LDO or Switcher?
…That is the Question

Choosing between an LDO or DC/DC Converter

Frank De Stasi
Texas Instruments

Agenda

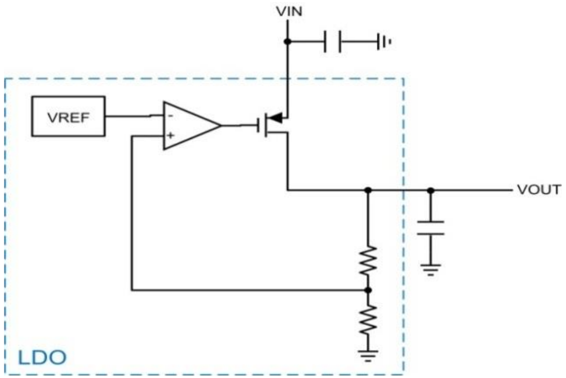
- **LDO Basics**
  - Operation
  - Pros & cons
- **Switcher Basics**
  - Nano module overview
  - Operation
  - Pros & cons
- **Example Comparisons**

LDO operation

- Linear Regulator
  - Most linear regulators are termed "LDO" (Low Drop Out)
  - Drop-out = Lowest (V_{IN} – V_{OUT}) while still in regulation
    - Allows regulation of rails that are close together with good efficiency
    - Allows better utilization of discharging battery voltage
  - Usually requires an input and output capacitor
    - Some only require an input capacitor
  - Can only produce an output voltage that is less than the input.

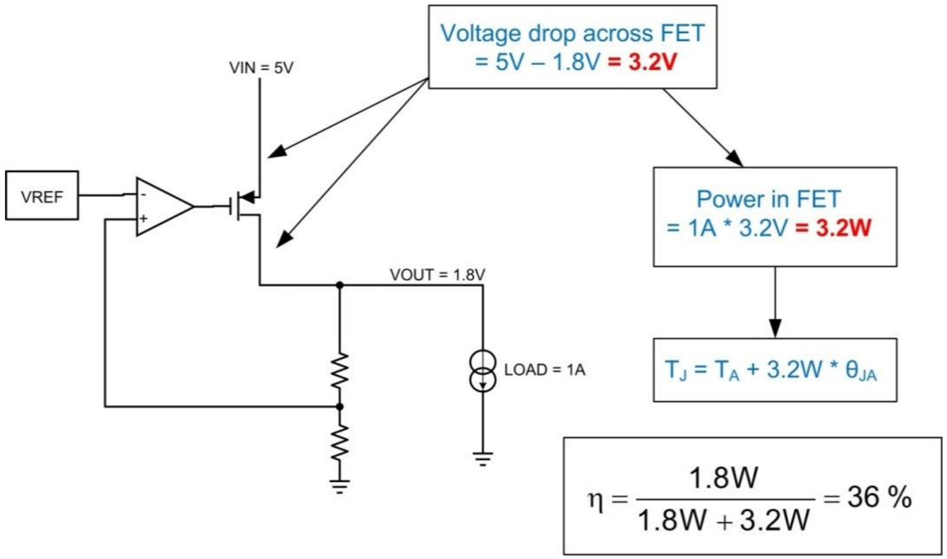
LDO operation

- **Linear Closed Loop System**
  - V_{OUT} is sampled by feedback resistors and compared to V_{REF} with the op-amp
    - Op-amp amplifies changes in V_{OUT} and controls the MOSFET to regulate the output
  - The MOSFET is used as a linear resistor between V_{IN} and V_{OUT}
    - All of the load current flows through the MOSFET
    - Large power loss in regulator when V_{IN} is much greater than V_{OUT}; and/or the load current is large



