SIMPLE SWITCHER® Design Guide

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Accelerate your design time with circuit and PCB design tips and recommendations.

SIMPLE SWITCHER

Easy-to-use tools. Simple solutions.

National Semiconductor

Table of Contents

Introduction

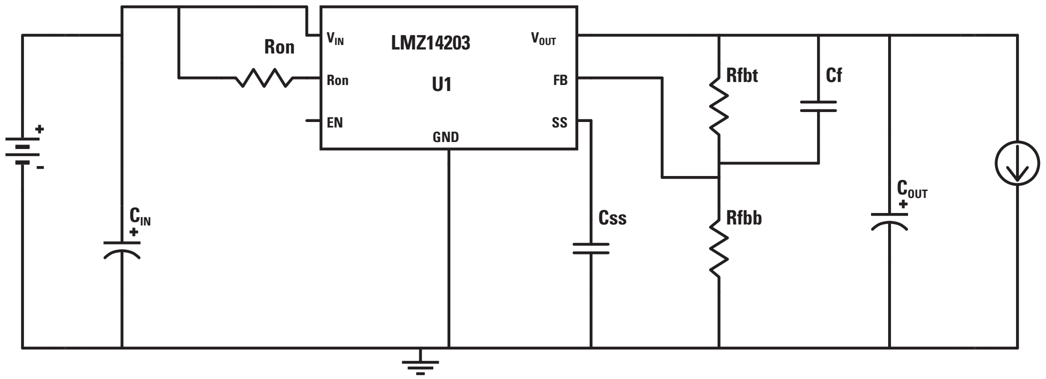
This design guide covers various designs using a select set of SIMPLE SWITCHER® products. For each product, the first section contains schematic, bill of material, technical tips and links to WEBENCH® designs. The second page shows the PCB layout and component placement suggestions to ensure a robust design. For more details please refer to the device datasheets and other documentation referenced.

Two different product families are introduced: The SIMPLE SWITCHER power modules and SIMPLE SWITCHER discrete regulators and controller. The SIMPLE SWITCHER power modules offer the greatest ease of use and fastest design time while the SIMPLE SWITCHER discrete regulators and controllers offer the most design flexibility.

For more information comparing the two families consult *Power Designer 129: Comparing the Merits of Integrated Power Modules versus Discrete Regulators.*

Both families are supported by the WEBENCH design tool, which creates custom power supply designs depending on the application requirements and provides the bill of material needed to create those designs.

LMZ1420x Designs



Design Considerations

- The bulk C_{IN} input capacitor supplies the instantaneous current demands of the IC and must be sized to satisfy the input ripple current requirement. Low ESR or ceramic capacitors are suggested to minimize input voltage ripple. An optional high frequency 1 µF ceramic cap can be placed farther away to reduce noise.
- For C_{OUT}, low ESR capacitors such as ceramics are recommended. This reduces output ripple but make sure to account for a DC bias derating when sizing the capacitor. C0G, X7R or X5R dielectrics are recommended as they are stable across a larger temperature range than others.
- The R_{ENT} & R_{ENB} circuit ensures robustness and prevents early turn on of the IC as the main supply voltage ramps up. If the supply voltage should rise and fall at the UVLO voltage then the LMZ14203's output may droop. Digital loads such as FPGAs are highly sensitive to this and a monotonic rise.
- For further details refer to the Design Documentation section.

Component Values (BOM)

The following table summarizes the values chosen for the designs listed here.

Common Components across all designs

C_{IN}	C_{OUT}	C_{SS}	C_F	R_{ENT}	R_{ENB}
10 µF, X5R, 50V	100 µF, X5R, 6.3V	22 nF, X7R, 16V	22 nF, X7R 16V	68.1kΩ	11.8kΩ

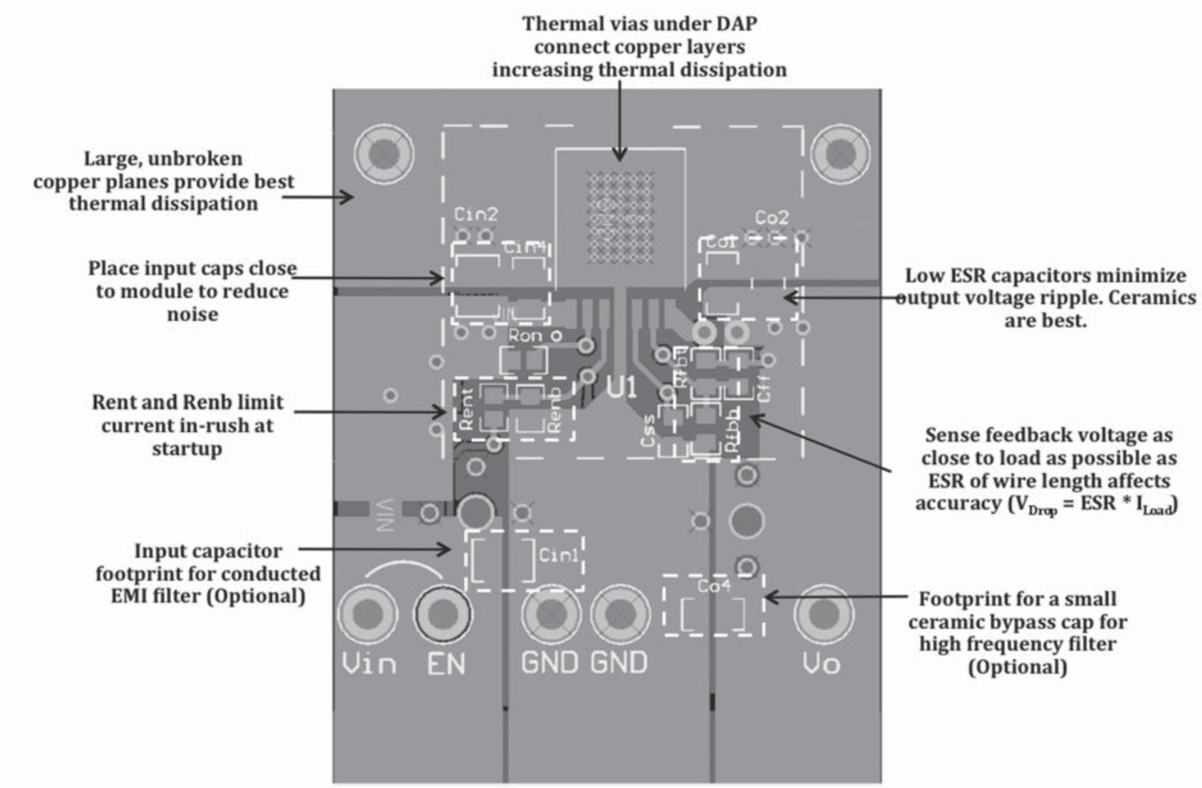
Design-Specific Components

V_{IN}	V_{OUT}	R_{FBT}	R_{FBB}	R_{ON}
8 to 42V	5V	5.62 kΩ	1.07 kΩ	100 kΩ
6 to 42V	3.3V	3.32 kΩ	1.07 kΩ	61.9 kΩ
6 to 30V	2.5V	2.26 kΩ	1.07 kΩ	47.5 kΩ
6 to 25V	1.8V	1.87 kΩ	1.50 kΩ	32.4 kΩ
6 to 21V	1.5V	1.00 kΩ	1.13 kΩ	28.0 kΩ
6 to 19V	1.2V	4.22 kΩ	8.45 kΩ	22.6 kΩ
6 to 18V	0.8V	0	39.2 kΩ	24.9 kΩ

Design Documentation

- Datasheets for: LMZ14203, LMZ14202, and LMZ14201
- AN-2024: LMZ1420x / LMZ1200x Evaluation Board
- AN-2052: National Semiconductor's SIMPLE SWITCHER Power Modules and EMI

LMZ14203 PCB Design



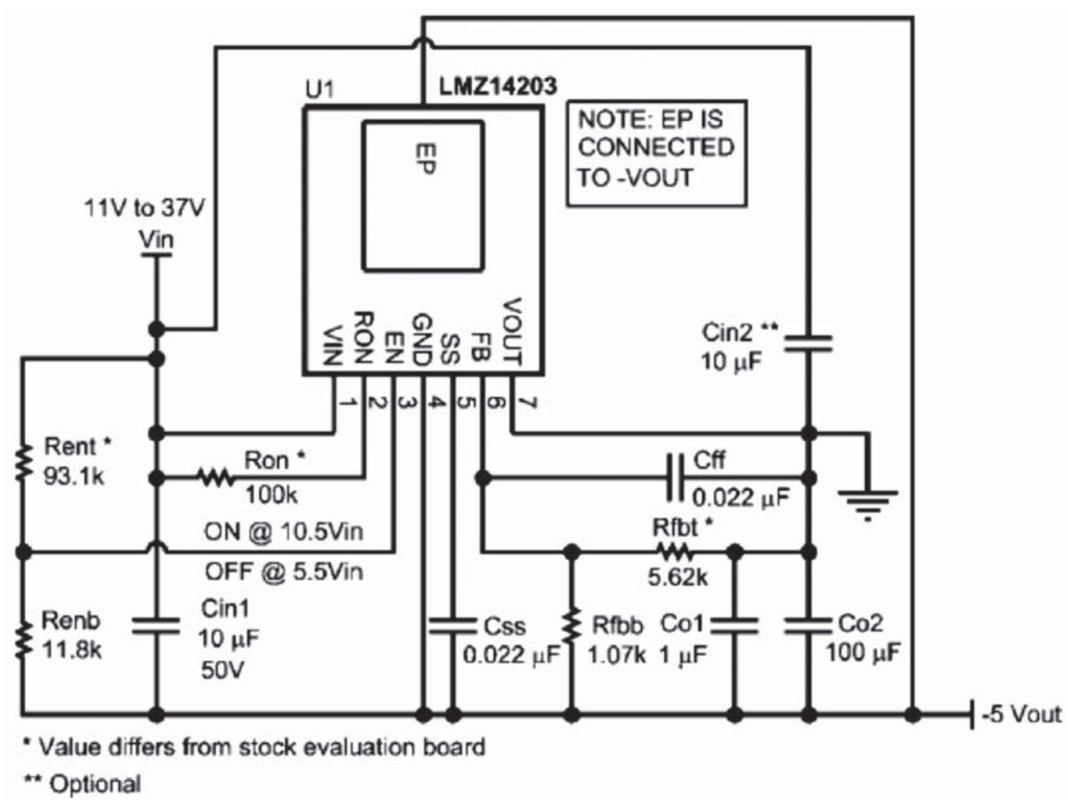
PCB effects on Thermal Performance

The SIMPLE SWITCHER power module's TO-PMOD7 package is very effective at heat transfer and PCB design has a great impact on the overall thermal performance of the device. Commonly referred to as θ_{JA}, this measures the device's temperature rise for a given power dissipation. Below are suggestions to follow when designing your PCB. For more details please refer to the datasheet and suggested further reading provided at the end.

- Solder the package's exposed pad DAP to ground plane
- Use copper planes with a 2-ounce copper weight
- Connect the copper planes with thermal vias
- Larger unbroken PCB area provide better thermal dissipation

Suggested Further Reading

- AN-2026: The effect of PCB Design on the Thermal Performance of SIMPLE SWITCHER Power Module
- AN-2020: Thermal Design by Insight, Not Hindsight
- AN-2078; PCB Layout For National Semiconductor's SIMPLE SWITCHER Power Module
- AN-2024: LMZ1420x / LMZ1200x Evaluation Board



Design Considerations

The LMZ14203 inverting design largely follow the LMZ14203 design. As seen in the schematic, the major difference is where the ground and V_{OUT} connections are made. In addition, while the R_{ENT} & R_{ENB} circuit can still be used, hysteresis occurs which maybe undesirable.

