# Design Considerations for Powering Industrial Non-Isolated 24V Rail Applications

**SIMPLE SWITCHER Team**

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# Agenda

- Discrete Regulator Design
  - Using WEBENCH for Part Selection
  - Design considerations
  - Selecting inductor, capacitors, and setting Vout
  - Layout example
- Module Design
  - Design considerations from module designer perspective
  - External component selection
  - Layout example
  - Hidden advantages of modules
- TI's Wide $V_{IN}$ DC/DC Step-Down Portfolio for Industry 4.0 Systems

# Discrete Regulator Design

# Design Considerations for a Regulator

- Design Inputs
- Switching frequency
- Inductor selection
- Setting output voltage
- Input and output caps
- Layout guidelines

# Regulator Design Inputs: 24V to 5V Intermediate Bus

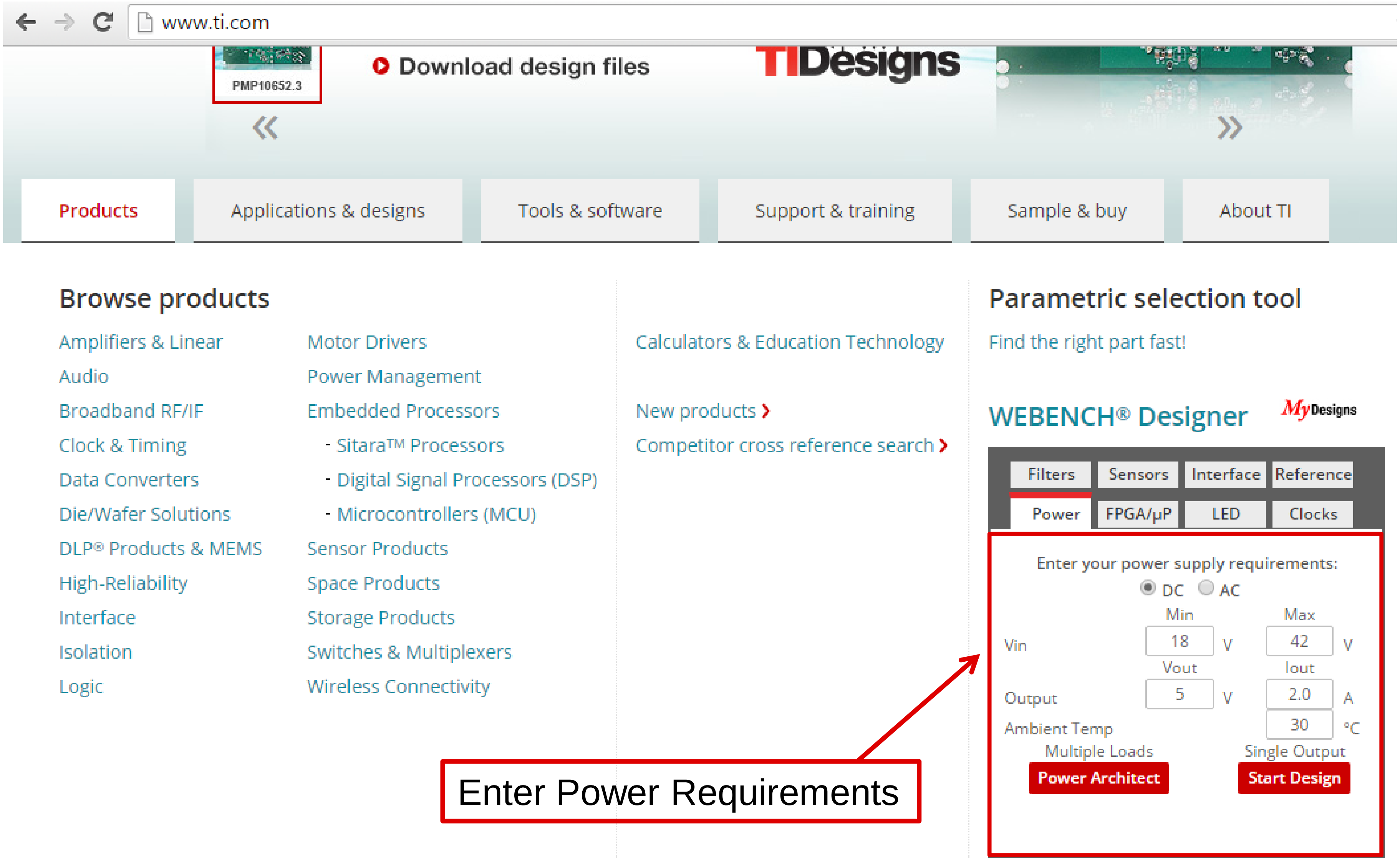
Input Specifications

- Nominal Input Voltage → **24V**
- Input Voltage Range → **18V to 42V**
- Output Voltage → **5V**
- Maximum Load Current → **2A**
- Synchronous Rectification → **Yes**

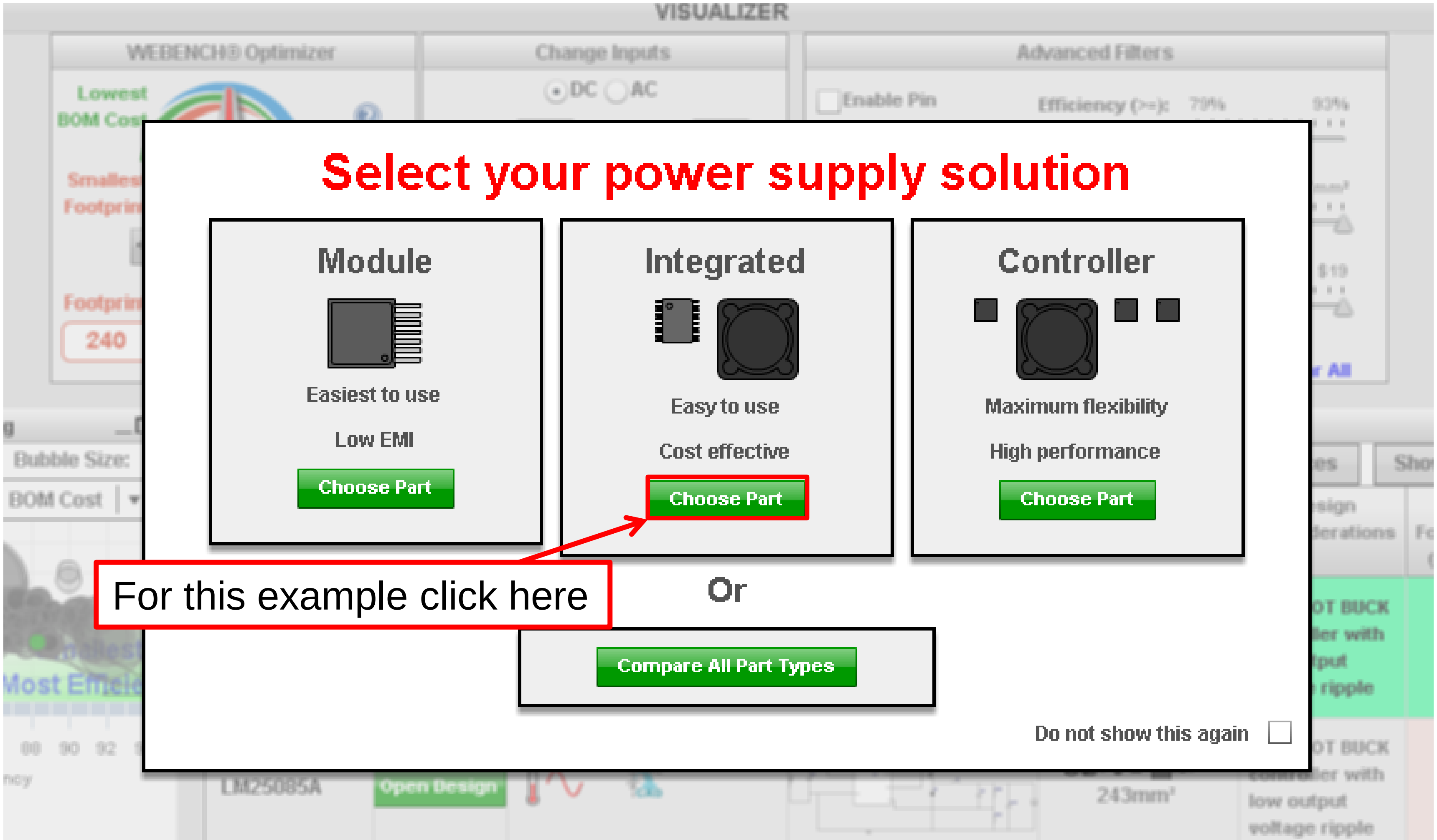
Desired Features

- Frequency Synchronization pin → **Yes**
- Low BOM count “Ease of Use” → **Yes**
- Small Solution Size → **Yes**

