Design Guidelines to Achieve 3% Core Voltage Tolerance for 28nm QorIQ Processors
Control of Manufacturing = On-Time Delivery

USA
2 Wafer Fabs (95%)

Penang, Malaysia Assembly (80%)

Singapore Final Test (100%)

4 Weeks
No Obsolescence Policy

PRODUCT OBSOLESCENCE POLICY
March, 2009

Linear Technology Corporation offers the following explanation of our process and policy regarding discontinuance or obsolescence of our products.

As a general practice, LTC prefers not to discontinue products and has discontinued very few products over the years we have been in business. From an industry view, the linear or analog integrated circuit business is not governed by and does not follow the same trends in technology or product obsolescence as found in other integrated circuit segments. The manufacturing processes, packages and functions serve their respective market segments for a much longer period of time than do faster changing technologies such as memory, programmable logic or microprocessors, to name a few.

Analog wafer fabrication processes are often in active use for decades while digital types of processing may be viable only a few years before they are made technically and /or financially

Only 2 reasons for obsolescence:
1) ZERO sales for many years
2) Cannot source raw materials
Power Management Solution Options

- **Linear Regulators**
  - Simple
  - Low noise
  - Few components
  - Low power

- **Monolithic Switchmode Regulators**
  - More components than linear reg.
  - Layout Consideration
  - Mid-to-high power
  - More efficient

- **Switchmode Controller Regulators**
  - More components than monolithic
  - More Complex layout
  - Mid-to-very high power, efficient

- **µModule Regulator Systems**
  - Complete circuit in a tiny package
  - Simple layout
  - Efficient
  - Low-to-high power
  - New: Low noise…
28nm QorIQ – Core (VCC) Power Requirements

• **VCC Core Requirements**
  • Voltage: sub-1V ± 3%
  • Current: >20A depending on application

• **Challenges**
  • DC accuracy
  • Low voltage, high current supplies - challenges
  • AC accuracy
  • Layout issues

• **Linear Technology Solutions**
  • New high power, integrated solutions
    • Using remote sense amplifier
  • **Innovative Power System Management**
    • Active servo loop can achieve 0.25% DC accuracy
  • **Robust board layout**
    • Minimize board space as much as possible, reduce complexity and BOM count.
Output Voltage Accuracy - Definitions

- **DC accuracy**
  - Output DC voltage *at* the point of load

- **AC accuracy**
  - Output voltage ripple
  - Output voltage transient response
Output Voltage - DC Accuracy
Output Voltage - DC Accuracy

- Factors affecting DC accuracy
  - Reference voltage accuracy - 0.5 - 1%
  - Feedback resistor tolerance - 0.1 - 1%
  - Load regulation - -0.1 - 0.1%
  - Line regulation – 0.002 – 0.02%

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### ELECTRICAL CHARACTERISTICS

The • denotes the specifications which apply over the full operating junction temperature range (E-Grade), otherwise specifications are at \( T_A = 25°C \). \( V_{IN} = 15V \), \( V_{RUN1,2} = 5V \) unless otherwise noted.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{IN} )</td>
<td>Input Voltage Range</td>
<td></td>
<td>4.5</td>
<td>38</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( V_{OUT} )</td>
<td>Output Voltage Range</td>
<td></td>
<td>0.6</td>
<td>12.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( V_{FB1,2} )</td>
<td>Regulated Feedback Voltage</td>
<td>( I_{TH1,2} ) Voltage = 1.2V (Note 4)</td>
<td>• 0.5955</td>
<td>0.600</td>
<td>0.6045</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( I_{TH1,2} ) Voltage = 1.2V (Note 4), ( T_A = 125°C )</td>
<td>• 0.594</td>
<td>0.600</td>
<td>0.606</td>
<td>V</td>
</tr>
<tr>
<td>( I_{FB1,2} )</td>
<td>Feedback Current</td>
<td>(Note 4)</td>
<td>–15</td>
<td>–50</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>( V_{REFLNREG} )</td>
<td>Reference Voltage Line Regulation</td>
<td>( V_{IN} = 4.5V ) to 38V (Note 4)</td>
<td>0.002</td>
<td>0.02</td>
<td></td>
<td>%/V</td>
</tr>
<tr>
<td>( V_{LOADREG} )</td>
<td>Output Voltage Load Regulation</td>
<td>(Note 4)</td>
<td>• 0.01</td>
<td>0.1</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Measured in Servo Loop; ( \Delta I_{TH} ) Voltage = 1.2V to 0.7V</td>
<td>• –0.01</td>
<td>–0.1</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Measured in Servo Loop; ( \Delta I_{TH} ) Voltage = 1.2V to 1.6V</td>
<td>•</td>
<td></td>
<td></td>
<td>%</td>
</tr>
</tbody>
</table>

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Found in Electrical Characteristic table

Look for specifications over temperature!
Low Voltage, High Current Supplies - Challenges

- Parasitic board resistance
  - Assume resistance = 2mOhm
  - For 20A, voltage droop = 20A * 2mOhm = 40mV
  - For 1V, this is 40mV/1V = 4%
    - This is already over the 3% DC accuracy specification!!