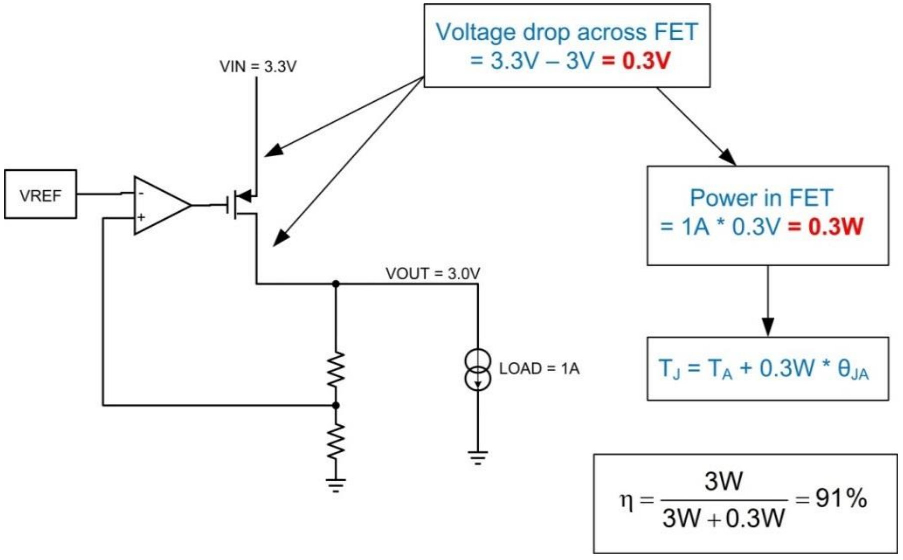
LDO operation

- Large power dissipation at high input-to-output voltage differential
  - More loss than output power is this example!
  - No advantage of "low drop-out"
  - Higher power loss means higher PCB temperature



LDO operation

- **Real advantage when input & output voltages are close together**
  - Use this fact when you can arrange two rails that are close in voltage



LDO pros & cons

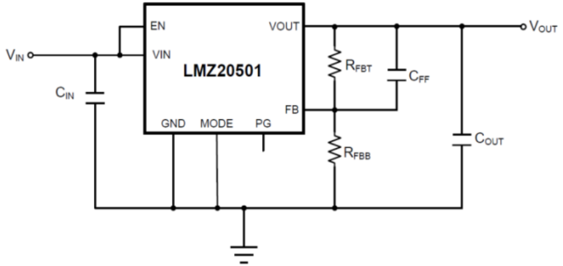
- **Pros**
  - Small size
    - Small packages available
  - Low noise
    - No EMI
  - Simple to use
    - Easy PCB layout
  - Can be inexpensive

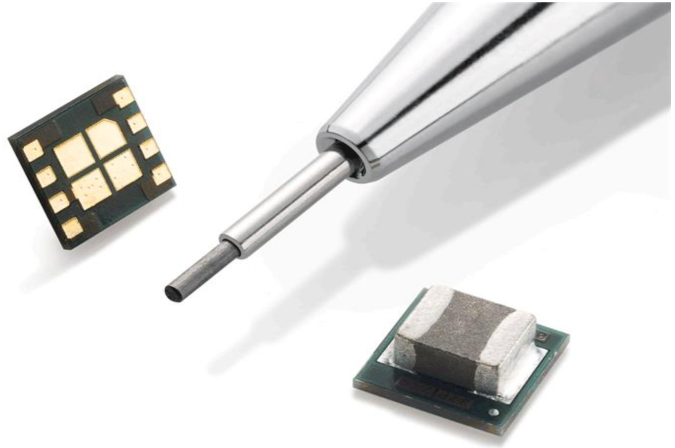
- **Cons**
  - Low efficiency
    - When $V_{IN} >> V_{OUT}$
  - Higher board temperature
  - Can only reduce input