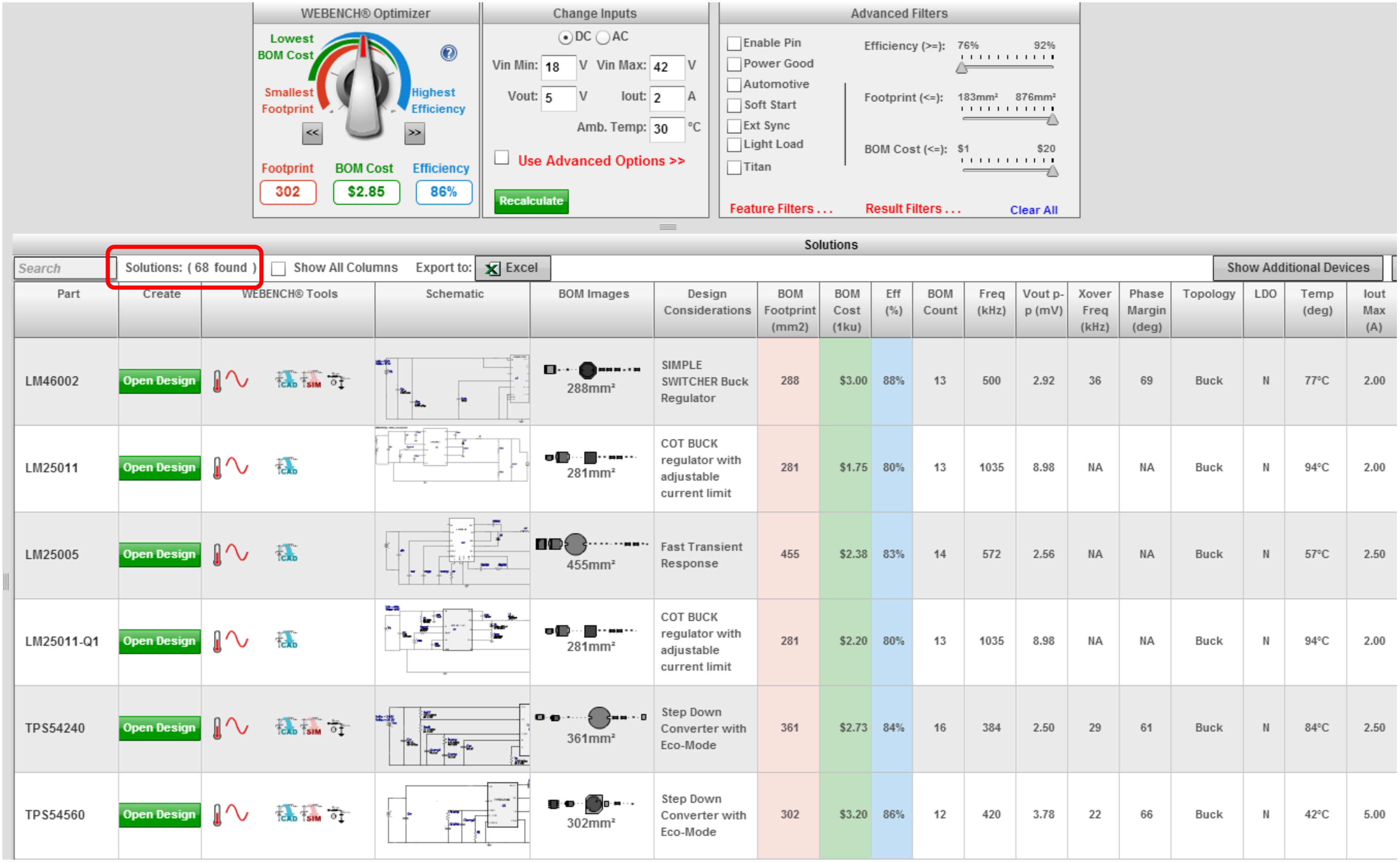
# Access WEBENCH From TI.com



# Select Power Supply Solution

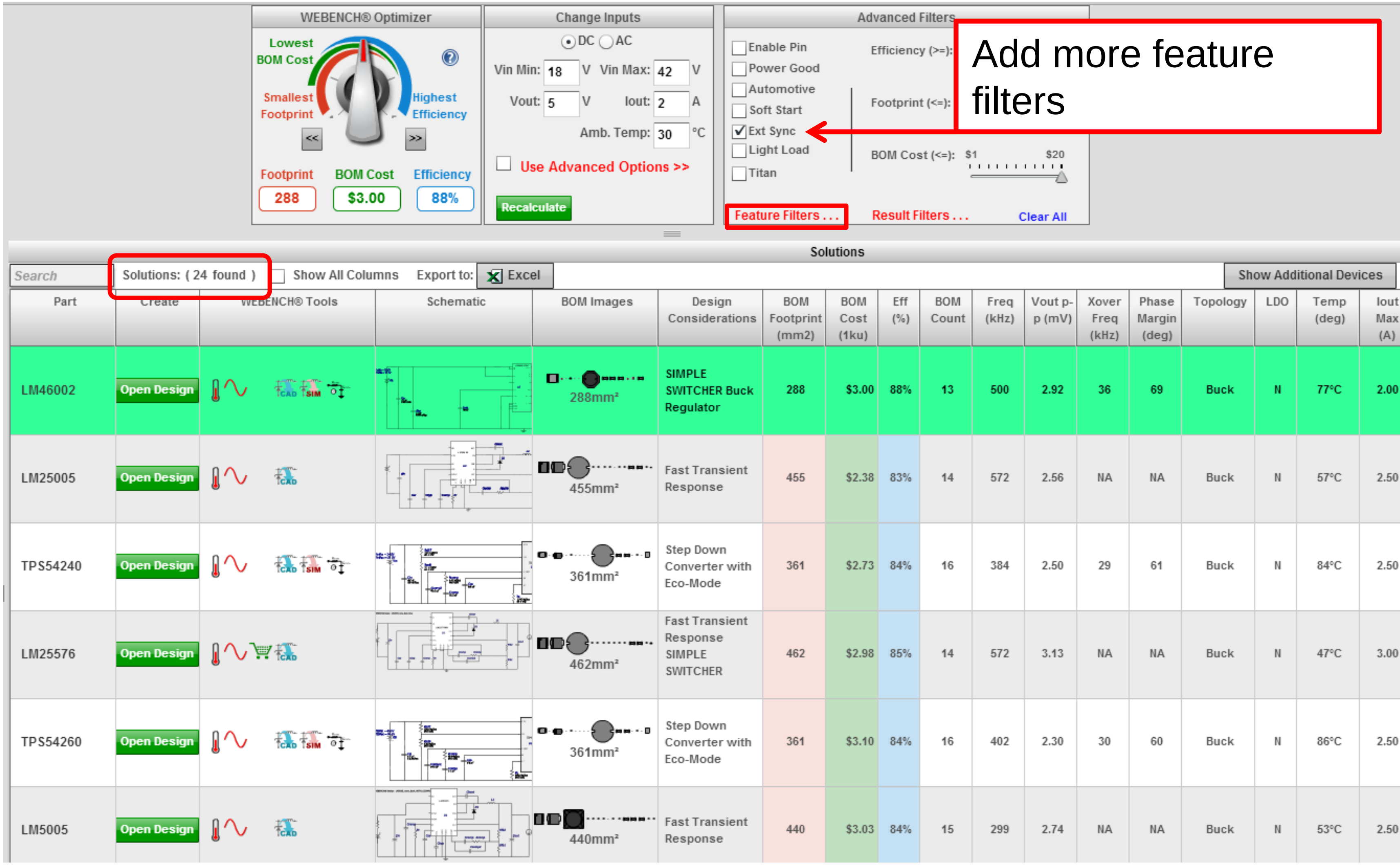


# Initial Device Selection Filter




| Part | Create | WEBENCH® Tools | Schematic | BOM Images | Design Considerations | BOM Footprint (mm2) | BOM Cost (1ku) | Eff (%) | BOM Count | Freq (kHz) | Vout p-p (mV) | Xover Freq (kHz) | Phase Margin (deg) | Topology | LDO | Temp (deg) | Iout Max (A) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LM46002 | Open Design | | | 288mm² | SIMPLE SWITCHER Buck Regulator | 288 | $3.00 | 88% | 13 | 500 | 2.92 | 36 | 69 | Buck | N | 77°C | 2.00 |
| LM25011 | Open Design | | | 281mm² | COT BUCK regulator with adjustable current limit | 281 | $1.75 | 80% | 13 | 1035 | 8.98 | NA | NA | Buck | N | 94°C | 2.00 |
| LM25005 | Open Design | | | 455mm² | Fast Transient Response | 455 | $2.38 | 83% | 14 | 572 | 2.56 | NA | NA | Buck | N | 57°C | 2.50 |
| LM25011-Q1 | Open Design | | | 281mm² | COT BUCK regulator with adjustable current limit | 281 | $2.20 | 80% | 13 | 1035 | 8.98 | NA | NA | Buck | N | 94°C | 2.00 |