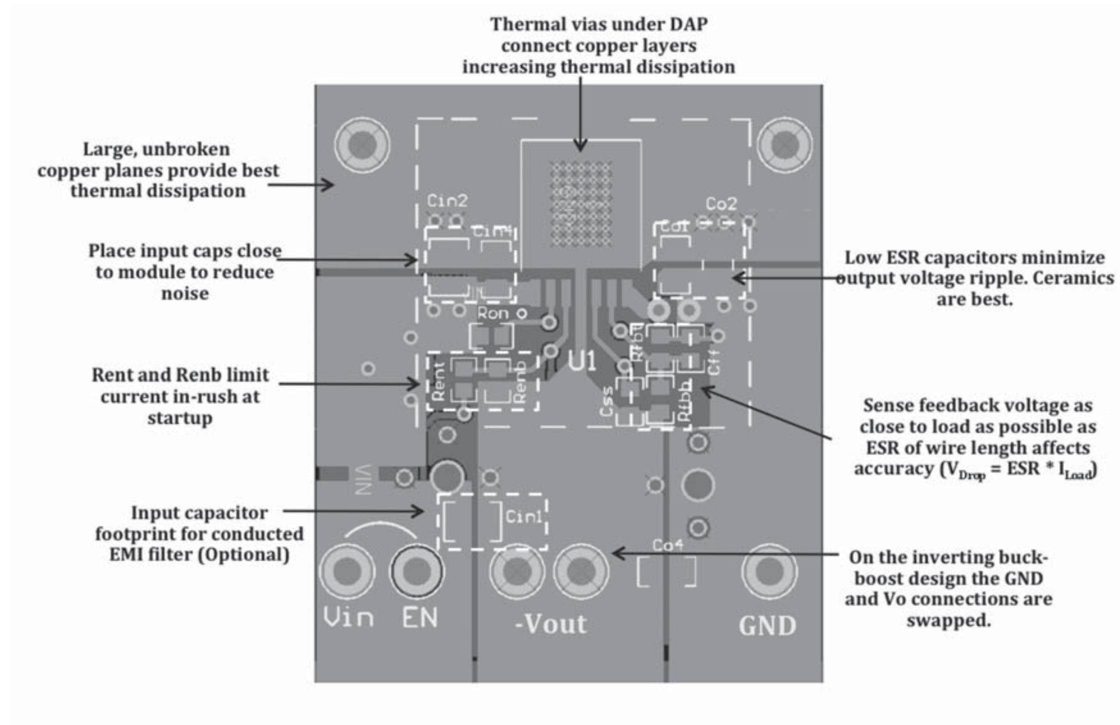
For further details refer to the Design Documentation section.

Design Documentation

- Datasheets for: LMZ14203, LMZ14202, and LMZ14201
- AN-2027: Inverting Application for the LMZ14203 SIMPLE SWITCHER Power Module
- AN-2024: LMZ1420x / LMZ1200x Evaluation Board

Component Values (BOM)

V_{IN}	V_{OUT}	C_{IN}	C_{OUT}	C_{SS}	C_F	R_{ENT}	R_{ENB}	R_{FBT}	R_{FBB}	R_{ON}
11V to 37V	-5V	10 µF, 50V X7R	100 µF, 6.3V X5R	22nF, 16V X7R	22nF, 16V X7R	93.1 kΩ	11.8 kΩ	5.62 kΩ	1.07 kΩ	100 kΩ
11V to 37V	-3.3V	10 µF, 50V X7R	100 µF, 6.3V X5R	22nF, 16V X7R	22nF, 16V X7R	93.1 kΩ	11.8 kΩ	3.32 kΩ	1.07 kΩ	100 kΩ



PCB effects on Thermal Performance

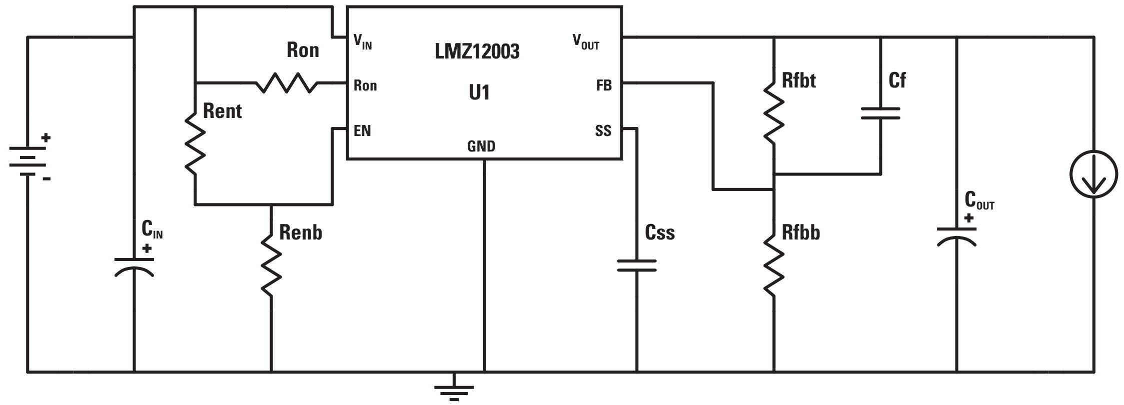
The SIMPLE SWITCHER Power Module's TO-PMOD7 package is very effective at heat transfer and PCB design has a great impact on the overall thermal performance of the device. Commonly referred to as θ_{JA}, this measures the device's temperature rise for a given power dissipation. Below are suggestions to follow when designing your PCB. For more details please refer to the datasheet and suggested further reading provided at the end.

- Solder the package's exposed pad DAP to ground plane
- Use copper planes with a 2-ounce copper weight
- Connect the copper planes with thermal vias
- Larger unbroken PCB area provide better thermal dissipation

Suggested Further Reading

- AN-2027: Inverting Application for the LMZ14203 SSPM
- AN-2026: The effect of PCB Design on the Thermal Performance of SIMPLE SWITCHER Power Module
- AN-2020: Thermal Design by Insight, Not Hindsight
- AN-2078: PCB Layout For National Semiconductor's SIMPLE SWITCHER Power Module

LMZ1200x Designs



Design Considerations/Performance

- The bulk C_{IN} input capacitor supplies the instantaneous current demands of the IC and must be sized to satisfy the input ripple current requirement. Low ESR or ceramic capacitors are suggested to minimize input voltage ripple. An optional high frequency 1 µF ceramic cap can be placed farther away to reduce noise.
- For C_{OUT}, low ESR capacitors such as ceramics are recommended. This reduces output ripple but make sure to account for a DC bias derating when sizing the capacitor. C0G, X7R or X5R dielectrics are recommended as they are stable across a larger temperature range than others.
- The R_{ENT} & R_{ENB} circuit ensures robustness and prevents early turn on of the IC as the main supply voltage ramps up. If the supply voltage should rise and fall at the UVLO voltage then the LMZ12003's output may droop. Digital loads such as FPGAs are highly sensitive to this and a monotonic rise.
- For further details refer to the Design Documentation section.

Design Documentation

- Datasheets for: LMZ12003 , LMZ12002, and LMZ12001
- AN-2024: LMZ1420x/LMZ1200x Evaluation Board
- AN-2052: National Semiconductor's SIMPLE SWITCHER Power Modules and EMI

Component Values (BOM)

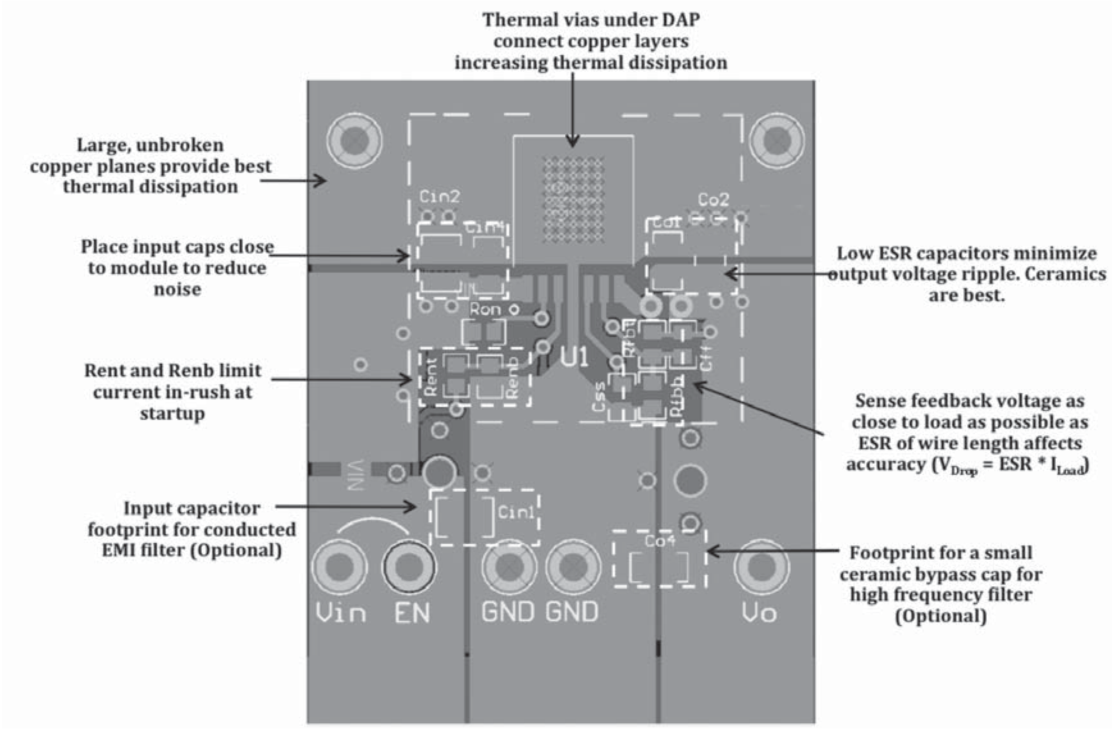
Common Components across all designs

C_{IN}	C_{OUT}	C_{SS}	C_F	R_{ENT}	R_{ENB}
10 µF, X5R, 50V	100 µF, X5R, 6.3V	22 nF, X7R, 16V	22 nF, X7R 16V	32.4 kΩ	11.8 kΩ

Design-Specific Components

V_{IN}	V_{OUT}	R_{FBT}	R_{FBB}	R_{ON}
8 to 20V	5V	5.62 kΩ	1.07 kΩ	100 kΩ
6 to 20V	3.3V	3.32 kΩ	1.07 kΩ	61.9 kΩ
5.5 to 20V	2.5V	2.26 kΩ	1.07 kΩ	47.5 kΩ
4.5 to 20V	1.8V	1.87 kΩ	1.50 kΩ	32.4 kΩ
4.5 to 20V	1.5V	1.00 kΩ	1.13 kΩ	28.0 kΩ
4.5 to 19V	1.2V	4.22 kΩ	8.45 kΩ	22.6 kΩ
4.5 to 18V	0.8V	0	39.2 kΩ	24.9 kΩ

LMZ1200x PCB Design



PCB effects on Thermal Performance

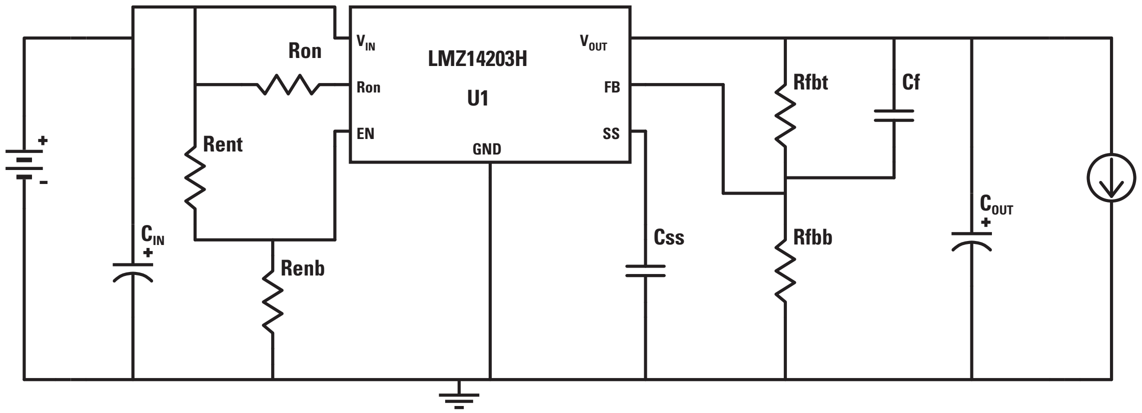
The TO-PMOD-7 package of the SIMPLE SWITCHER Power Module is so effective at heat transfer PCB design has a great impact on the overall thermal performance of the device. Commonly referred to as θ_{JA}, this number measures the temperature rise of the device gets for a given power dissipation. Below are guidelines when designing your PCB. For more details please refer to the datasheet and other references provided at the end.