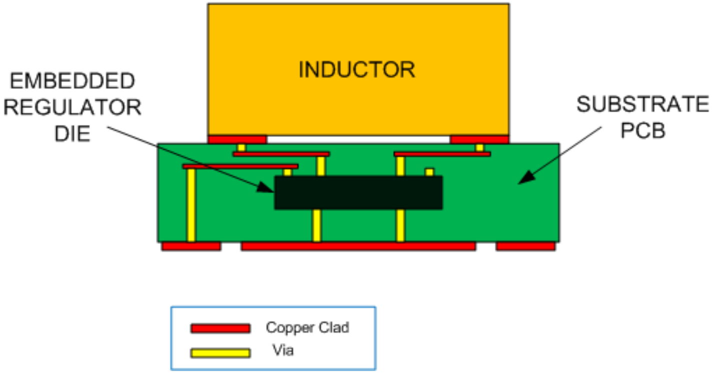
LMZ20501 SIMPLE SWITCHER® Nano Module

Features

- Integrated Inductor
- Miniature 3.5 mm x 3.5 mm x 1.75 mm Package
- 1 A Maximum Load Current
- Input Voltage Range of 2.7 V to 5.5 V
- Adjustable Output Voltage Range of 0.8 V to 3.6 V
- ± 1% Feedback Tolerance Over Temperature
- 2.4 µA (max) Quiescent Current In Shutdown
- 3 MHz Fixed PWM Switching Frequency
- -40°C to 125°C Junction Temperature Range
- Power Good Flag Function
- Pin-Selectable Switching Modes
- Internal Compensation and Soft-Start
- Current Limit, Thermal Shutdown, and UVLO Protection



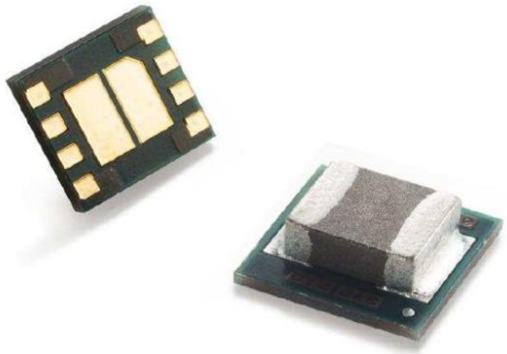


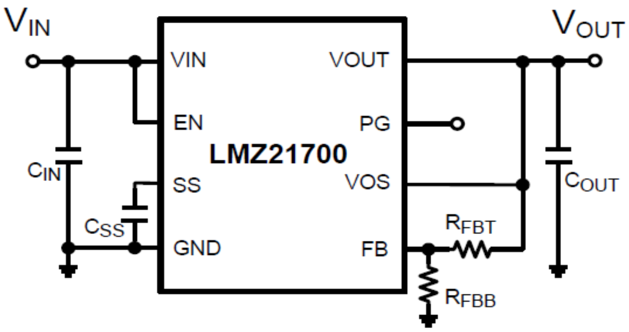


LMZ21700 SIMPLE SWITCHER® Nano Module

Features

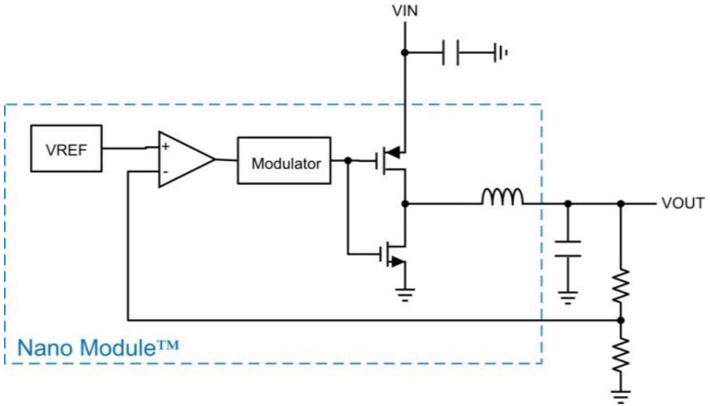
- Integrated Inductor
- Miniature 3.5 mm x 3.5 mm x 1.75 mm Package
- 35 mm² Solution Size (Single Sided)
- -40 °C to 125 °C Junction Temperature Range
- Adjustable Output Voltage
- Integrated Compensation
- Adjustable Soft Start Function
- Starts into Pre-Biased Loads
- Power Good and Enable Pins
- Seamless Transition to Power-Save Mode
- Up to 650 mA Output Current
- Input Voltage Range 3 V to 17 V
- Output Voltage Range 0.9 V to 6 V
- Efficiency up to 95 %
- 1.5 µA Shutdown Current
- 17 µA Quiescent Current