| TPS54240 | Open Design | | | 361mm² | Step Down Converter with Eco-Mode | 361 | $2.73 | 84% | 16 | 384 | 2.50 | 29 | 61 | Buck | N | 84°C | 2.50 |
| TPS54560 | Open Design | | | 302mm² | Step Down Converter with Eco-Mode | 302 | $3.20 | 86% | 12 | 420 | 3.78 | 22 | 66 | Buck | N | 42°C | 5.00 |

# Filter results for parts with Ext Sync (frequency sync)

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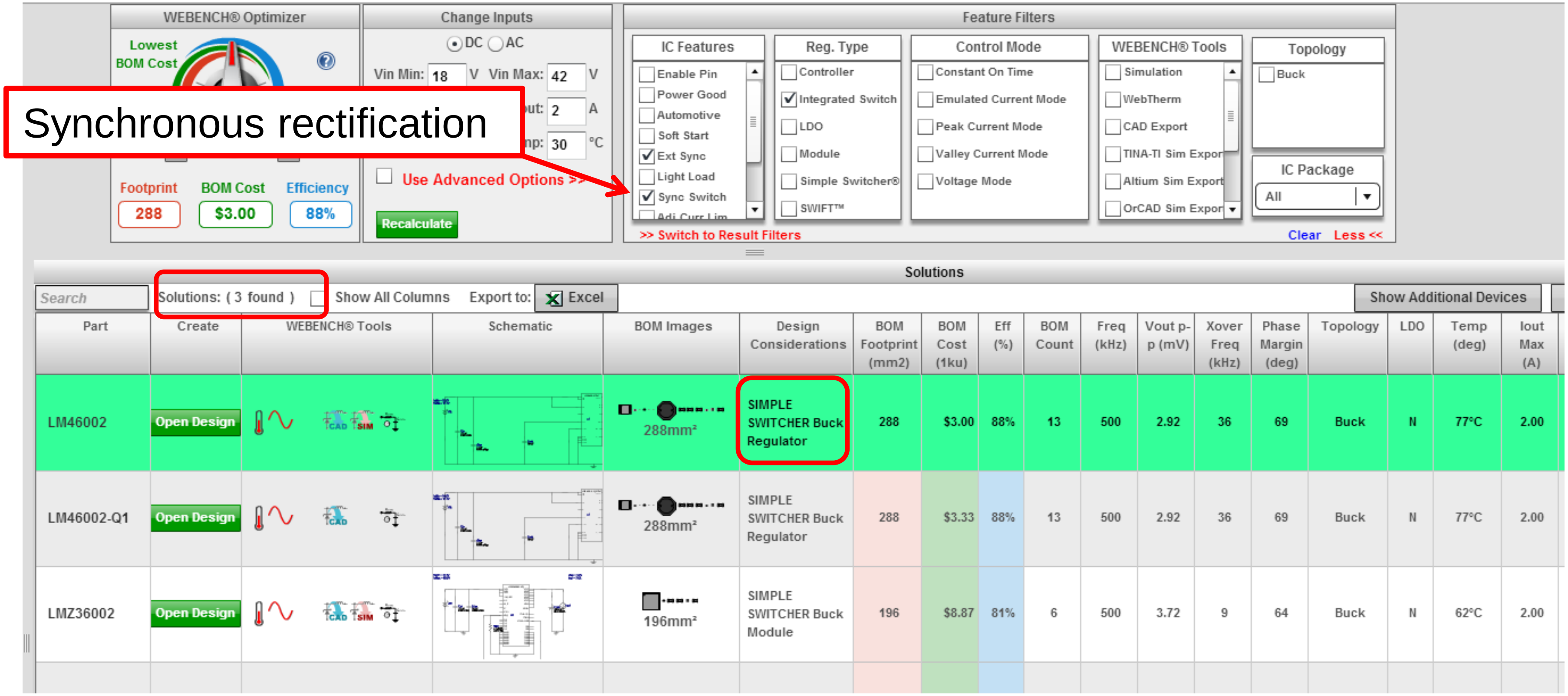
| TPS54240 | Open Design | Step Down Converter with Eco-Mode | 361 | $2.73 | 84% | 16 | 384 | 2.50 | 29 | 61 | Buck | N | 84°C | 2.50 |
| LM25576 | Open Design | Fast Transient Response SIMPLE SWITCHER | 462 | $2.98 | 85% | 14 | 572 | 3.13 | NA | NA | Buck | N | 47°C | 3.00 |
| TPS54260 | Open Design | Step Down Converter with Eco-Mode | 361 | $3.10 | 84% | 16 | 402 | 2.30 | 30 | 60 | Buck | N | 86°C | 2.50 |
| LM5005 | Open Design | Fast Transient Response | 440 | $3.03 | 84% | 15 | 299 | 2.74 | NA | NA | Buck | N | 53°C | 2.50 |