- Solutions
  - Lots of copper to reduce parasitic resistance
    - Thick copper pours, use many layers
    - Increases real estate and cost for the board
  - Use remote sense amplifier
  - Use active servo loop
Remote sense amplifier

- Sense the voltage at the processor pins and regulates right at the VCC pins
- Simple differential lines going back to the power supply IC
Low Voltage, High Current Supplies - Solutions

Active Servo Loop

- Active servo loop
  - Digital telemetry continuously monitors the output voltage and servos to the programmed voltage
  - ADC to sense the voltage, DAC to inject current into the feedback node to manipulate output voltage
  - **Can achieve 0.25% DC accuracy**
Companion IC - LTC2977 Digital Power System Manager

8-Channel PMBus Power System Manager

- **V_PWR**
- **V_DD33**
- **V_IN_EN**
- **SDA**
- **SCL**
- **ALERTB**
- **CONTROL0**
- **WP**
- **FAULTB00**
- **SHARE_CLK**
- **IN_SNS**
- **DACPO0**
- **SENSEPO0**
- **INSENS**
- **DACMO0**
- **SENSEO0**
- **OUT_EN0**
- **PWRGD**
- **WDI/RESETB**
- **ASEL0**
- **ASEL1**

**V_IN**
- **V_OUT**
- **DIGITALLY MANAGED POWER SUPPLY**
- **V_FB**
- **GND**
- **SGND**
- **RUN/SS**

- **TO INTERMEDIATE BUS CONVERTER ENABLE**
- **PMBus INTERFACE**
- **WRITE-PROTECT**
- **TO/FROM OTHER LTC POWER SUPPLY MANAGERS**

**4.5V < V_BUS < 15V**

**3.3V**

*Some details omitted for clarity only one of eight channels shown

**May be powered from either an external 3.3V supply or the intermediate bus
Power Converter IC - LTC3880
LTM4676: Dual-13A μModule® Regulator with Power System Management

• Complete Dual 13A DC/DC based on LTC3880
  • Includes inductors and power stage
  • Parallel outputs for 26A supply
• Features
  • Wide Input Range: 4.5V to 24V
  • 12-bit $V_{OUT}$ Programming up to 5.5V with ±0.5% Accuracy
  • 16-bit A/D Monitor of $V_{IN}$, $V_{OUT}$, $I_{OUT}$, $I_{IN}$, Temperature, Duty Cycle
  • High accuracy $I_{OUT}$, $I_{IN}$ measurement
  • Soft-Start/Stop, Sequencing, Margining, and Poly-Phase Operation
  • Internal, External Temperature Monitors
  • Fault Logging
  • Programmable UV/OV/OC Supervisors
  • 16mm x 16mm x 5.01mm BGA
Inside a DC/DC μModule System

- All power components are inside and are protected by an encapsulated surface-mount LGA or BGA Package
Output Voltage - AC Accuracy

• Factors affecting AC accuracy
  • Output Voltage Ripple
    • Inductor Switching Current
    • Output Capacitor Equivalent Series Resistance
  • Transient Response
    • Output capacitance
    • Feedback loop bandwidth
AC Accuracy – Output Voltage Ripple

CONTINUOUS MODE

- Voltage
- Current
- Continuous Current
- Pulsating Current
- High dv/dt node

Diagram showing the circuit with components labeled:
- VIN+
- ESRin
- Cin
- ST
- SB
- LF
- Co
- Ro
- SW
- PGND
- V Vin
- Vo
- R

Diagram illustrates the flow of continuous and pulsating currents with labeled nodes and components.
AC Accuracy – Output Voltage Ripple

Measuring Output Voltage Ripple
AC Accuracy – Output Voltage Ripple

• **Output voltage ripple**
  • At the switching frequency
  • Multiplication of inductor ripple current and output capacitor ESR
    • Ripple Current = 30-60% of output current by design
    • Output ESR = Combined effective series resistance for all output capacitors

• **Reducing output ripple voltage**
  • Reduce the inductor ripple current
    • Increase switching frequency
      • Tradeoff: efficiency hit
    • Use low ESR output capacitors
      • Ceramics in parallel with bulk capacitors
AC Accuracy – Transient Response

• Output voltage dips or overshoots when output load changes
  • The regulator takes finite amount of time to respond to output load changes
• Factors affecting transient response (for a current mode controller)
  • Output capacitors
  • Loop compensation – bandwidth and phase margin

• **Ways of improving transient response**
  • Multiphase operation: LTM4620 module, LTC3855, LTC3829
  • Valley Current Mode/Controlled on-time architecture: LTC3878, LTC3833
  • Non-linear control: LTC3829, LTC3867, LTC3856
  • Active Voltage Positioning: LTC3829
AC Accuracy – Transient Response