- Solder the package's exposed pad DAP to ground plane
- Use copper planes with a 2-ounce copper weight
- Connect the copper planes with thermal vias
- Larger unbroken PCB area provide better thermal dissipation

Suggested Further Reading

- AN-2026: The effect of PCB Design on the Thermal Performance of SIMPLE SWITCHER Power Module
- AN-2020: Thermal Design by Insight, Not Hindsight
- AN-2078: PCB Layout For National Semiconductor's SIMPLE SWITCHER Power Module
- AN-2024: LMZ1420x / LMZ1200x Evaluation Board

LMZ1420xH Designs



Design Considerations/Performance

- The bulk C_{IN} input capacitor supplies the instantaneous current demands of the IC and must be sized to satisfy the input ripple current requirement. Low ESR or ceramic capacitors are suggested to minimize input voltage ripple. An optional high frequency 1 µF ceramic cap can be placed farther away to reduce noise.
- For C_{OUT}, low ESR capacitors such as ceramics are recommended. However, ceramics have a limited voltage range and often a polymer electrolytic must be used instead. Be aware that using high ESR caps may inadvertently trigger OVP.
- The R_{ENT} & R_{ENB} circuit ensures robustness and prevents early turn on of the IC as the main supply voltage ramps up. If the supply voltage should rise and fall at the UVLO voltage then the LMZ14203H's output may droop. Digital loads such as FPGAs are highly sensitive to this and a monotonic rise.
- For further details refer to the Design Documentation section

Design Documentation

- Datasheets for: LMZ14203H, LMZ14202H, and LMZ14201H
- AN-2089: LMZ1420xH Evaluation Board
- AN-2052: National Semiconductor's SIMPLE SWITCHER Power Modules and EMI

Component Values (BOM)

The following table summarizes the values chosen for the designs listed here.

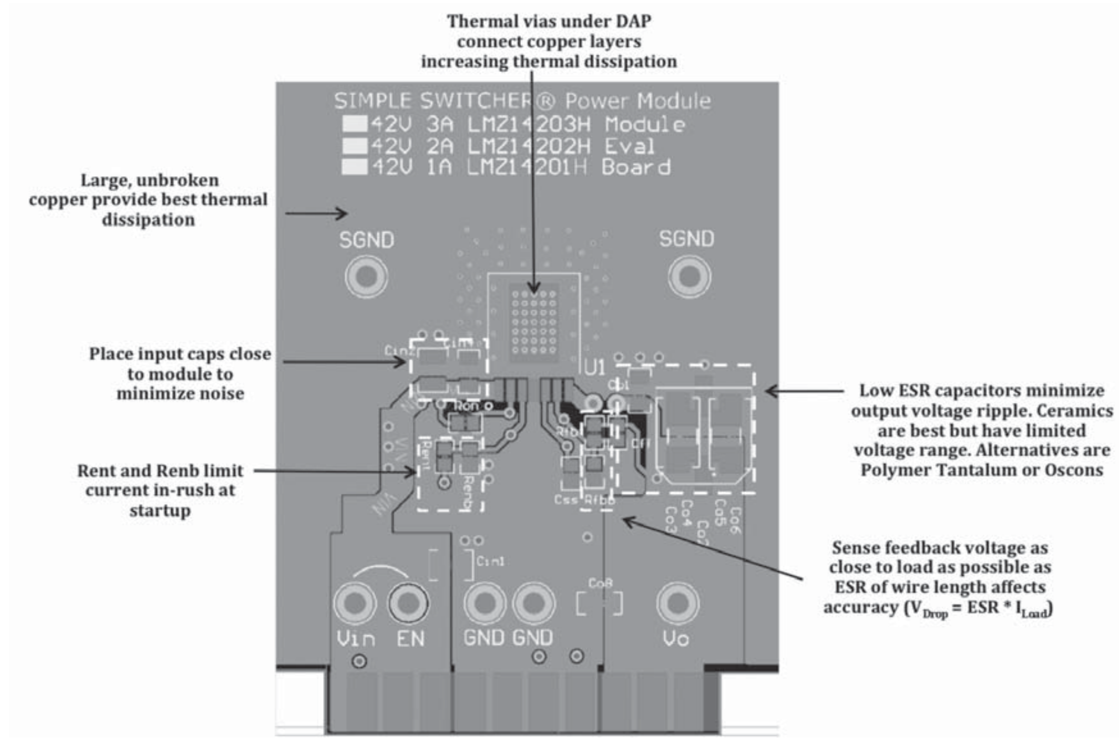
Common Components across all designs

C_{IN}	C_{SS}	C_F	R_{ENT}	R_{FBT}	R_{ENB}
4.7 µF, 100V, X7R	10 nF, 25V, X7R	22 nF, 50V, X7R	68.1 kΩ	34 kΩ	11.8 kΩ

Design-Specific Components

V_{IN}	V_{OUT}	C_{OUT}	R_{ENB}	R_{FBB}	R_{ON}
8 to 42V	5	100 µF, 6.3V, X5R	11.8 kΩ	6.49 kΩ	97.6 kΩ
18 to 42V	12	47 µF, 35V, X5R	4.75 kΩ	2.43 kΩ	187 kΩ
18 to 42V	15	33 µF, 35V, Tantalum	4.75 kΩ	1.91 kΩ	357 kΩ
24 to 42V	18	33 µF, 35V, Tantalum	3.57 kΩ	1.58 kΩ	287 kΩ
30 to 42V	24	47 µF, 35V, AL Polymer	2.8 kΩ	1.18 kΩ	487 kΩ

LMZ1420xH PCB Designs



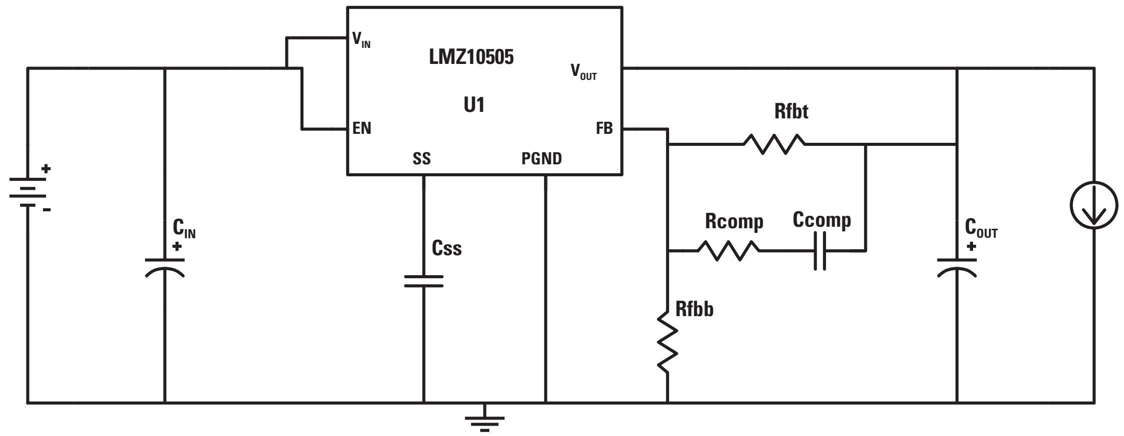
PCB effects on Thermal Performance

The TO-PMOD7 package of the SIMPLE SWITCHER power module is so effective at heat transfer PCB design has a great impact on the overall thermal performance of the device. Commonly referred to as θ_{JA}, this number measures the temperature rise of the device gets for a given power dissipation. Below are guidelines when designing your PCB. For more details please refer to the datasheet and other references provided at the end.

- Solder the package's exposed pad DAP to ground plane
- Use copper planes with a 2-ounce copper weight
- Connect the copper planes with thermal vias
- Larger unbroken PCB area provide better thermal dissipation

Suggested Further Reading

- AN-2026: The effect of PCB Design on the Thermal Performance of SIMPLE SWITCHER Power Module
- AN-2020: Thermal Design by Insight, Not Hindsight
- AN-2078: PCB Layout For National Semiconductor's SIMPLE SWITCHER Power Module
- AN-2024: LMZ1420x / LMZ1200x Evaluation Board



Design Considerations/Performance

- The bulk C_{IN} input capacitor supplies the instantaneous current demands of the IC and must be sized to satisfy the input ripple current requirement. Low ESR or ceramic capacitors are suggested to minimize input voltage ripple.
- For C_{OUT}, low ESR capacitors such as ceramics are recommended. This reduces output ripple but make sure to account for a DC bias derating when sizing the capacitor. C0G, X7R or X5R dielectrics are recommended as they are stable across a larger temperature range than others.
- The LMZ10505 features an internal Type II compensation network. To optimize load transient performance, add a resistor and capacitor (Type III compensation) network across the upper feedback resistor. Choosing these components changes the crossover frequency of the converter and affects responsiveness to load transients.These components also affect phase margin which is a measure of the stability of the power supply to load transients.
- For further details refer to the Design Documentation section

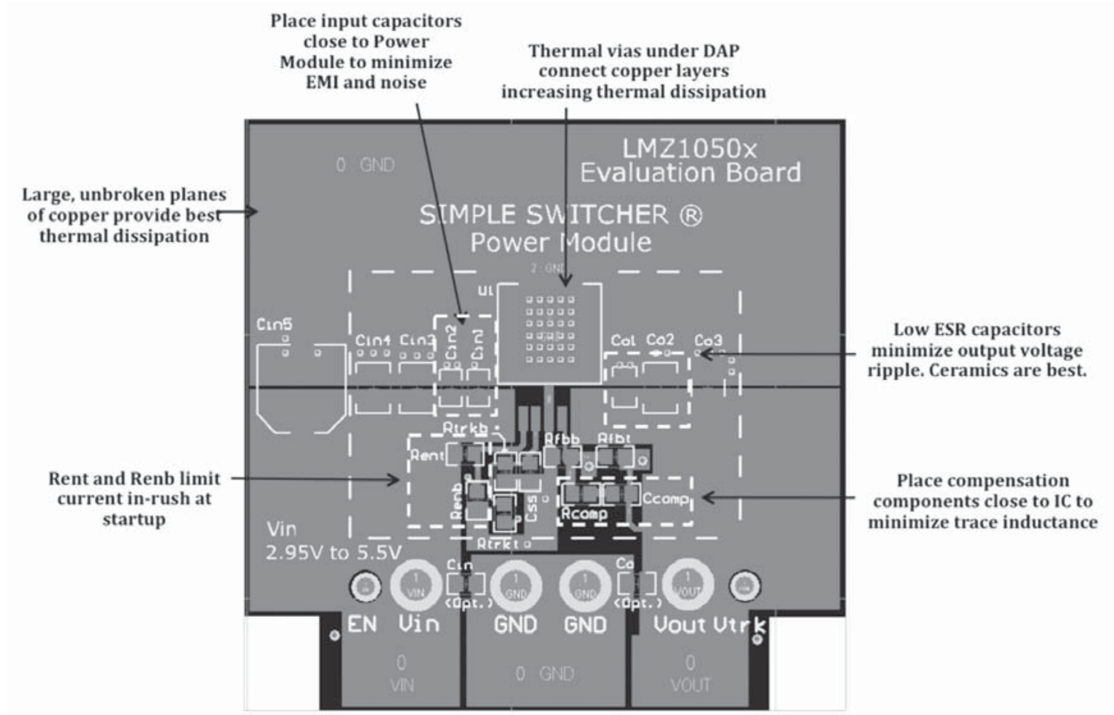
Design Documentation

- Datasheets: LMZ10505, LMZ10504, LMZ10503
- AN-2013: LMZ1050x SIMPLE SWITCHER Power Module Quick Compensation Guide

Component Values (BOM)

The following table summarizes the values chosen for the designs listed here.