# Filter results for parts with synchronous rectification

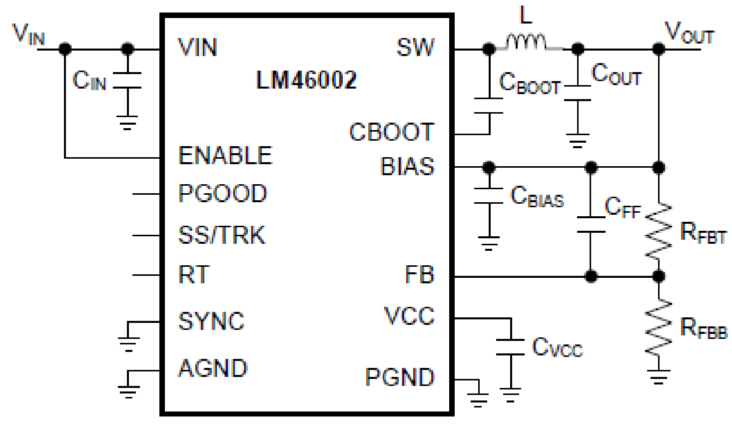



| Part | Create | WEBENCH® Tools | Schematic | BOM Images | Design Considerations | BOM Footprint (mm2) | BOM Cost (1ku) | Eff (%) | BOM Count | Freq (kHz) | Vout p-p (mV) | Xover Freq (kHz) | Phase Margin (deg) | Topology | LDO | Temp (deg) | Iout Max (A) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LM46002 | Open Design | | | 288mm² | SIMPLE SWITCHER Buck Regulator | 288 | $3.00 | 88% | 13 | 500 | 2.92 | 36 | 69 | Buck | N | 77°C | 2.00 |
| LM46002-Q1 | Open Design | | | 288mm² | SIMPLE SWITCHER Buck Regulator | 288 | $3.33 | 88% | 13 | 500 | 2.92 | 36 | 69 | Buck | N | 77°C | 2.00 |
| LMZ36002 | Open Design | | | 196mm² | SIMPLE SWITCHER Buck Module | 196 | $8.87 | 81% | 6 | 500 | 3.72 | 9 | 64 | Buck | N | 62°C | 2.00 |

# LM46002 SIMPLE SWITCHER® 3.5 V to 60 V 2 A Synchronous Step-Down Voltage Converter

## 1 Features

- 27 µA Quiescent Current in Regulation
- High Efficiency at Light Load (DCM and PFM)
- Meets EN55022/CISPR 22 EMI standards
- Integrated Synchronous Rectification
- Adjustable Frequency Range: 200 kHz to 2.2 MHz (500 kHz default)
- Frequency Synchronization to External Clock
- Internal Compensation
- Stable with Almost Any Combination of Ceramic, Polymer, Tantalum, and Aluminum Capacitors
- Power-Good Flag
- Soft-Start into Pre-Biased Load
- Internal Soft-Start: 4.1 ms
- Extendable Soft-Start Time by External Capacitor
- Output Voltage Tracking Capability
- Precision Enable to Program System UVLO
- Output Short Circuit Protection with Hiccup Mode
- Over Temperature Thermal Shutdown Protection





## 2 Applications

- Industrial Power Supplies
- Telecommunications Systems
- Sub-AM Band Automotive
- Commercial Vehicle Power Supplies
- General Purpose Wide $V_{IN}$ Regulation
- High Efficiency Point-Of-Load Regulation

# Switching Frequency Selection

- **Size of Inductor**
  - Higher frequency allows for a smaller inductor, both electrically and physically.

$$L \propto \frac{1}{F_S}$$

Switching Frequency

$$L \propto N^2$$

Number of Turns of Wire

  - Higher frequency → Smaller L → Smaller N → Smaller package size

- **Efficiency**
  - Higher switching frequency generates more power loss in regulator and the inductor; this reduces efficiency.

$$\text{Loss in regulator} \propto F_S \cdot T_t \cdot V_{IN} \cdot I_{LOAD}$$

Switching Frequency

  - Higher frequency → Increased Loss → Reduced Efficiency

# Switching Frequency Selection

- **EMI**
  - – Some customers require that no harmonics of the DC/DC converter fall in the AM radio band.
    - Example: 530kHz to 1.7MHz
  - – Some systems require that the switching frequency be locked to a system clock.
    - Use a regulator with a synchronizing capability

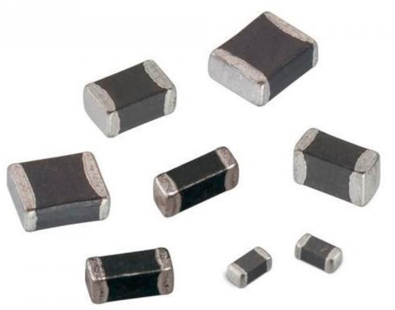
# LM46002 Switching Frequency Selection

- **LM46002 is optimized for a switching frequency of 500kHz**
  - Can be adjusted with one resistor to tailor the regulator to the customer's requirements.
  - Can be synchronized to and external clock or to another DC/DC converter to reduce noise.
- **500 kHz will be used in this example**

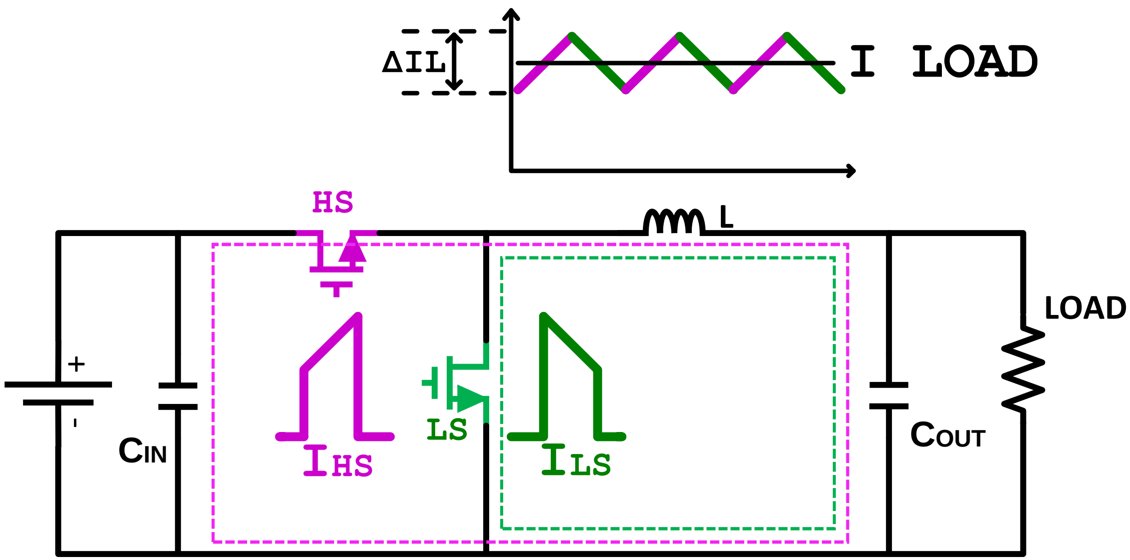
# Inductor Selection

- **Inductor selection is one of the most important aspects of the DC-DC converter design.**

  – Inductor characteristics
    - Inductance value
      – Affects size, ripple, transient response, peak current, efficiency
    - Winding resistance
      – Affects size, ripple, dropout, efficiency
    - Core material
      – Affects size, core power losses
    - Saturation current
      – Affects size, peak current, overload protection
    - Shielding
      – Affects EMI performance