Step-down converter module

- **Inductive Switching Regulator**
  - Provides high efficiency over large range of input voltage and load current
    - Special modes provide good efficiency at very light load currents
    - Inductor allows storing energy, which improves efficiency
  - High switching frequency
    - Allows smaller input and output capacitors
  - The Inductor is integrated into the package
    - Saves PCB space
    - Simplifies component selection



Step-down converter module

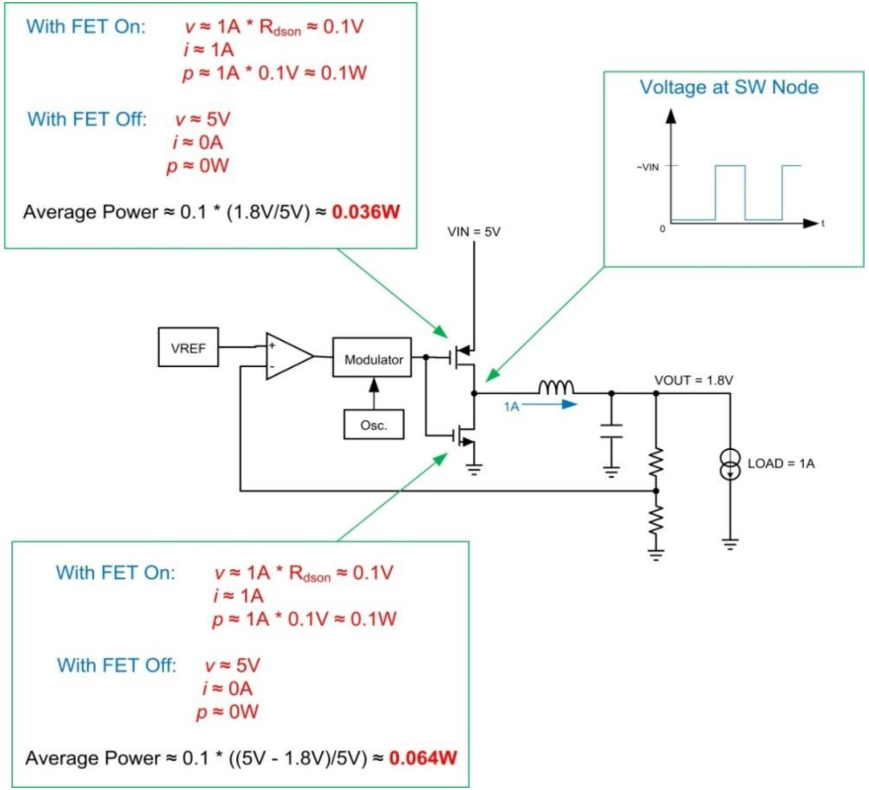
- **Inductive Switching Regulator**

  - V_{OUT} is sampled by feedback resistors and compared to VREF with the op-amp
    - Op-amp amplifies changes in V_{OUT} and controls the modulator
    - Modulator controls the MOSFET switches.

  - Uses MOSFETS as switches to control output power
    - Very small voltage drop across switches
    - Some additional small loss due to charging MOSFET capacitance

  - High efficiency over wide input voltage ranges
    - MOSFET voltage drop does not depend on input and output voltage; like an LDO

Step-down converter operation



Step-down converter operation

- Compare total losses for LDO & switcher: **V_{in} = 5V, V_{out} = 1.8V, I_{out} = 1A**