V_{IN}	V_{OUT}	I_{OUT}	C_{IN}	C_{OUT}	C_{SS}	C_{COMP}	R_{COMP}	R_{FBT}	R_{FBB}
5v	0.9	5A	10 uF, 10V X5R	100 uF, 6.3V X5R	2.7 nF, 50V X7R	390 pF, 50V X7R	511Ω	43.2 kΩ	340 kΩ
5V	1.2	5A	10 uF, 10V X5R	100 uF, 6.3V X5R	2.7 nF, 50V X7R	390 pF, 50V X7R	511Ω	43.2 kΩ	86.6 kΩ
5V	1.5	5A	10 uF, 10V X5R	100 uF, 6.3V X5R	2.7 nF, 50V X7R	220 pF, 50V X7R	909Ω	61.9 kΩ	54.9 kΩ
5V	1.8	5A	4.7 µF, 50V X5R	47 µF, 6.3V X5R	2.7 nF, 50V X7R	180 pF, 50V X7R	523Ω	52.3 kΩ	64.9 kΩ
5V	2.5	5A	4.7 µF, 50V X5R	47 µF, 6.3V X5R	2.7 nF, 50V X7R	100 pF, 50V X7R	931Ω	82.5 kΩ	39.2 kΩ
5V	3.3	5A	4.7 µF, 50V X5R	47 µF, 16V X5R	2.7 nF, 50V X7R	100 pF, 50V X7R	931Ω	82.5 kΩ	26.7 kΩ



PCB effects on Thermal Performance

The TO-PMOD7 package of the SIMPLE SWITCHER power module is so effective at heat transfer PCB design has a great impact on the overall thermal performance of the device. Commonly referred to as θ_{JA}, this number measures the temperature rise of the device gets for a given power dissipation. Below are guidelines when designing your PCB. For more details please refer to the datasheet and other references provided at the end.

- Solder the package's exposed pad DAP to ground plane
- Use copper planes with a 2-ounce copper weight
- Connect the copper planes with thermal vias
- Larger unbroken PCB area provide better thermal dissipation

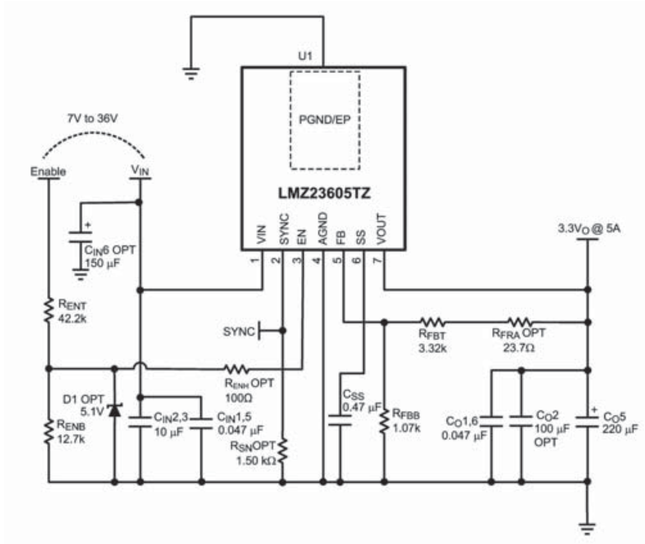
Suggested Further Reading

- AN-2026: The effect of PCB Design on the Thermal Performance of SIMPLE SWITCHER Power Module
- AN-2020: Thermal Design by Insight, Not Hindsight
- AN-2078: PCB Layout For National Semiconductor's SIMPLE SWITCHER Power Module
- AN-2022: LMZ1050x Evaluation Board

LMZ23603/5 Designs

Design Considerations

- The C_{IN} input capacitor supplies the instantaneous current demands of the IC and must be sized to satisfy the input ripple current requirement. Low ESR or ceramic capacitors are suggested to minimize input voltage ripple. An optional high frequency 1 µF ceramic cap can be placed farther away to reduce noise.
- For C_{OUT}, low ESR capacitors such as ceramics are recommended. This reduces output ripple but make sure to account for a DC bias derating when sizing the capacitor. C0G, X7R or X5R dielectrics are recommended as they are stable across a larger temperature range than others.
- The R_{ENT} & R_{ENB} circuit ensures robustness and prevents early turn on of the IC as the main supply voltage ramps up. If the supply voltage should rise and fall at the UVLO voltage then the LMZ23605's output may droop. Digital loads such as FPGAs are highly sensitive to this and a monotonic rise.
- For further details refer to the Design Documentation section



Design Documentation

- Datasheets for: LMZ23605 and LMZ23603
- AN-2085: LMZ2360x / LMZ2200x Evaluation Board
- AN-2125: LMZ23605 Demonstration Board

Component Values (BOM)

Common Components across all designs

C_{IN}	C_{OUT}	C_{SS}	R_{SN}	R_{ENT}	R_{ENB}	R_{ENH}
10 µF, X7R, 50V	100 µF, X7R, 6.3V	0.47 µF, X7R, 16V	1.5 kΩ	42.2 kΩ	12.7 kΩ	100Ω

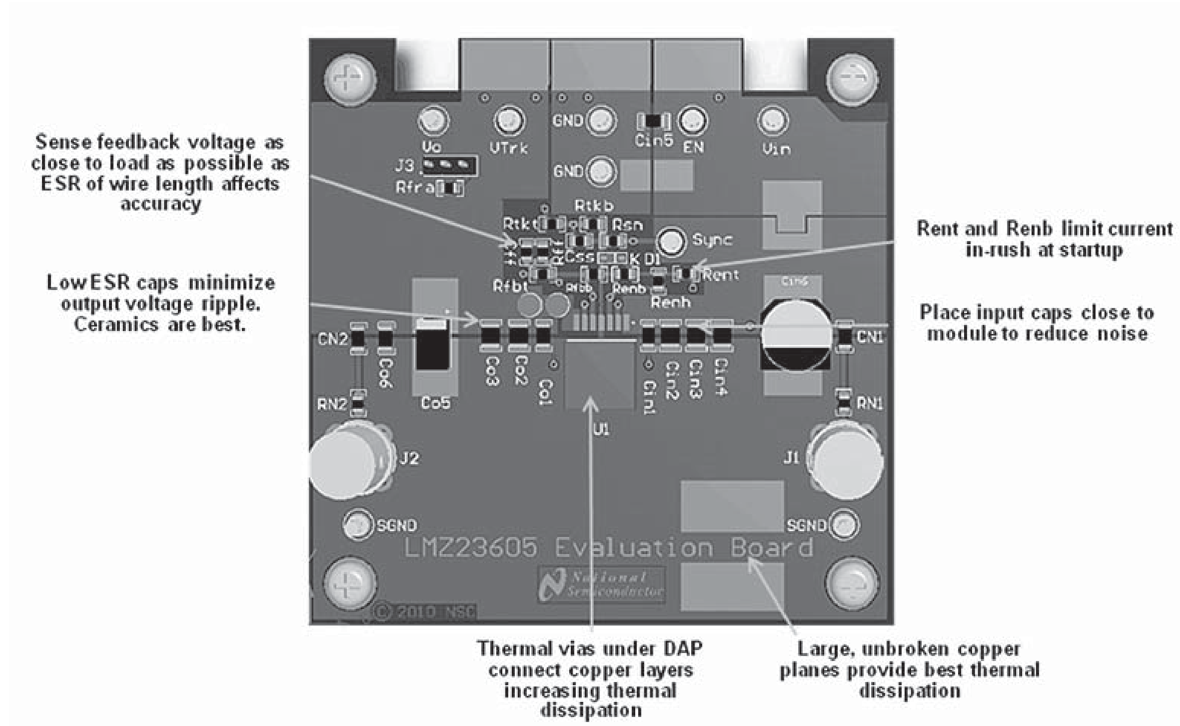
Common Components across all designs

C_{IN} (opt)	C_{OUT} (opt)	R_{FRA} (opt)	D1 (opt)
150 µF, CAP, AL, 50V	220 µF, SP-CAP, 6.3V	23.7Ω	0.5W, 5.1V

Design-specific components

V_{IN}	V_{OUT}	R_{FBT}	R_{FBB}
10 to 36V	6V	15.4 kΩ	2.37 kΩ
9 to 36V	5V	5.62 kΩ	1.07 kΩ
7 to 36V	3.3V	3.32 kΩ	1.07 kΩ
6 to 36V	2.5V	2.26 kΩ	1.07 kΩ
6 to 36V	1.8V	1.87 kΩ	1.5 kΩ
6 to 36V	1.5V	1.00 kΩ	1.13 kΩ
6 to 36V	1.2V	1.07 kΩ	2.05 kΩ
6 to 36V	1.0V	1.62 kΩ	6.49 kΩ
6 to 36V	0.8V	0	8.06 kΩ

LMZ23605 PCB Design



PCB effects on Thermal Performance

The SIMPLE SWITCHER power module's TO-PMOD7 package is very effective at heat transfer and PCB design has a great impact on the overall thermal performance of the device. Commonly referred to as θ_{JA}, this measures the device's temperature rise for a given power dissipation. Below are suggestions to follow when designing your PCB. For more details please refer to the datasheet and suggested further reading provided at the end.

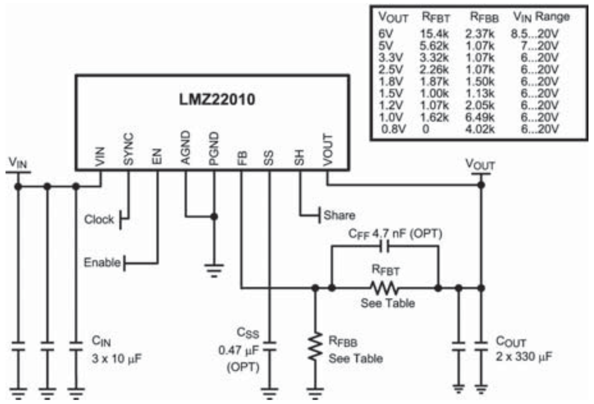
- Solder the package's exposed pad DAP to ground plane
- Use copper planes with a 2-ounce copper weight
- Connect the copper planes with thermal vias
- Larger unbroken PCB area provide better thermal dissipation

Suggested Further Reading

- AN-2026: The effect of PCB Design on the Thermal Performance of SIMPLE SWITCHER Power Module
- AN-2020: Thermal Design by Insight, Not Hindsight
- AN-2078: PCB Layout For National Semiconductor's SIMPLE SWITCHER Power Module
- AN-2085: LMZ2360x / LMZ2200x Evaluation Board
- AN-2125: LMZ23605 Demonstration Board

Design Considerations

- The C_{IN} input capacitor supplies the instantaneous current demands of the IC and must be sized to satisfy the input ripple current requirement. Low ESR or ceramic capacitors are suggested to minimize input voltage ripple. An optional high frequency 1µF ceramic cap can be placed farther away to reduce noise.
- For C_{OUT}, low ESR capacitors such as Poscap or SP caps are recommended. This reduces output ripple but make sure to account for a DC bias derating when sizing the capacitor.
- The R_{ENT} & R_{ENB} circuit ensures robustness and prevents early turn on of the IC as the main supply voltage ramps up. If the supply voltage should rise and fall at the UVLO voltage then the LMZ22008/10's output may droop. Digital loads such as FPGAs are highly sensitive to this and a monotonic rise.
- For further details refer to the Design Documentation section



Design Documentation

- Datasheets for: LMZ22010 and LMZ22008
- AN-2093: LMZ236xx / LMZ20xx Evaluation Board

Component Values (BOM)