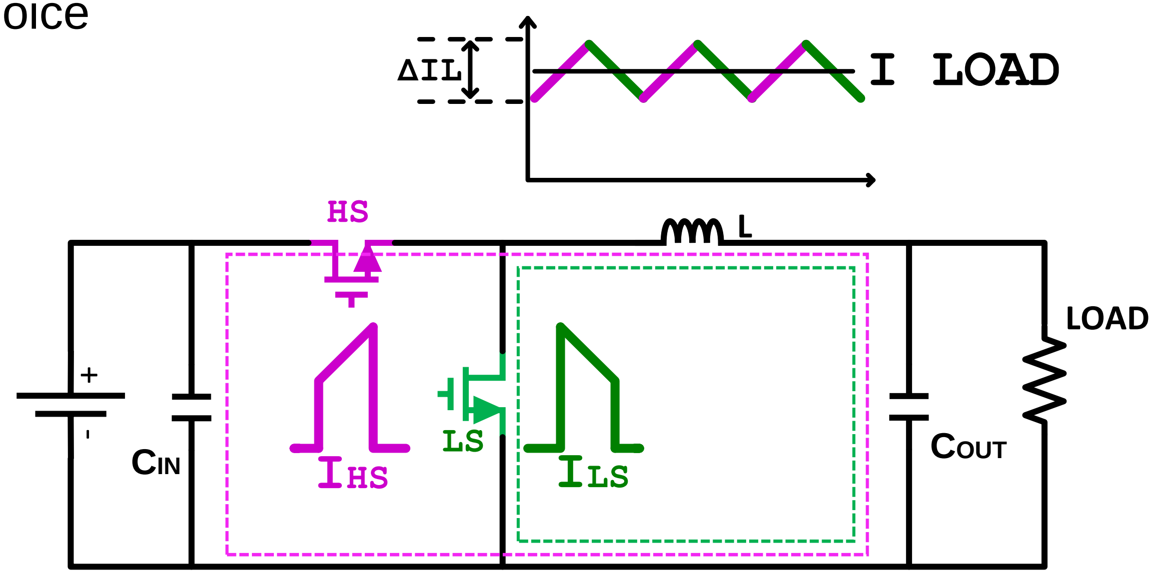
# Inductor Selection




- **Electrical value of inductor**
  - Determines ripple current
    - Smaller inductor → Large ripple current → increased power loss
  - Impacts maximum load current
    - Large ripple current → large peak current → need higher HS current limit to support load
  - Impacts load transient response
    - Small inductance → faster current response → smaller output voltage transient

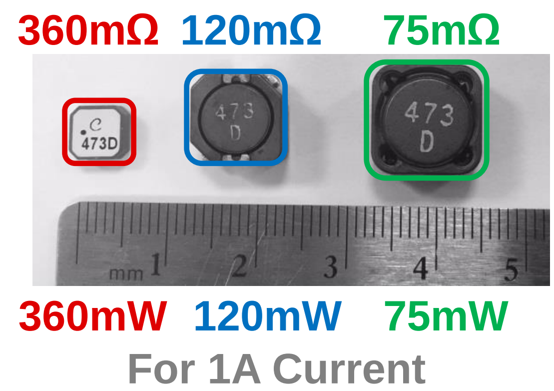
# Inductor Selection

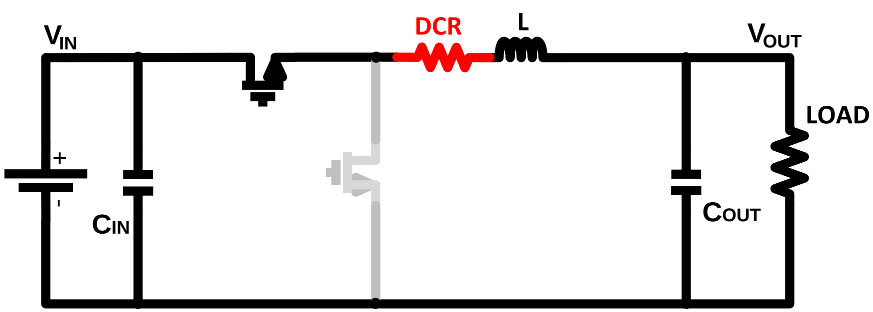
- **Electrical value of inductor (cont.)**
  - Impacts physical size
    - Larger inductance → more turns on winding → larger package → higher winding resistance
- **Select inductor ripple current**
    - ~30% of maximum load current is good compromise for the ripple current choice

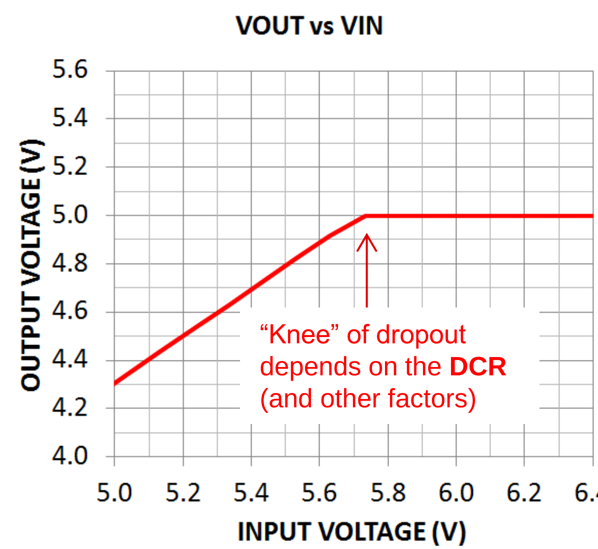


# Inductor Selection

- **Winding resistance**
  - Resistance causes power loss ($I^2 \cdot R$)
    - Small resistance → less loss → larger wire → larger package
  - Impacts PCB temperature
    - Increased loss → more heat to dissipate → higher PCB temperature
  - Affects regulator drop-out performance
    - Resistance causes voltage drops between input and output
      - Larger resistance → more headroom between input and output needed for regulation.

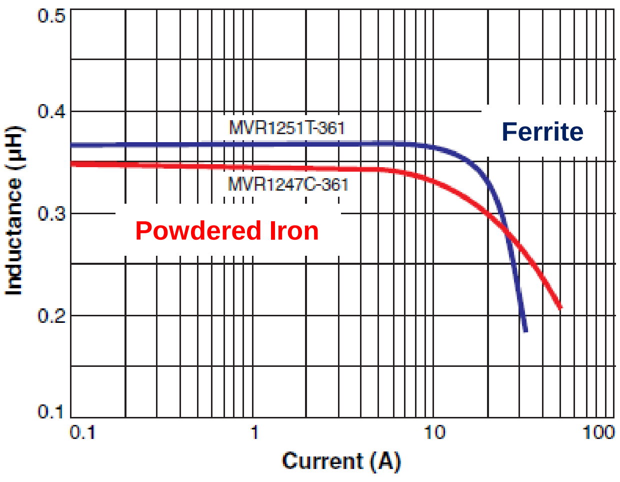


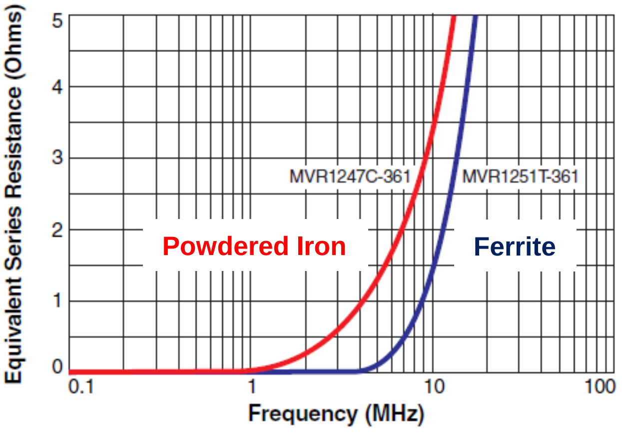



# Inductor Selection

- **Core Material**
  - Ferrite core
    - Air gap causes “hard” saturation
      - Inductance falls very quickly with current, once the saturation value is reached
    - Small A.C. core loss at >1MHz
  - Powdered iron core
    - Air gap is “distributed”; saturation is “soft”
      - Inductance falls slowly with current, once saturation value is reached
        - » More tolerant of overloads
    - Large A.C. core loss at >1MHz