- For example DC/DC converter:
  - **≈ 0.1W**

$$\eta = \frac{1.8\,W}{1.8\,W + 0.1\,W} = 95\ \%$$

- For example LDO:
  - **≈ 3.2W**

$$\eta = \frac{1.8W}{1.8W + 3.2W} = 36\ \%$$

Switcher pros & cons

- **Pros**
  - High efficiency
  - Easier heat dissipation
  - Lower PCB temperature
  - Flexible conversion
    - Can be used as an inverter
- **Cons**
  - More complex layout
    - PCB layout is critical
  - Switching noise
    - EMI
  - Can be more expensive

Example 1

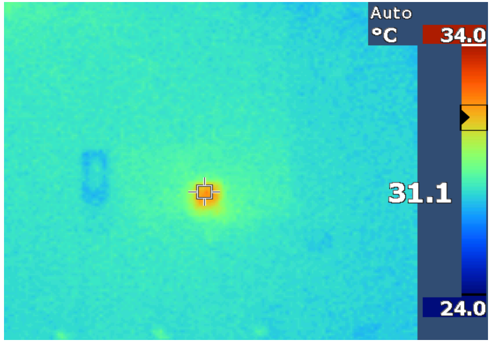
- V_{in} = 3.3V to 5.5V
- V_{out} = 1.8V
- I_{out} = 0.5A
- Ambient Temperature = 25°C

- Key Issues in Application
  - Power dissipation
  - Size

Example 1

LMZ21700 Nano Module

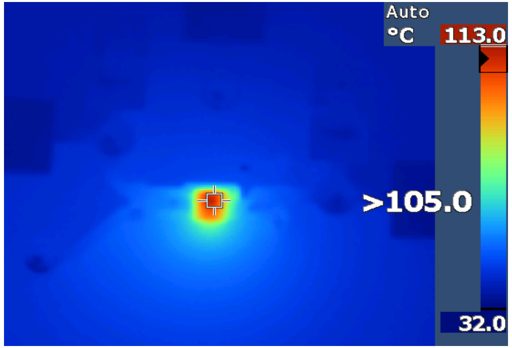
- PCB area ≈ 1700mm^2
- Solution size ≈ 100mm^2
- Max temperature ~ 32°C



Thermal Camera Image

LP38693 LDO

- PCB area ≈ 2600mm^2
- Solution size ≈ 100mm^2
- Max temperature > 105°C



Thermal Camera Image

Conclusion

- LMZ21700 is much cooler; can achieve design objectives
- LP38693 is much hotter; even with more PCB area than LMZ21700
- **LMZ21700 is Winner**

Example 2

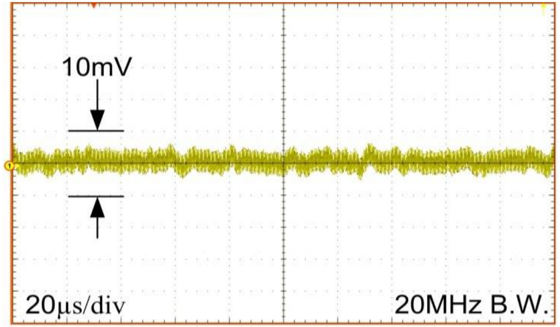
- V_{in} = 5.5V
- V_{out} = 1.8V
- I_{out} = 1A

- Key Issues in Application
  - Noise on output
  - EMI

Example 2

LMZ20501 Nano Module

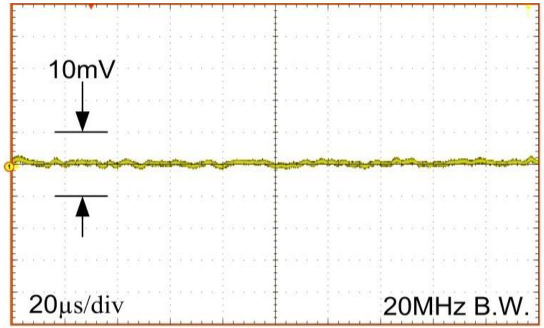
- Meets input and output specs
- EN and PGOOD
- +/- 1.5% output accuracy
- I_Q ≈ 80µA at no load