Common Components across all designs

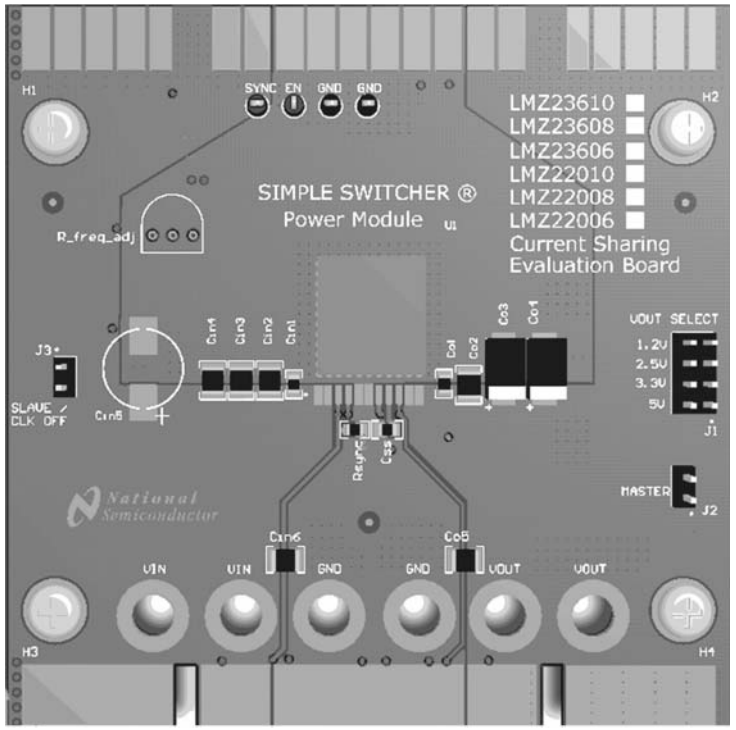
C_{IN}	C_{OUT}	C_{SS}	R_{SN}	R_{ENT}	R_{ENB}	R_{ENH}
3 x 10uF, 50V	2 x 330uF, 6.3V	0.47uF, 16V	1.5K	42.2K	12.7K	NA

Common Components across all designs

C_{IN} (opt)	C_{OUT}(opt)	D1 (opt)
150 µF, CAP, AL, 50V	2 x 47uF, 10V	5.1V, 0.5W

Design-specific components

V_{IN}	V_{OUT}	R_{FBT}	R_{FBB}
8.5 to 20V	6V	15.4 kΩ	2.37 kΩ
7 to 20V	5V	5.62 kΩ	1.07 kΩ
6 to 20V	3.3V	3.32 kΩ	1.07 kΩ
6 to 20V	2.5V	2.26 kΩ	1.07 kΩ
6 to 20V	1.8V	1.87 kΩ	1.5 kΩ
6 to 20V	1.5V	1.00 kΩ	1.13 kΩ
6 to 20V	1.2V	1.07 kΩ	2.05 kΩ
6 to 20V	1.0V	1.62 kΩ	6.49 kΩ
6 to 20V	0.8V	0	4.02 kΩ



PCB effects on Thermal Performance

The SIMPLE SWITCHER Power Module's TO-PMOD11 package is very effective at heat transfer and PCB design has a great impact on the overall thermal performance of the device. Commonly referred to as θ_{JA}, this measures the device's temperature rise for a given power dissipation. Below are suggestions to follow when designing your PCB. For more details please refer to the datasheet and suggested further reading provided at the end.

- Solder the package's exposed pad DAP to ground plane
- Use copper planes with a 2-ounce copper weight
- Connect the copper planes with thermal vias
- Larger unbroken PCB area provide better thermal dissipation

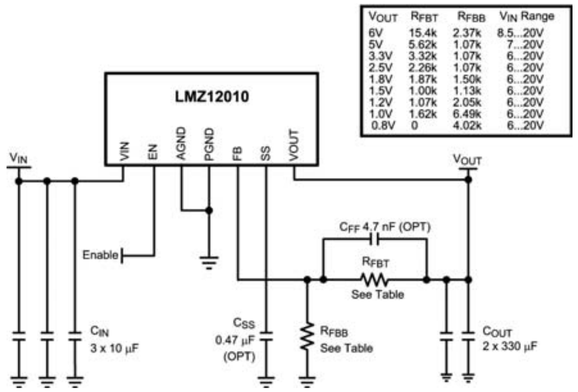
Suggested Further Reading

- AN-2026: The effect of PCB Design on the Thermal Performance of SIMPLE SWITCHER Power Module
- AN-2020: Thermal Design by Insight, Not Hindsight
- AN-2078: PCB Layout For National Semiconductor's SIMPLE SWITCHER Power Module
- AN-2093: LMZ236xx / LMZ20xx Evaluation Board

LMZ12008/10 Designs

Design Considerations

- The C_{IN} input capacitor supplies the instantaneous current demands of the IC and must be sized to satisfy the input ripple current requirement. Low ESR or ceramic capacitors are suggested to minimize input voltage ripple. An optional high frequency 1 µF ceramic cap can be placed farther away to reduce noise.
- For C_{OUT}, low ESR capacitors such as Poscap or SP caps are recommended. This reduces output ripple but make sure to account for a DC bias derating when sizing the capacitor.
- The R_{ENT} & R_{ENB} circuit ensures robustness and prevents early turn on of the IC as the main supply voltage ramps up. If the supply voltage should rise and fall at the UVLO voltage then the LMZ12008/10's output may droop. Digital loads such as FPGAs are highly sensitive to this and a monotonic rise.
- For further details refer to the Design Documentation section



Design Documentation

- Datasheets for: LMZ12010 and LMZ12008
- AN-xxxx: LMZ136xx / LMZ10xx Demonstration Board

Component Values (BOM)

Common components across all designs (R_{ENT} and R_{ENB} – On EVB but not required)

C_{IN}	C_{OUT}	C_{SS}	R_{SN}	R_{ENT}	R_{ENB}	R_{ENH}
3 x 10uF, 50V	2 x 330uF, 6.3V	0.47uF, 16V	1.5K	42.2K	12.7K	NA

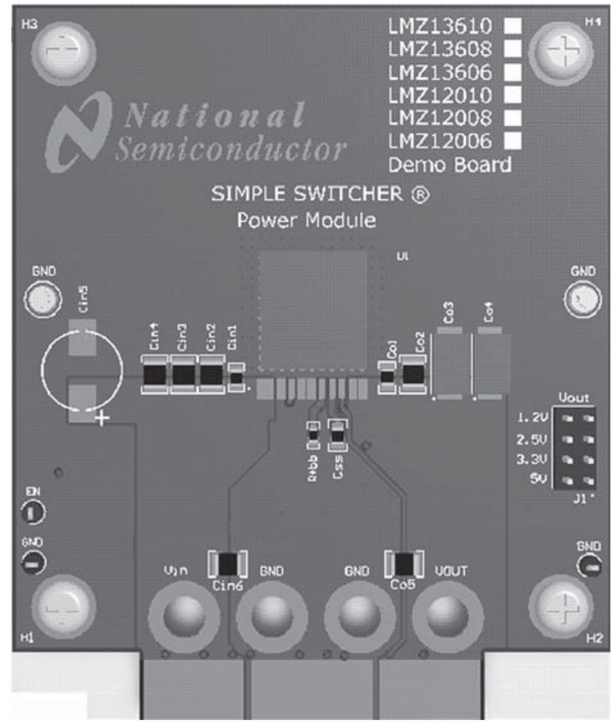
Common Components across all designs

C_{IN} (opt)	C_{OUT} (opt)	R_{FRA} (opt)	D1 (opt)
2 x 0.047uF, 50V	2 x 47uF, 10V	NA	5.1V, 0.5W

Design specific components

V_{IN}	V_{OUT}	R_{FBT}	R_{FBB}
8.5 to 20V	6V	15.4 kΩ	2.37 kΩ
7 to 20V	5V	5.62 kΩ	1.07 kΩ
6 to 20V	3.3V	3.32 kΩ	1.07 kΩ
6 to 20V	2.5V	2.26 kΩ	1.07 kΩ
6 to 20V	1.8V	1.87 kΩ	1.5 kΩ
6 to 20V	1.5V	1.00 kΩ	1.13 kΩ
6 to 20V	1.2V	1.07 kΩ	2.05 kΩ
6 to 20V	1.0V	1.62 kΩ	6.49 kΩ
6 to 20V	0.8V	0	4.02 kΩ

LMZ12008/10 PCB Design



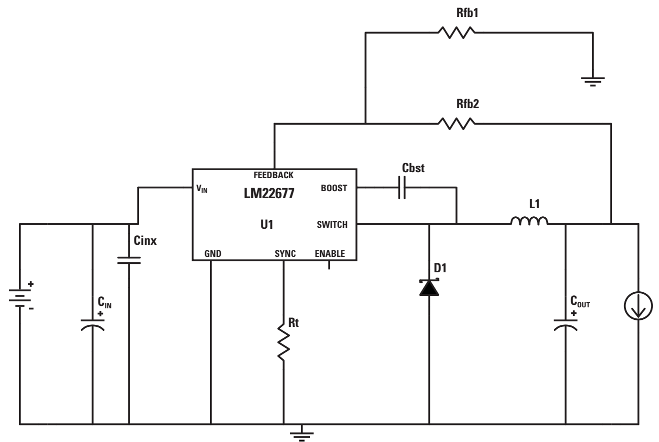
PCB effects on Thermal Performance

The SIMPLE SWITCHER power module's TO-PMOD11 package is very effective at heat transfer and PCB design has a great impact on the overall thermal performance of the device. Commonly referred to as θ_{JA}, this measures the device's temperature rise for a given power dissipation. Below are suggestions to follow when designing your PCB. For more details please refer to the datasheet and suggested further reading provided at the end.

- Solder the package's exposed pad DAP to ground plane
- Use copper planes with a 2-ounce copper weight
- Connect the copper planes with thermal vias
- Larger unbroken PCB area provide better thermal dissipation

Suggested Further Reading

- AN-2026: The effect of PCB Design on the Thermal Performance of SIMPLE SWITCHER Power Module
- AN-2020: Thermal Design by Insight, Not Hindsight
- AN-2078: PCB Layout For National Semiconductor's SIMPLE SWITCHER Power Module
- AN-xxxx: LMZ136xx / LMZ10xx Demonstration Board



Design Considerations/Performance

- The bulk C_{IN} input capacitor supplies the instantaneous current demands of the IC and must be sized to satisfy the input ripple current requirement. Low ESR or ceramic capacitors are suggested to minimize input voltage ripple.
- For C_{OUT}, low ESR capacitors such as ceramics are recommended. This reduces output ripple but make sure to account for a DC bias derating when sizing the capacitor. C0G, X7R or X5R dielectrics are recommended as they are stable across a larger temperature range than others. Higher value capacitors can be placed in parallel to provide bulk capacitance during transient load steps.
- The re-circulating diode, D1, should be a Schottky due to its reverse recovery characteristics and low forward voltage drop. This helps improve efficiency of the converter.
- The schematic and PCB layout shown are for the LM22677 but apply to all LM2267x/LM22680 devices. For BOM component choice using devices other than LM22677 please use the WEBENCH links below to run the designs.
- For further details refer to the Design Documentation section

Component Values (BOM)

The following table summarizes the values chosen for the designs listed here.