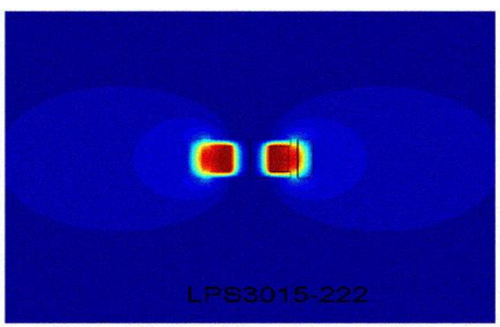
# Inductor Selection

- **Saturation current**
  - Maximum current before inductance drops dramatically
    - Core saturation → air core inductor → very small inductance
  - Very small inductance can damage regulator and other components
    - Small inductance means high current slew rate
      - Protection circuits may not respond fast enough to protect the system
  - Select inductor saturation current based on regulator current limit
  - For a “hard” saturating inductor
    - Select a saturation current ≥ maximum regulator current limit
  - For a “soft” saturating inductor
    - Select a saturation current ≥ typical regulator current limit
  - Impacts physical size
    - Higher current → larger wire in winding → larger package
- **Avoid inductor saturation**

# Inductor Selection

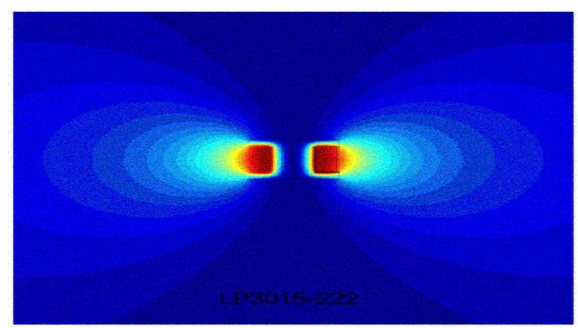
## Shielded Inductor 

- Helps to reduce EMI
  - Reduced external magnetic field
- More core material used for shield
  - More A.C. core loss
  - More expensive
  - Physically larger




## Un-shielded Inductor 

- Large external magnetic field
  - May be issue for some systems
- Minimum amount of core material needed
  - Less A.C. core loss
  - Less expensive
  - Physically smaller



# Inductor Selection w/ LM46002

- Application Inputs
  - $F_s$ = 500kHz
  - $V_{IN}$ = 42V
  - $V_{OUT}$ = 5V
  - $I_{LOAD}$ = 2A
  - Ripple current = ΔI = 0.3·2A = 0.6A

- Inductor value

$$L = \frac{(V_{IN} - V_{OUT})}{\Delta I \cdot F_S} \cdot \frac{V_{OUT}}{V_{IN}} = \frac{(42-5)}{0.6 \cdot 500e^3} \cdot \frac{5}{42} = 14.7\mu H$$

  - Use the next closest standard value → 15µH



TEXAS INSTRUMENTS

# Inductor Selection w/ LM46002 (cont.)

- Check currents over full input voltage range at full load

| Input Voltage | Ripple Current | Valley Current | Peak Current |
|---|---|---|---|
| 18V | 0.48A | 1.76A | 2.24A |
| 24V | 0.53A | 1.74A | 2.26A |
| 42V | 0.59A | 1.71A | 2.29A |

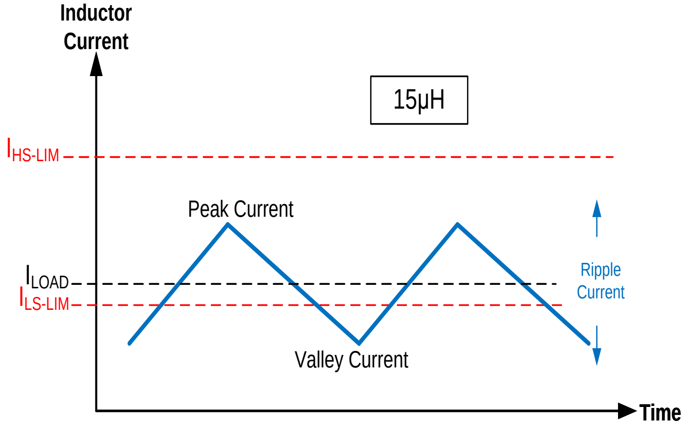
$$\Delta I = \frac{(V_{IN} - V_{OUT})}{L \cdot F_S} \cdot \frac{V_{OUT}}{V_{IN}}$$

$$I_{VALLEY} = I_{LOAD} - \frac{\Delta I}{2}$$

$$I_{PEAK} = I_{LOAD} + \frac{\Delta I}{2}$$

# Inductor Selection w/ LM46002 (cont.)

- The peak and valley current should be checked against the IC current limit specs. The LM46002 provides both peak and valley current limit protection




- The maximum peak inductor current must be less than the minimum specified high-side current limit of the LM46002
  - From data sheet → $I_{HS\text{-}LIMIT}$ = **3.6A** (min)
  - Peak current in application → **2.29A** (max)

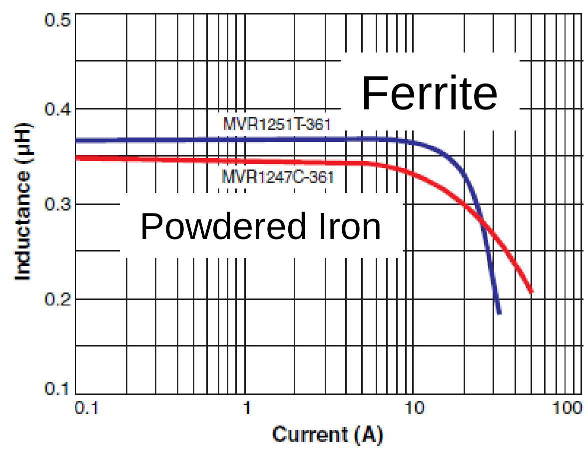
- The maximum valley inductor current must be less than the minimum specified low-side current limit of the LM46002
  - From data sheet → $I_{LS\text{-}LIMIT}$ = **1.8A** (min)
  - Valley current in application → **1.76A** (max)

# Inductor Selection w/ LM46002 (cont.)

- The inductor current rating selection depends on its saturation characteristics
  - A "hard" saturating ferrite inductor should be rated for the maximum peak current limit
  - A "soft" saturating powdered iron inductor can be rated for the typical peak current limit, or somewhat less.

- For a ferrite inductor select an conservative current rating
  - From LM46002 data sheet → $I_{HS\text{-}LIMIT}$ = **5A** (max)
  - Use inductor with **5A** saturation current

- For a powdered iron inductor the current rating can be smaller
  - Inductance will not fall much when saturation current is reached
  - Use inductor with **3A** saturation current



# Setting output voltage of LM46002

- From Webench Design Tool
  - Feedback divider
    - $R_{FBT} = 1M\Omega$
    - $V_{FB} = 1.011V$

$$R_{FBB} = \frac{V_{FB}}{V_{OUT} - V_{FB}} \cdot R_{FBT} = \frac{1.011}{5 - 1.011} \cdot 1M\Omega = 253k \quad \Rightarrow \quad R_{FBB} = 255k$$

  - Feed-forward Capacitor
    - Can improve load transients and phase margin
    - Easily tailored by customer
      - $C_{FF} = 27pF$

