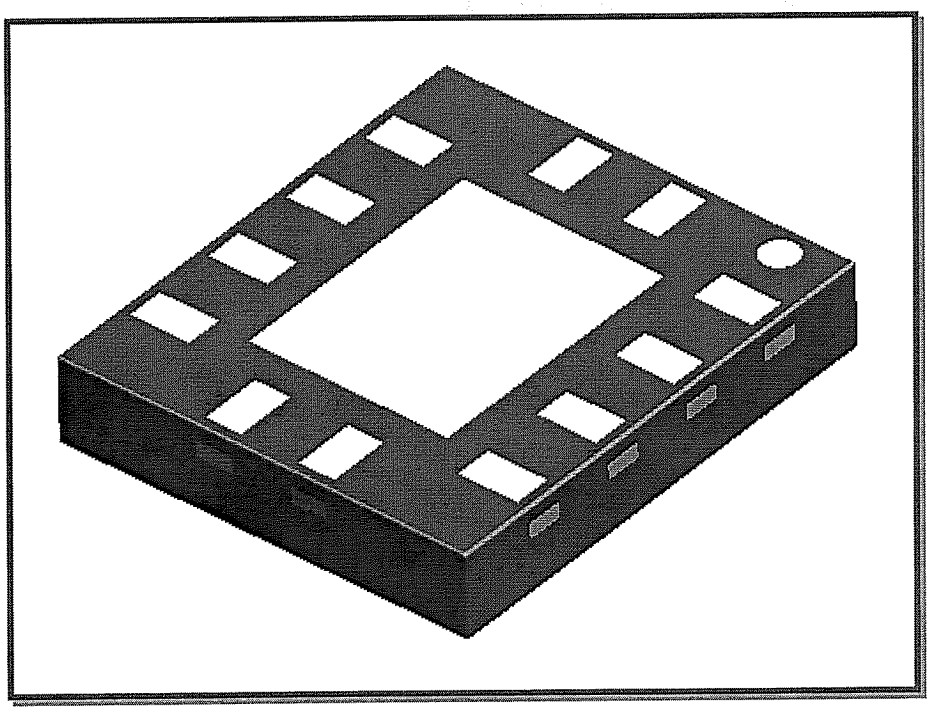
USB Hub Protection Application

Package Technology: Enabling Improved Power Density

- Power management is about a compromise between conversion efficiency, complexity, cost, size and performance
- Semiconductor packaging is central to the compromise equation.