Common Components across all designs

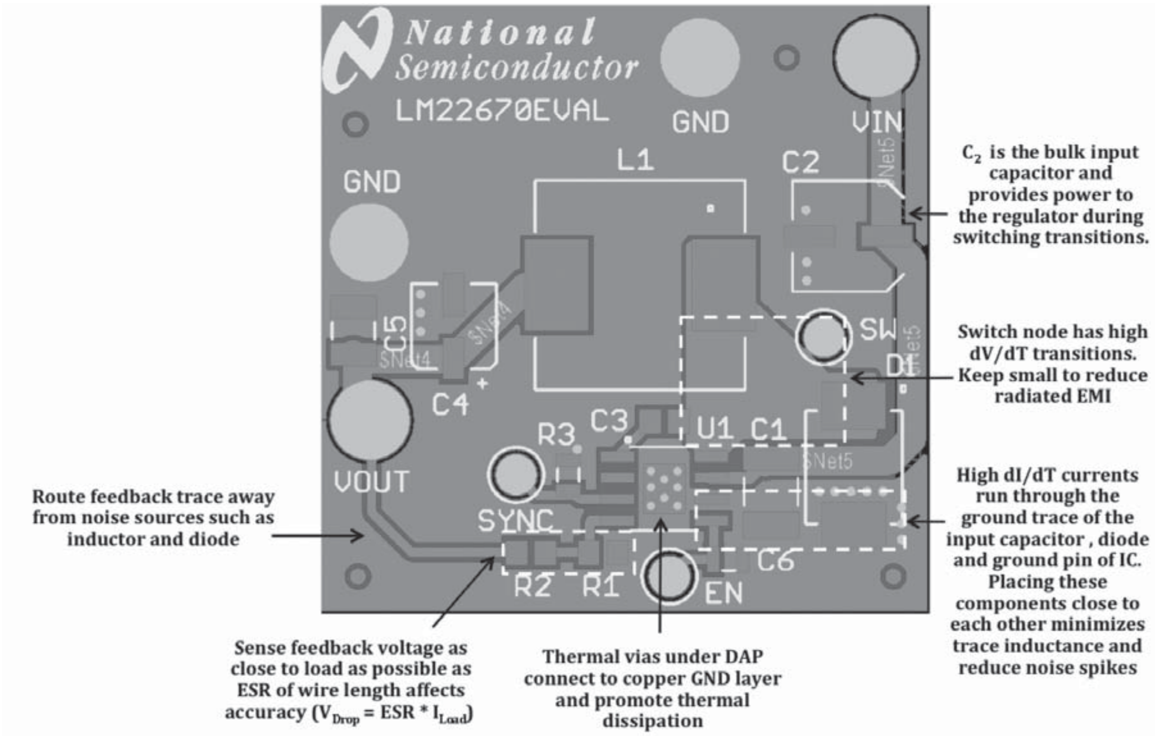
C_{BST}	C_{INX}	D1
10 nF, 50V, X7R	1 uF, 100V, X7R	100V, Schottky Diode

Design-Specific Components

V_{IN}	V_{OUT}	C_{IN}	C_{OUT}	L1	R_{FB1}	R_{FB2}	Rt
4.5 to 42	1.5	150 µF, 200V AL-EI	680 µF, 2.5V AL Polymer	4.7 µH	1 kΩ	169Ω	113 kΩ
4.5 to 42	1.8	150 µF, 200V AL-EI	680 µF, 2.5V AL Polymer	4.7 µH	1 kΩ	402Ω	102 kΩ
4.5 to 42	2.5	150 µF, 200V AL-EI	470 µF, 4V AL Polymer	4.7 µH	1 kΩ	953Ω	82.5 kΩ
4.5 to 42	3.3	68 µF, 200V AL-EI	180 µF, 6.3V AL Polymer	10 µH	1 kΩ	1.58 kΩ	182 kΩ
7 to 42	5	150 µF, 200V AL-EI	68 µF, 10V AL Polymer	10 µH	1 kΩ	2.87 kΩ	100 kΩ
18 to 42	12	100 µF, 250V AL-EI	33 µF, 16V AL-EI	18 µH	1 kΩ	8.45 kΩ	113 kΩ
24 to 42	15	2.2 µF, 100V AL-EI	100 µF, 25V AL-EI	22 µH	1 kΩ	10.7 kΩ	118 kΩ
36 to 42	18	4.7 µF, 100V AL-EI	22 µF, 35V AL-EI	22 µH	1 kΩ	13 kΩ	110 kΩ
36 to 42	24	2.2 µF, 100V AL-EI	100 µF, 35V AL-EI	22 µH	1 kΩ	17.8 kΩ	165 kΩ

Design Documentation

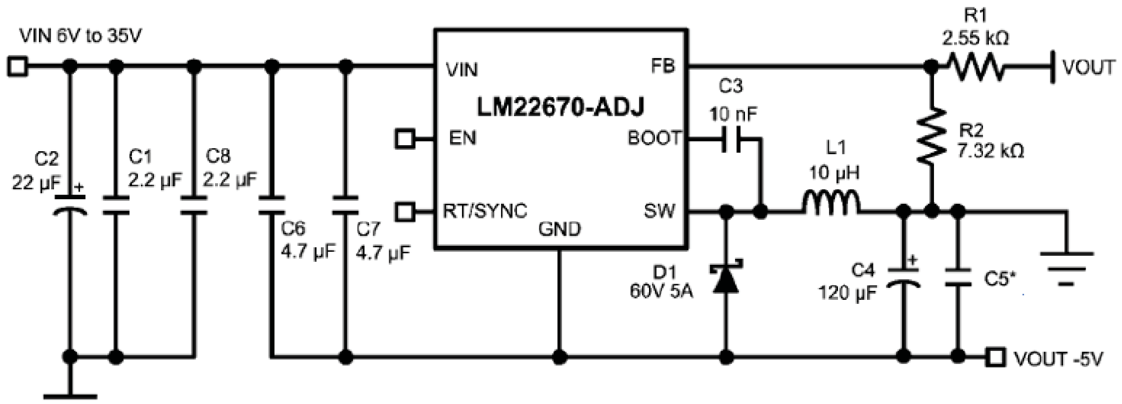
- Datasheets: LM22670, LM22671, LM22672, LM22673, LM22674, LM22675, LM22676, LM22677, LM22678, LM22679, LM22680
- AN2024: LMZ1420x/LMZ1200x Evaluation Board
- AN-1246: Stresses in Wide Input DC-DC Converters



Suggested Further Reading

- AN-1892: LM22677 Evaluation Board
- AN-1891: LM22679 Evaluation Board
- AN-1894: LM22673 Evaluation Board
- AN-1885: LM22670 Evaluation Board
- AN-1911: LM22680 Evaluation Board
- AN-1896: LM22672 Evaluation Board
- AN-1895: LM22671 Evaluation Board
- AN-1229: SIMPLE SWITCHER PCB Layout Guidelines
- AN-1149: Layout Guidelines for Switching Power Supplies
- Online Seminar: PCB Layout for Switchers
- AN-1157: Positive to Negative Buck-Boost converter using LM267x

LM2267x/LM22680 Inverting Buck-Boost Design



* component not populated on LM22670INVEVAL evaluation board

Design Considerations/Performance

- The LM22680 inverting buck-boost schematic shown above is similar to the LM22680 standard buck design but with some critical differences. C6 and C7 are additional capacitors connecting the input to the negative output to provide additional phase margin for stability. The GND pin of the IC is also connected to $-V_{OUT}$ and the feedback pin's references to ground.
- The design presented here can apply to any of the LM2267x/LM22680 family.
- For further details refer to the Design Documentation section.

Design Documentation

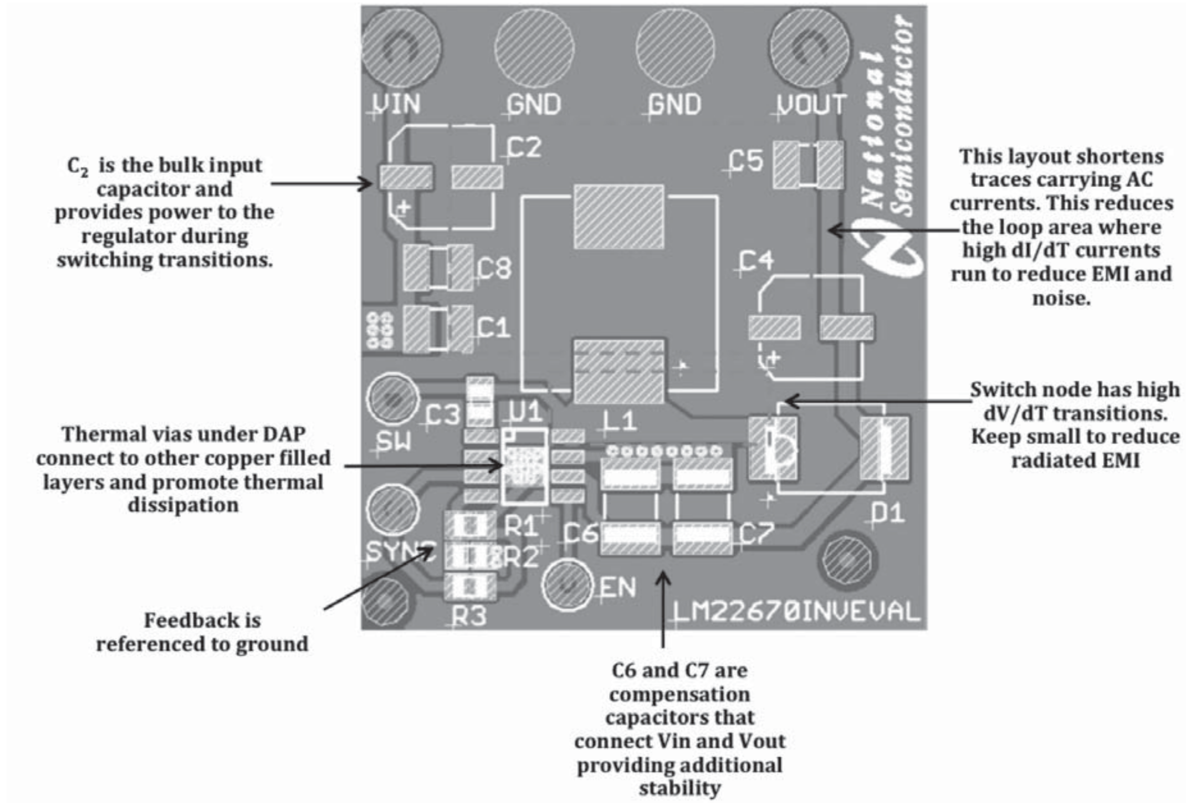
- Datasheets: LM22670, LM22671, LM22672, LM22673, LM22674, LM22675, LM22676, LM22677, LM22678, LM22679, LM22680
- AN-1888: LM22670 Evaluation Board Inverting Topology

Component Values (BOM)

The following table summarizes the values chosen for the designs listed here.

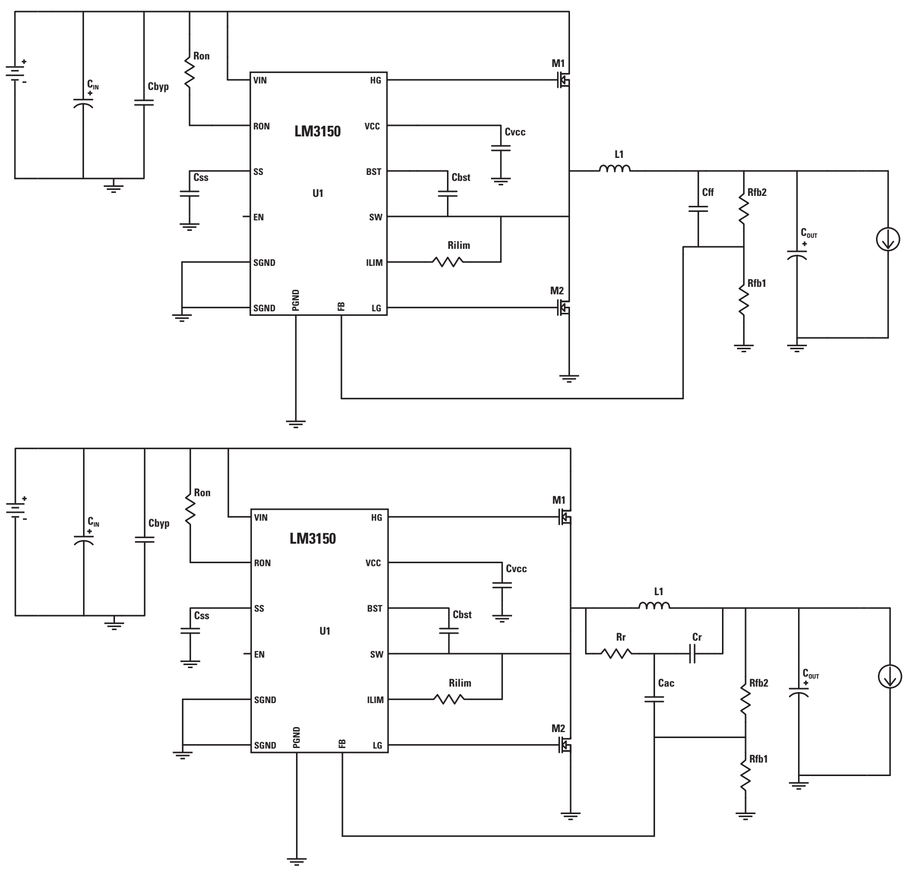
C_{IN1}	C_{IN2}	C_{IN6}	C_{IN7}	C_{IN8}	L1	C_{BOOT3}	C_{OUT4}	R1	R2
2.2 µF 50V, X7R	22 µF, 63V, AL-El	4.7 µF, X7R, 50V	4.7 µF, 50V, X7R	2.2 µF, 50V, X7R	10 µH	10 nF 50V, X7R	120 µF AL Polymer, 6.3V	2.55 kΩ	7.32 kΩ

LM2267x/LM22680 Inverting Buck-Boost PCB Design



Suggested Further Reading

- AN-1888: LM22670 Evaluation Board Inverting Topology and Application Notes
- AN-1229: SIMPLE SWITCHER PCB Layout Guidelines
- AN-1149: Layout Guidelines for Switching Power Supplies
- Online Seminar: PCB Layout for Switchers



Use top schematic for 5V and below. Use bottom schematic for 12V and above.