# Input and Output Capacitors w/ LM46002

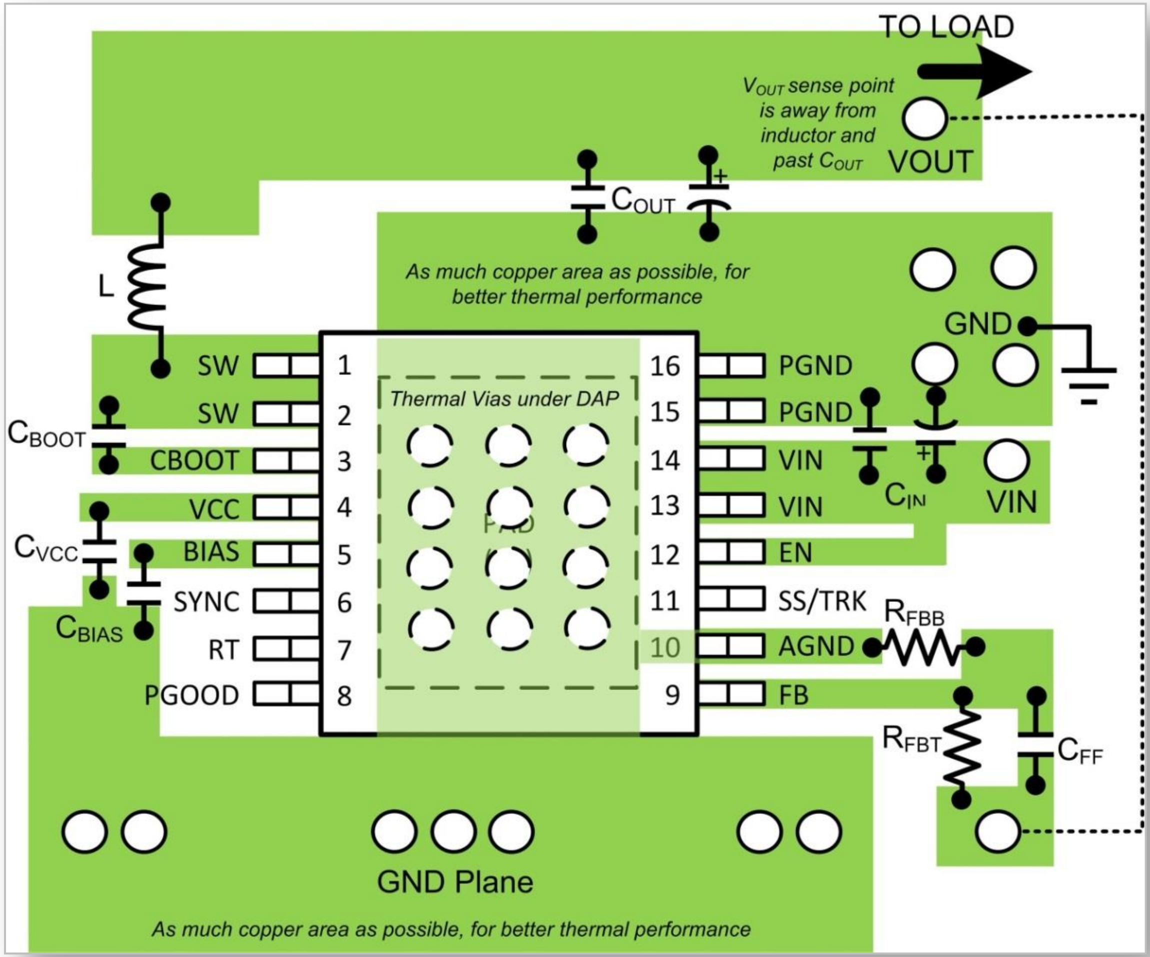
- From Webench Design Tool

  - Input Capacitor(s)
    - Supply pulse currents to regulator
    - Ensure low impedance input for control circuits
      - **$C_{IN}$ = 1x 1µF  and 1x 4.7µF,  Ceramic**

  - Output Capacitor(s)
    - Value based on:
      - Output voltage ripple (depends on inductor current ripple)
      - Load transient response

    - **$C_{OUT}$ = 3x 22µF,  Ceramic**

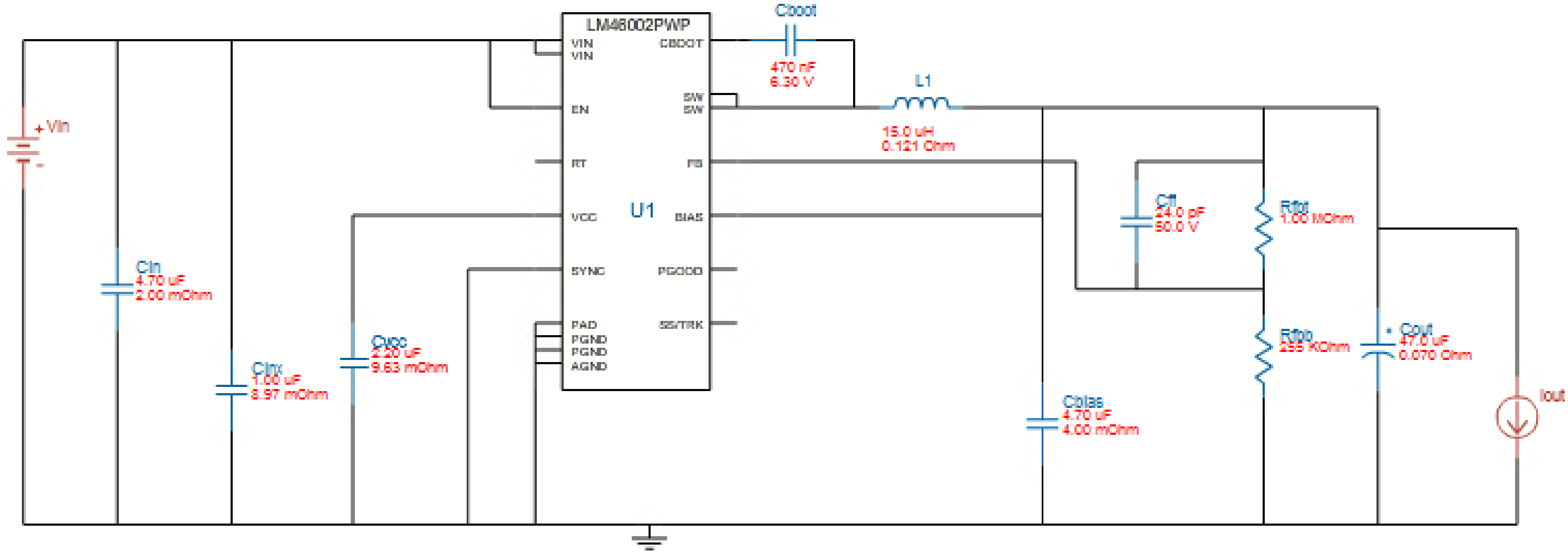
# PCB Layout for example for LM46002 (regulator)




## Minimum Best Practices for IC Layout

- ✓ **Place CIN very close to LM46002 input and ground pin. Grounding for both input/output caps should consist of localized top side planes that connect to the ground pins and PAD**
- ✓ **Make VIN and ground connections as wide as possible**
- ✓ **Both feedback resistors should be located close to the FB pin**
- ✓ **Use a ground plane in one of the middle layers as noise shielding and heat dissipation path. Have a single point ground connection to the plane.**

# Application Schematic in WEBENCH




**The schematic (and layout!) can be exported to your favorite CAD tool!**

# Module Design

# Supplier Considerations for Creating a Module

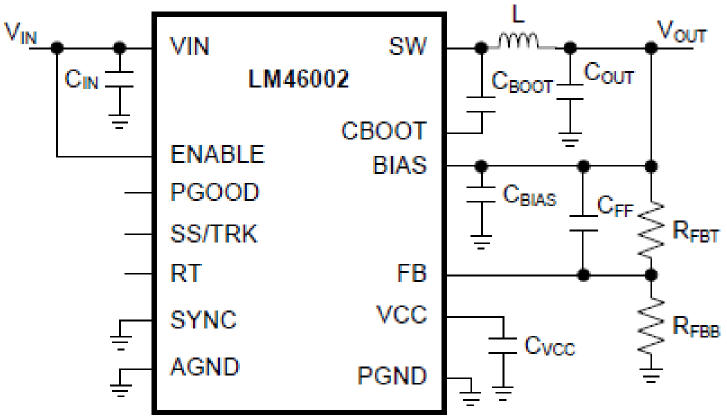
- Design inputs
- Silicon selection
- Package selection
- Internal component selection
  - Inductor
  - Stability components
  - Programming components
- Setting safe operating limits: electrical & thermal specifications
- External component considerations