Leadless Leadframe Package (LLP): Combines Thermal Enhancement With Small Size





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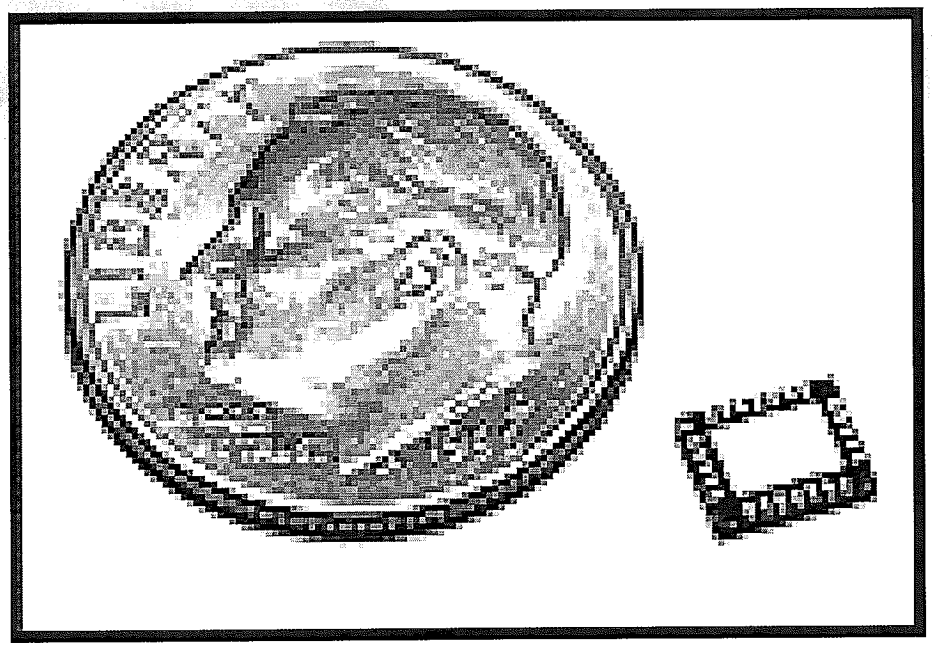
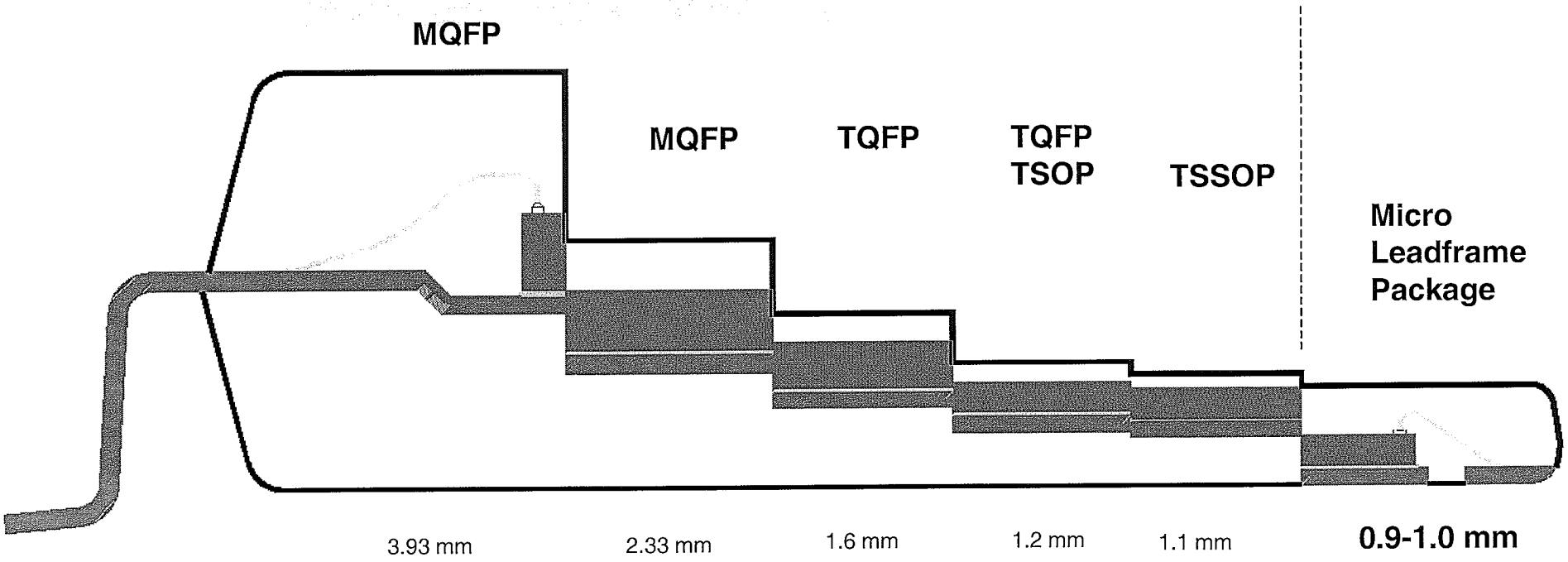
LLP=Leadless Leadframe Package