Design Considerations/Performance

- Two schematics are presented depending on the desired output voltage. The schematic used when the output voltage is 12V or above uses Rr and Cr to generate the necessary ripple voltage while the Cac capacitor AC couples the signal to the feedback pin for proper regulation.
- When selecting M1 and M2, choosing low Rdson FETs is necessary to minimize conduction losses. However, pay attention to the FETs' gate charge (Qg) requirements and the switching frequency to ensure that switching losses does not result in excessive power dissipation.
- The schematic and PCB layout shown are for the LM3150 but apply to all LM315x devices. For BOM component choice using devices other than LM3150 please use the WEBENCH links below to run the designs.
- For further details refer to the Design Documentation section.

Design Documentation

- Datasheet: LM3150, LM3151, LM3152, and LM3153.
- AN1628: Minimizing FET Losses in a High Input Rail Buck Converter
- AN1628: Minimizing FET Losses in a High Input Rail Buck Converter (Chinese)
- AN1481: Controlling Output Ripple and Achieving ESR Independence in COT designs

Component Values (BOM)

The following table summarizes the values chosen for the designs listed here.

Common Components across all designs

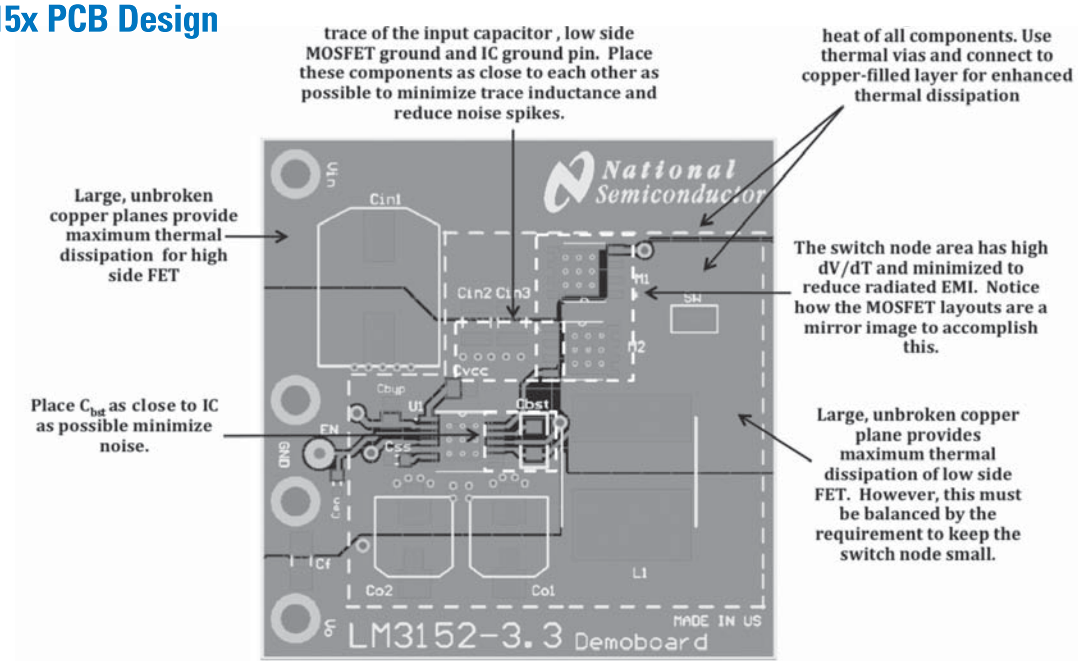
C_{BST}	C_{BYP}	C_{SS}	M1	M2
470 nF, 16V X7R	100 nF, 100V X7R	15 nF, 50V X7R	VdsMax=80V 100A	VdsMax=80V 100A

Design-Specific Components

V_{IN}	V_{OUT}	I_{OUT}	C_{FF}	C_{IN}	C_{OUT}	C_{VCC}	L1	R_{FB1}	R_{FB2}	R_{ILIM}	R_{ON}
6 to 42V	1.2V	5A	2.7 nF, 50V X7R	27.872 μF, 56V	1 mF, 2.5V Tantalum	1 uF, 10V X7R	6 μH	10 kΩ	10 kΩ	2.05 kΩ	51.1 kΩ
6 to 42V	1.5V	5A	2.2 nF 50V X7R	30.126 μF, 56V	680 μF, 4V Tantalum	1 uF, 10V X7R	6 μH	10 kΩ	15 kΩ	2.05 kΩ	59 kΩ
6 to 42V	1.8	5A	1.6 nF, 50V X7R	32.266 μF, 56V	470 μF, 6.3V Tantalum	1 uF, 10V X7R	6 μH	10 kΩ	20 kΩ	2.05 kΩ	66.5 kΩ
6 to 42V	2.5	5A	1.1 nF, 50V X7R	35.746 μF, 56V	330 μF, 6.3V Tantalum	1 uF, 10V X7R	6.8 μH	10 kΩ	31.6 kΩ	2.05 kΩ	78.7 kΩ
6 to 42V	3.3	5A	820 pF, 50V X7R	37.401 μF, 56V	220 μF, 6.3V Tantalum	1 uF, 10V X7R	10 μH	10 kΩ	45.3 kΩ	2.05 kΩ	84.5 kΩ
7 to 42	5	5A	560 pF, 50V X7R	29.742 μF, 50V	68 μF, 20V Tantalum	1 uF, 10V X7R	10 μH	10 kΩ	73.2 kΩ	2.1 kΩ	95.3 kΩ

V_{IN}	V_{OUT}	I_{OUT}	C_{FF}	C_{IN}	C_{OUT}	CV_{CC}	L1	R_{FB1}	R_{FB2}	R_{ILIM}	R_{ON}	R_R	C_R	C_{AC}
20 to 42	12	5A	DNS	2.2 μF, 100V X7R	10 μF, 16V X7R	2.2 μF, 10V X7R	10 μH	10 kΩ	191 kΩ	4.87 kΩ	187 kΩ	4.87 MΩ	180 pF, 50V X7R	560pF, 50V X7R
20 to 42	18	5A	DNS	10 μF, 63V X7R	22 μF, 25V X7R	2.2 μF, 10V X7R	39 μH	9.76 kΩ	287 kΩ	1.91 kΩ	1.02 MΩ	5.9 MΩ	560 pF, 50V X7R	1.8nF, 50V X7R
36 to 42	24	5A	DNS	4.7 μF, 100V X7R	10 μF, 50V X7R	2.2 μF, 10V X7R	18 μH	10 kΩ	392 kΩ	2.05 kΩ	487 kΩ	3.16 MΩ	220 pF, 50V X7R	680pF, 50V X7R
36 to 42	30	5A	DNS	2.2 μF, 100V X7R	10 μF, 50V X7R	2.2 μF, 10V X7R	22 μH	10kΩ	487 kΩ	1.91 kΩ	1.15 MΩ	2.67 MΩ	390 pF, 50V X7R	1.2nF, 100V X7R

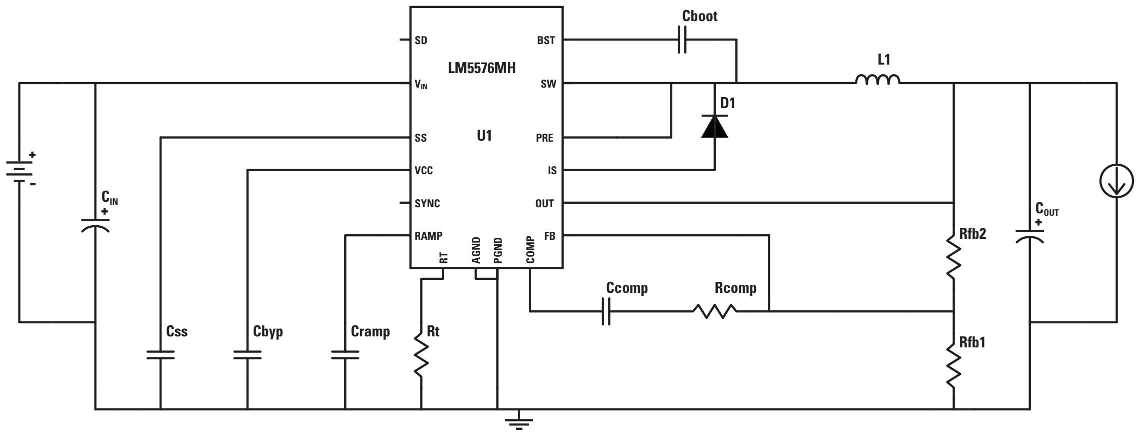
LM315x PCB Design



Suggested Further Reading

- AN-1900: LM3150 Evaluation Boards
- AN-1229: SIMPLE SWITCHER PCB Layout Guidelines
- AN-1149: Layout Guidelines for Switching Power Supplies
- Online Seminar: PCB Layout for Switchers

LM557x Designs



Design Considerations/Performance

- The schematic and PCB layout shown are for the LM5576 but apply to all LM557x devices. For BOM component choice please use the WEBENCH links provided to create the designs.
- For further details refer to the Design Documentation section.

Design Documentation

- Datasheets for: LM5576, LM5575, and LM5574
- AN-1570: LM5576 Evaluation Board
- AN-1569: LM5575 Evaluation Board
- AN-1568: LM5574 Evaluation Board
- Understanding and Applying Current-Mode Control Theory
- Current Mode Modeling – Reference Guide

Component Values (BOM)

The following table summarizes the values chosen for the designs listed here.