- **Definitions:**
  - Load step (start and stop)
  - Slew rate
AC Accuracy – Transient Response
Anatomy of a Transient Response

- Three distinct sections
  - Droop due to output capacitor ESR: (A)
  - Recovery due to power supply control: (B)
  - Output voltage regulation point: (C)
Transient Response – Multiphase Operation

• Implemented with any multiphase converters

• Parallel two or more “phases” or “channels”
  • Effectively double the switching frequency and faster response to transients
  • The converter does not have to wait for another switch cycle
Transient Response – Multiphase Operation

TYPICAL APPLICATION

26A, 1.2V Output DC/DC µModule® Regulator

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Transient Response – Multiphase Operation Example with LTC3829

Single Phase
Load step up: 0~25A, 25A/µs

Multiphase (3 phases or channels in parallel)
Load step up: 0~75A, 75A/µs
Transient Response – Controlled On-Time

- During a load step, the regulator does not wait until next cycle

**Constant On-time Control**

\[ \text{i}_L \times R_i \]

\[ V_{\text{th}} \]

\[ d \]

\[ \text{Fixed } T_{\text{on}} \]
Transient Response – Controlled On-Time Example with LTC3833

Load step up: 0~25A, 25A/µs

- **Peak Current Mode Control** (LTC3855, 1-phase)
  - $T_{\text{delay}} = 2.18\mu\text{S}$

- **Constant On-time Control** (LTC3833, 1-phase)
  - $T_{\text{delay}} = 0.65\mu\text{S}$

- LTC3833 does NOT have switching cycle delay.
- LTC3833 has multiple pulses during load step up.
- LTC3833 reduces $V_{\text{OUT}}$ undershoot by 40%.
Transient Response – Nonlinear Control Example with LTC3829

Load step up: 0~25A, 25A/µs

w/o the nonlinear function

w/ the nonlinear function
Transient Response – Adaptive Voltage Scaling

- For the same output capacitors, the peak-to-peak voltage spike is reduced by half.
- For the same voltage tolerance window, the output capacitor can be reduced.
Transient Response – Adaptive Voltage Scaling
Example with LTC3829

Transients w/ AVP ($R_{\text{droop}} = 1.5\text{m}\Omega$)

Load step up: 0~75A, 75A/µs

Load step down: 75~0A, 75A/µs
Digital Control Loop Vs. Analog Control Loop: Analog is Faster

- LTC3880 has lower overshoot and undershoot
- Digital loop non-linear control can cause oscillations
LTspice Simulation Results for Transient Response
Reality Check………………

If you:
1.) Are working with a short design schedule, or……
2.) Have tight board real estate constraints, or……
3.) Do not have time for detailed debug and optimization of a DC/DC converter circuit, or ……
4.) Are not a power supply designer

Then a Linear Tech uModule DC/DC converter is a great solution for your power supply application.
Devices recommended for 28nm QorIQ Designs

Core Power

- **LTM4630**: Dual 18A (single 36A) uModule
- **LTM4620A**: Dual 13A (single 26A) uModule
- **LTM4676**: Dual 13A (single 26A) uModule with Digital PSM
- **LTM4628**: Dual 8A (single 16A) uModule
- **LTM4616**: Dual 8A (single 16A) uModule
- **LTC3880**: Dual Output PolyPhase Step-Down DC/DC Controller with Digital Power System Management
- **LTC3829**: 3-Phase, Single Output Synchronous Step-Down DC/DC Controller with Diffamp
- **LTC3855**: Dual, Multiphase Synchronous DC/DC Controller with Differential Remote Sense
- **LTC2977**: Octal Digital Power Supply Manager with EEPROM
  (Please note this is a companion IC and not a power supply)
Devices recommended for 28nm QorIQ Designs
Transceiver Power

- **LTM4616**: Dual 8A (single 16A) uModule
- **LTM8028**: 36VIN, UltraFast, Low Output Noise 5A μModule Regulator
- **LT3070**: 5A, Low Noise, Programmable Output, 85mV Dropout Linear Regulator
- **LT3080**: Adjustable 1.1A Single Resistor Low Dropout Regulator
- **LTC3026**: 1.5A Low Input Voltage VLDO Linear Regulator
Devices recommended for 28nm QorIQ Designs DDR Termination

- **LTC3876**: Dual DC/DC Controller for DDR Power with Differential VDDQ Sensing and ±50mA VTT Reference
- **LT3618**: Dual 4MHz, ±3A Synchronous Buck Converter for DDR Termination
- **LTC3634**: 15V Dual 3A Monolithic Step-Down Regulator for DDR Power
LTC Bay Sales Teams (408-428-2050)

Mark Cosgrove’s Team
• Holly Huynh – North San Jose
• Terry Hou – Mountain View, Cupertino, OTH
• Alicia Prado – South San Jose, MH, Los Gatos
• Bryan Peachey – Sunnyvale
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Linear Technology Program Manager for Freescale
• Gerard Velcelean – Partner Solutions Manager
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