- A breakthrough in power density

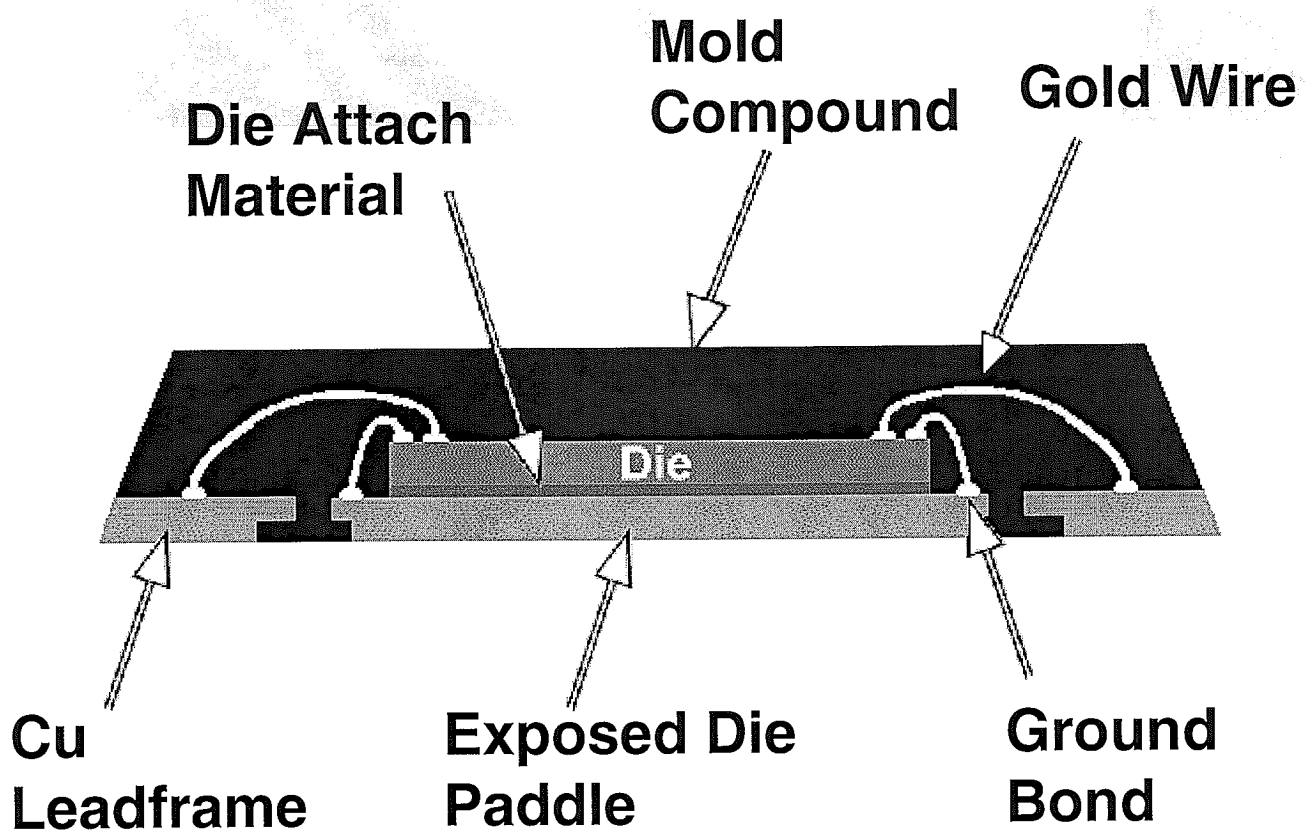
LLP Package Height Comparison

Height Reduction

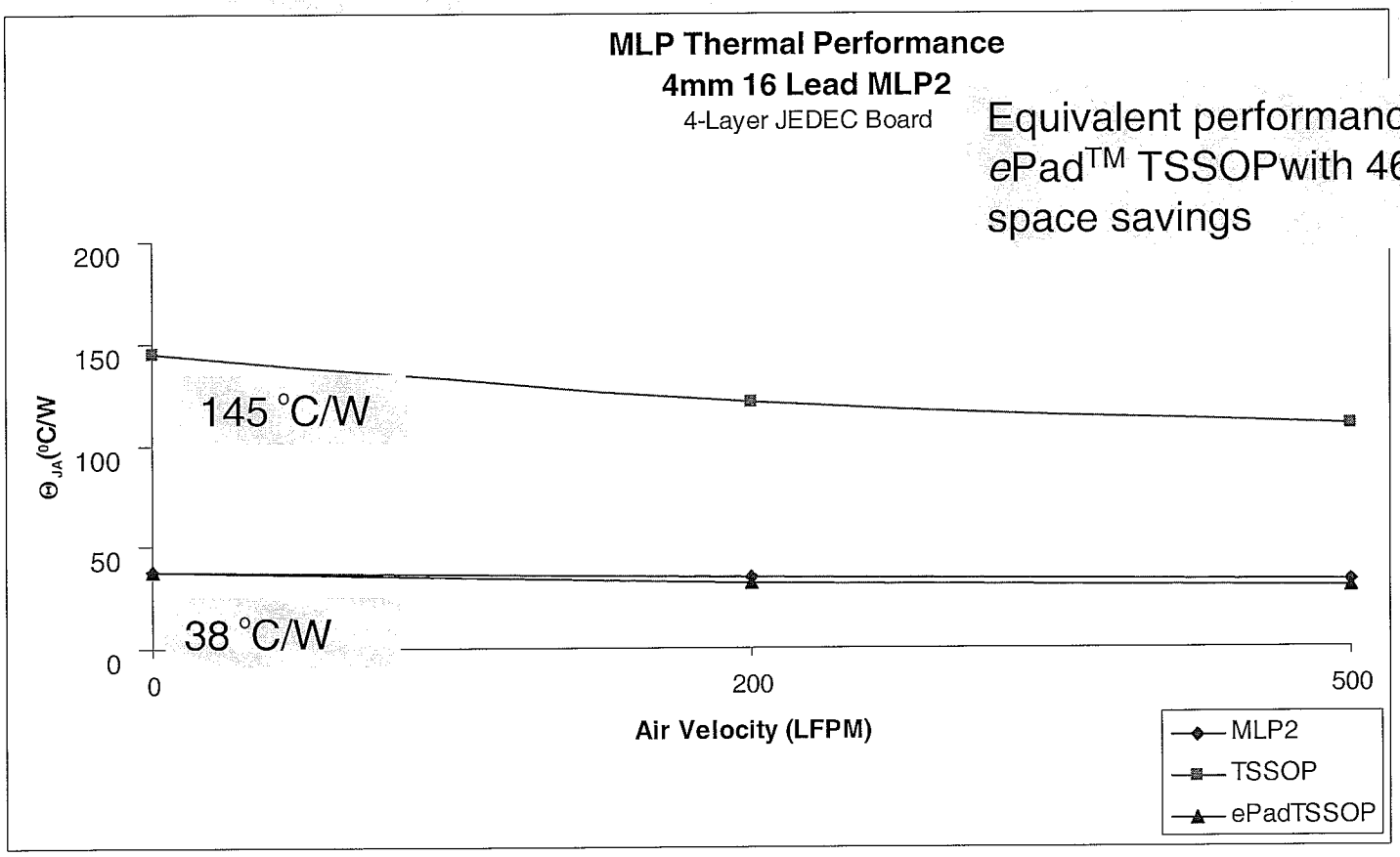


National Semiconductor

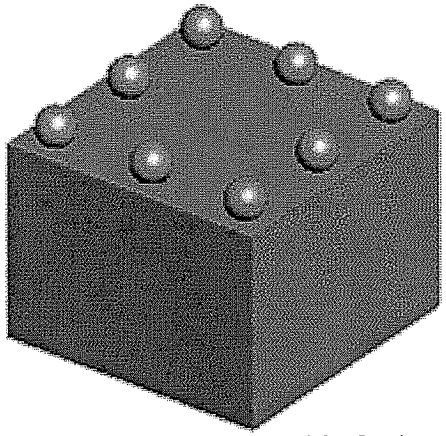
LEADFRAME CSP



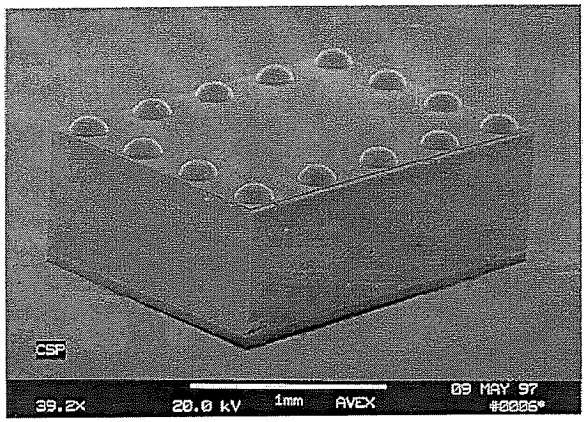
LEADFRAME CSP



Micro SMD (uSMD): The Die is the Package!



8 I/O 0.5 mm pitch



14 I/O 0805 0.4 mm pitch Daisy Chain

- One Example:
- 8 I/O 0.5 mm pitch
- **No under-fill**
- BCB front coating
- Epoxy back coating
- Surface mount design

- A range of 4 To 14 Pins

Package Size Comparison