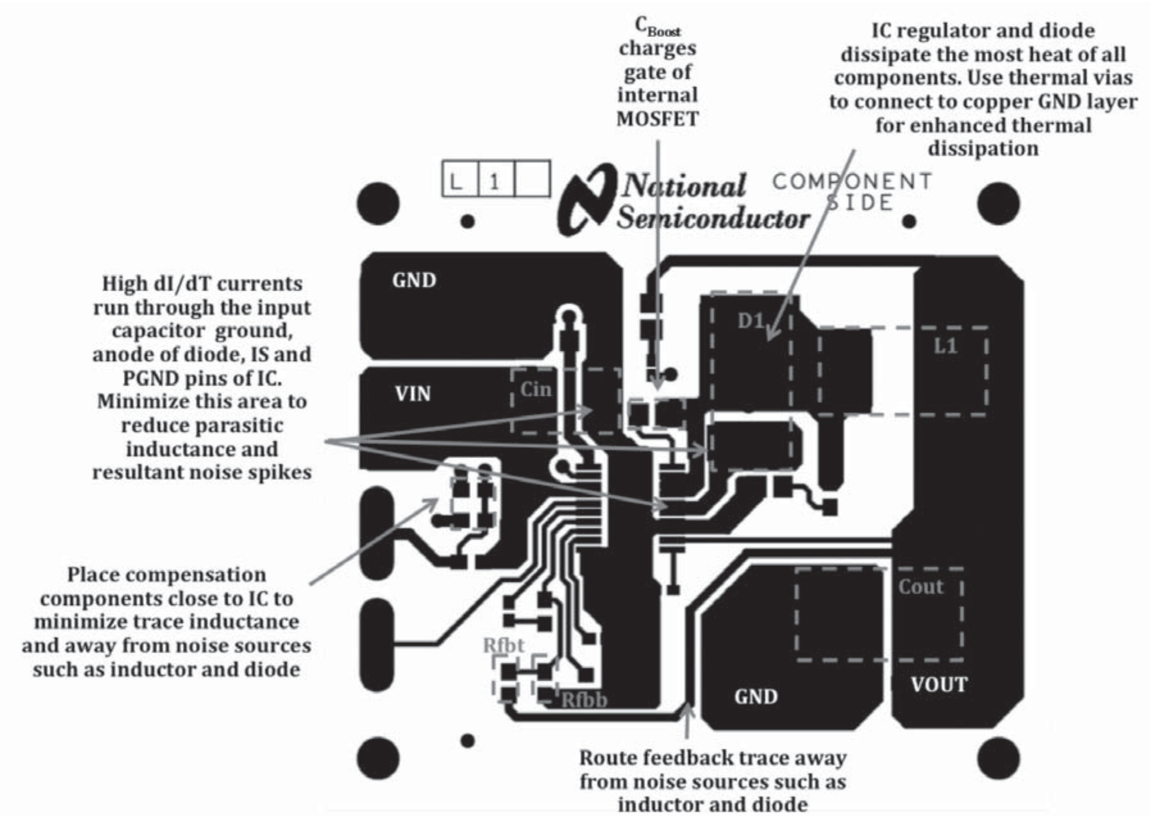
Common Components across all designs

C_{BOOT}	C_{BYP}	C_{SS}	D1
22 nF, X7R, 50V	100 nF, X7R, 25V	10 nF, X7R, 50V	100V, Schottky

Design Specific Components

V_{IN}	V_{OUT}	C_{COMP}	C_{RAMP}	L1	R_{COMP}	C_{COMP2}	C_{IN}	C_{OUT}	C_{RAMP}	R_{FB1}	R_{FB2}	Rt	R_{RAMP}
7V to 75V	1.5V	4.7 nF, X7R, 50V	120 pF, 50V	12 µH	12.44 kΩ	680 pF, X7, 50V	4.7 µF, X7R,100V	680 µF, 2.5V, Tantalum	120 pF, 50V, C0G	1 kΩ	226Ω	24.3 kΩ	Not used
7V to 75V	1.8V	2.2 nF, X7R, 50V	150 pF, 50V	15 µH	23.7 kΩ	560 pF, X7R, 50V	4.7 µF, X7R, 100V	560 µF, 2.5V, AL-Polymer	150 pF, 50V, C0G	1 kΩ	475Ω	21.5 khΩ	Not used
7V to 75V	2.5V	2.7 nF, X7R, 50V	150 pF, 50V	15 µH	21.5 kΩ	270 pF, X7R, 50V	1 µF, X7R,100V	220 µF, 4V, AL-Polymer	150 pF, 50V, C0G	1.02 kΩ	1.05 kΩ	20.5 kΩ	Not used
7V to 75V	3.3V	1.8 nF, X7R, 50V	180 pF, 50V	18 µH	28.7 kΩ	150 pF, C0G, 50V	2.2 µF, X7R,100V	180 µF, 6.3V, AL-Polymer	180 pF, 50V, C0G	1 kΩ	1.69 kΩ	20.5 kΩ	Not used
7V to 75V	5V	2.2 nF, X7R, 50V	330 pF, 50V	33 µH	34 kΩ	82 pF, C0G, 50V	15 µF, X7R,100V	180 µF, 16V, AL-Polymer	330 pF, 50V, X7R	1 kΩ	3.09 kΩ	34 kΩ	Not used
36V to 75V	12V	1.5 nF, X7R, 50V	470 pF, 50V	47 µH	36.5 kΩ	Not used	1 µF, X7R,100V	22 µF, 16V, X5R	470 pF, 50V, X7R	1.02 kΩ	8.87 kΩ	20.5 kΩ	Not used
36V to 75V	15V	330 pF, X7R, 50V	560 pF, 50V	56 µH	158 kΩ	150 pF, C0G,50V	1 µF, X7R,100V	150 µF, 25V, AL-El	560 pF, 50V, X7R	1 kΩ	11.3 kΩ	20.5 kΩ	Not used
36V to 75V	18V	820 pF, X7R, 50V	680 pF, 50V	68 µH	69.8 kΩ	180 pF, C0G, 50V	1 µF, X7R,100V	27 µF, 25V, AL-El	680 pF, 50V, X7R	1 kΩ	13.7 kΩ	20.5 kΩ	110 kΩ
36V to 75V	24V	1 nF, X7R, 50V	1 nF, 50V	100 µH	57.6 kΩ	220 pF, C0G, 50V	1 µF, X7R,100V	33 µF, 35V, AL-El	1 nF, 50V, X7R	1 kΩ	18.7 kΩ	20.5 kΩ	75 kΩ
42V to 75V	30V	470 pF, X7R, 50V	1 nF, 50V	100 µH	124 kΩ	150 pF, C0G, 50V	1 µF, X7R,100V	56 µF, 50V, AL-El	1 nF, 50V, ,X7R	1 kΩ	23.7 kΩ	20.5 kΩ	57.6 kΩ

LM557x PCB Design



Suggested Further Reading

- AN-1570: LM5576 Evaluation Board
- AN-1569: LM5575 Evaluation Board
- AN-1568: LM5574 Evaluation Board
- RD-128 Reference Design Document
- AN-1566: Techniques for Thermal Analysis of Switching Power Supply Designs
- AN-1229: SIMPLE SWITCHER PCB Layout Guidelines
- AN-1149: Layout Guidelines for Switching Power Supplies
- Online Seminar: PCB Layout for Switchers

LMZ1-Series Power Modules

Product ID	Output Current (A) Max.	Input Voltage (V)	Adjustable Output Voltage (V)	Peak Efficiency (%)	Operating Junction Temperature (°C)	Features	EMI EN55022/CISPR22 Class B Certification Radiated	Conducted*	Packaging
LMZ10503/04/05	3/4/5	2.95 to 5.5	0.8 to 5	96	-40 to 125	EN, SS	✔	✔	TO-PMOD-7
LMZ12001/02/03	1/2/3	4.5 to 20	0.8 to 6	92	-40 to 125	EN, SS	✔	✔	TO-PMOD-7
LMZ14201/02/03	1/2/3	6 to 42	0.8 to 6	90	-40 to 125	EN, SS	✔	✔	TO-PMOD-7
LMZ12008/10	8/10	6 to 20	0.8 to 6	92	-40 to 125	EN, SS	✔	✔	TO-PMOD-11
LMZ13608/10	8/10	6 to 36	0.8 to 6	92	-40 to 125	EN, SS	✔	✔	TO-PMOD-11

NEW

Extended Temperature and High Output Voltage Power Modules

Product ID	Output Current (A) Max.	Input Voltage (V)	Adjustable Output Voltage (V)	Peak Efficiency (%)	Operating Junction Temperature (°C)	Features	EMI EN55022/CISPR22 Class B Certification Radiated	Conducted*	Mil Std–883 Testing	Packaging
LMZ10503/04/05EXT	3/4/5	2.95 to 5.5	0.8 to 5	96	-55 to 125	EN, SS	✔	✔	✔	TO-PMOD-7
LMZ12001/02/03EXT	1/2/3	4.5 to 20	0.8 to 6	92	-55 to 125	EN, SS	✔	✔	✔	TO-PMOD-7
LMZ14201/02/03EXT	1/2/3	6 to 42	0.8 to 6	90	-55 to 125	EN, SS	✔	✔	✔	TO-PMOD-7
LMZ14201H/02H/03H	1/2/3	6 to 42	5 to 24	97	-40 to 125	EN, SS	✔	✔	—	TO-PMOD-7

LMZ2-Series Power Modules

Product ID	Output Current (A) Max.	Input Voltage (V)	Adjustable Output Voltage (V)	Operating Junction Temperature (°C)	Features	EMI EN55022/CISPR22 Class B Certification Radiated	Conducted*	Packaging
LMZ22003/5	3/5	6 to 20	0.8 to 5	-40 to 125	EN, SS, Freq Sync	✔	✔	TO-PMOD-7
LMZ23603/5	3/5	6 to 36	0.8 to 6	-40 to 125	EN, SS, Freq Sync	✔	✔	TO-PMOD-7
LMZ22008/10	8/10	6 to 20	0.8 to 6	-40 to 125	EN, SS, Freq Sync, Current Share	✔	✔	TO-PMOD-11
LMZ23608/10	8/10	6 to 36	0.8 to 6	-40 to 125	EN, SS, Freq Sync, Current Share	✔	✔	TO-PMOD-11

NEW

*Additional input filter required

Non-Synchronous Regulators

Product ID	Output Current (A)	Input Voltage (V)	Adjustable Output Voltage (V)	Frequency Range (kHz)	Adj.	On/Off Pin	PWM Mode	Packaging
LM22671/74	0.5	4.5 to 42	1.285 to 37	200 to 1000 Adj	✔/–	✔	Voltage	PSOP-8
LM22672/75	1	4.5 to 42	1.285 to 37	200 to 1000 Adj	✔/–	✔	Voltage	PSOP-8
LM22680	2	4.5 to 42	1.285 to 37	200 to 1000 Adj	✔	✔	Voltage	PSOP-8
LM22670/73/76	3	4.5 to 42	1.285 to 37	200 to 1000 Adj	✔/–/–	–/✔/✔	Voltage	TO263-7 Thin, PSOP-8
LM22677/78/79	5	4.5 to 42	1.285 to 37	200 to 1000 Adj	✔/–/–	✔/✔/–	Voltage	TO263-7 Thin
LM25574	0.5	6 to 42	1.23 to 40	50 to 1000, Sync	✔	✔	Current	TSSOP-16
LM25575	1.5	6 to 42	1.23 to 40	50 to 1000, Sync	✔	✔	Current	eTSSOP-16
LM25576	3	6 to 42	1.23 to 40	50 to 1000, Sync	✔	✔	Current	eTSSOP-20
LM5574	0.5	6 to 75	1.23 to 70	50, Sync	✔	✔	Current	TSSOP-16
LM5575	1.5	6 to 75	1.23 to 70	50, Sync	✔	✔	Current	eTSSOP-16
LM5576	3	6 to 75	1.23 to 70	50, Sync	✔	✔	Current	eTSSOP-20

Synchronous Regulators

Product ID	Output Current (A)	Input Voltage (V)	Adjustable Output Voltage (V)	Frequency Range (kHz)	Sync	PWM Mode	Packaging
LM3103	0.75	4.5 to 42	0.6 to 38	up to 1000 Adj	—	COT	eTSSOP-16
LM3100	1.5	4.5 to 36	0.8 to 32	up to 1000 Adj	—	COT	eTSSOP-20
LM3102	2.5	4.5 to 42	0.8 to 38	up to 1000 Adj	—	COT	eTSSOP-20
LM2852	2	2.85 to 5.5	0.8 to 3.3	500, 1500	—	Voltage Mode	eTSSOP-14
LM2853	3	3 to 5.5	0.8 to 3.3	550	—	Voltage Mode	eTSSOP-14
LM2854	4	2.95 to 5.5	0.8 to 5	500, 1000	—	Voltage Mode	eTSSOP-16

Synchronous Controllers

Product ID	Input Voltage (V)	Output Min (V)	Output Max (V)	Feedback Tolerance (%)	Frequency Range (kHz) and Sync	Packaging
LM3150	6 to 42	0.6	Adj	1.50	up to 1000 Adj	eTSSOP-14
LM3151	6 to 42	3.3	3.3	1.50	250	eTSSOP-14
LM3152	6 to 33	3.3	3.3	1.50	500	eTSSOP-14
LM3153	6 to 18	3.3	3.3	1.50	750	eTSSOP-14

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