Output Voltage Ripple

TPS72518 LDO

- Meets input and output specs
- EN and PGOOD
- +/- 2% output accuracy
- I_Q ≈ 80µA at no load



Output Voltage Ripple

Conclusion

- Both solutions achieve the nominal application specifications
- Both have nearly the same features and key specifications
- The TPS72518 is specified for 150µV noise
  - No EMI issues
- **TPS72518 is Winner**

Example 3

- V_{in} = 5V
- V_{out} = 3.3V
- I_{out} = 0.5A

- Key Issues in Application
  - Drop-out voltage for V_{out}-0.1V at 0.5A

Example 3

LMZ21700 Nano Module

- Meets input and output specs
- Rated maximum load = 650mA
- EN and PGOOD
- Drop-out voltage = **107mV @ 500mA**

TPS7133 LDO

- Meets input and output specs
- Rated maximum load = 500mA
- EN and PGOOD
- Drop-out voltage = **250mV @ 500mA**

Conclusion

- Both solutions achieve the nominal application specifications
- Both have nearly the same features.
- The LMZ21700 drop-out is less than half that of the TPS7133
- **LMZ21700 is Winner**

Example 4

- V_{in} = 3.3V
- V_{out} = 1.8V
- I_{out} = 1A

- Key Issues in Application
  - Minimum input voltage

Example 4

LMZ20501 Nano Module

- Meets nominal input and output specifications
- EN and PGOOD
- +/- 1.5% output accuracy
- Minimum rated input voltage = **2.7V**

TPS72518 LDO

- Meets nominal input and output specifications
- EN and PGOOD
- +/- 2% output accuracy
- Minimum input voltage = **2.01V**

Conclusion

- Both solutions achieve the nominal application specifications and have the same features
- The TPS72518 has a drop-out of 210mV at 1A

  → 1.8V + 0.21V = **2.01V**
- The LMZ20501 has a minimum input voltage of 2.7V regardless of other conditions.

- **TPS72518 is Winner**

Example 5

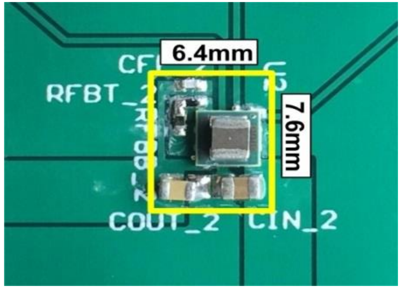
- V_{in} = 3.3V
- V_{out} = 1.8V
- I_{out} = 1A

- Key Issues in Application
  - Solution size

Example 5

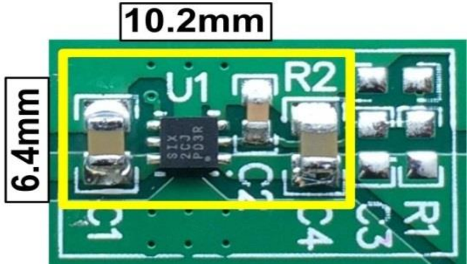
LMZ20501 Nano Module

- Meets nominal input and output specifications
- EN and PGOOD
- +/- 1.5% output accuracy
- Solution size = 49 mm^2



TPS7A37 LDO

- Meets nominal input and output specifications
- EN
- +/- 1% output accuracy
- Solution size = 65 mm^2



Conclusion

- Both solutions achieve the nominal application specifications and have similar features
- Solution size for LMZ20501:
  - 6.4 mm x 7.6 mm = **49 mm^2**
- Solution size for TPS7A37:
  - 6.4 mm x 10.2 mm = **65 mm^2**
- 25% Less board space with LMZ20501
- **LMZ20501 is Winner**

Summary

- **Use an LDO when your application requires:**
  - Low output voltage noise
  - No EMI
  - Operation at very low input voltages
  - The input voltage is close to the output voltage
- **Use a Nano-Module™ DC/DC converter when your application requires:**
  - Very high efficiency
  - Low PCB temperature
  - Small solution size
  - Large variations in input voltage

For more information, visit www.simpleswitcher.com