# Design Inputs

- Support wide input range: 4.5V to 60V
  - Nominal Input Voltage → 24V
  - Input Voltage Range → 18V to 42V
  - Output Voltage → 5V
- Support common output voltages: 2.5V, 3.3V, 5V
- Support output current up to 2A
- Small solution size
- Low EMI (Meet CISPR22 Class B Radiated EMI)
- Provide pin for synchronizing to external frequency
- Low BOM count
- Operate over industrial temperature range (-40C to 105C Ambient)

# Silicon Selection

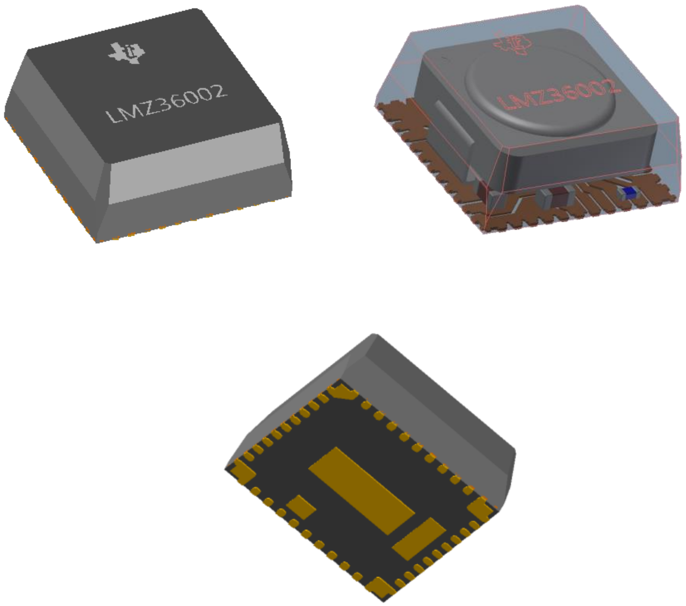
- Selected LM46002 to meet design inputs (surprise!)
  - $V_{IN}$ range **3.5V-60V**
  - $V_{OUT}$ Range **1.0V to 28V**
  - **Synchronous** Peak Current Mode architecture
  - Output current: **2A**
  - Precision Enable
  - Default frequency of 500kHz, Adjustable c Synchronize from **200kHz – 2.2MHz**
  - Power Good output
  - **Internal Compensation**
  - Operating Junction Temperature: **-40 to 125C**



# Package Selection

## Selected BQFN 3D Packaging

- **Better Thermal Efficiency in 40% Smaller Package**
  - 12-13°C/W (BQFN) vs 15.4-24.4°C/W (LGA)
  - Yields up to 50% longer life
- **Access to Signal Pins**
  - Pins on Outside
  - Easy to route Signals, Vias, Power
  - Easy to inspect solder joints
- **High Temp Reflow**
  - BQFN capability for 260°C
  - LGA / BGA <250°C otherwise internal solder can melt and spread thru delaminated areas



# Module Internal Component Selection

- Inductor
  - Single value must cover
    - Input Voltage Range
    - Output Voltage Range
    - Entire Frequency Range
  - Current capability
    - Heating rating
    - Saturation current rating
- Compensation components
  - Stability
  - Transient response
- Integrated Programming Components
  - Bypass caps
  - Compensation
  - Features (soft-start, power good)

# Internal Inductor Selection

$V_{IN}$ = 60V, $F_S$ = 500 kHz

$$L=\frac{(V_{IN}-V_{OUT})}{\Delta I\cdot F_S}\cdot\frac{V_{OUT}}{V_{IN}}=\frac{(60-5)}{0.6\cdot 500e^3}\cdot\frac{5}{60}=15.3\mu H$$

$V_{IN}$ = 60V, $F_S$ = 1 MHz

$$L=\frac{(V_{IN}-V_{OUT})}{\Delta I\cdot F_S}\cdot\frac{V_{OUT}}{V_{IN}}=\frac{(60-5)}{0.6\cdot 1000e^3}\cdot\frac{5}{60}=7.6\mu H$$

$V_{IN}$ = 12V, $F_S$ = 500 kHz

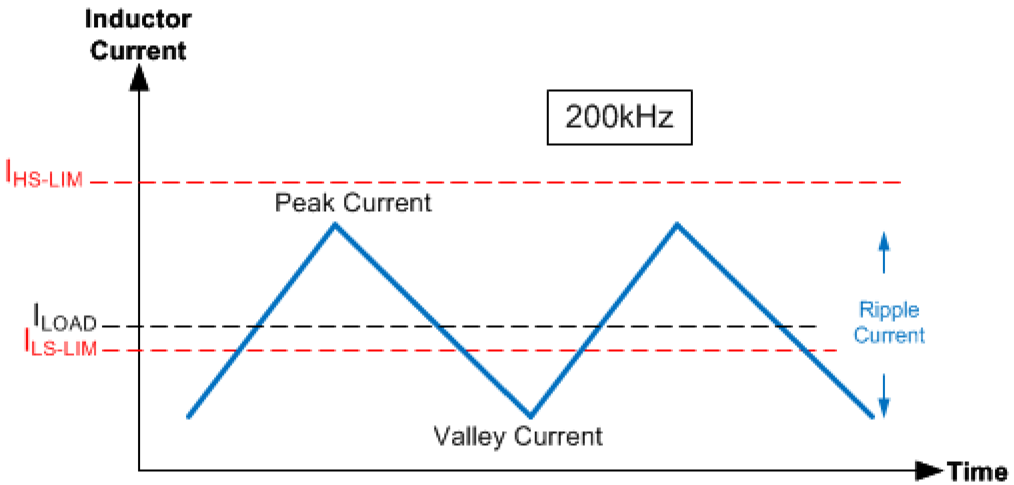
$$L=\frac{(V_{IN}-V_{OUT})}{\Delta I\cdot F_S}\cdot\frac{V_{OUT}}{V_{IN}}=\frac{(12-5)}{0.6\cdot 500e^3}\cdot\frac{5}{12}=9.7\mu H$$

$V_{IN}$ = 12V, $F_S$ = 1 MHz

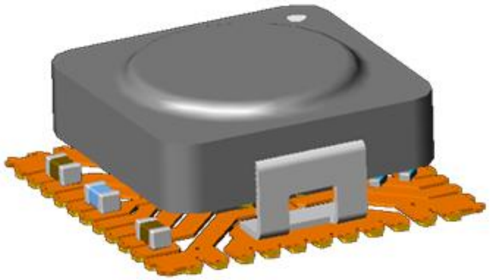
$$L=\frac{(V_{IN}-V_{OUT})}{\Delta I\cdot F_S}\cdot\frac{V_{OUT}}{V_{IN}}=\frac{(12-5)}{0.6\cdot 1000e^3}\cdot\frac{5}{12}=4.9\mu H$$

Inductance Selected: 10 µH

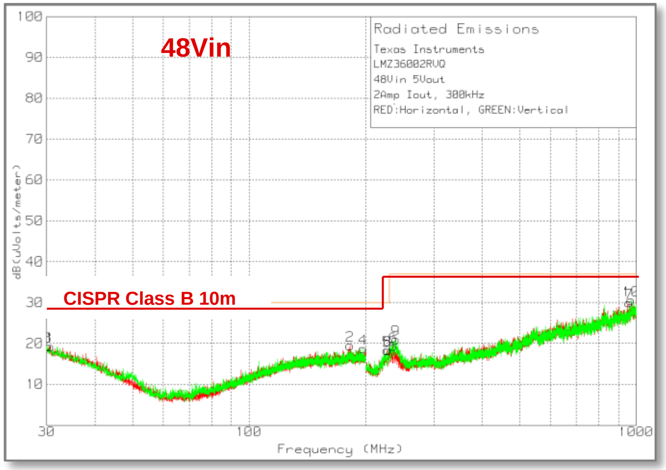
# Fixed Inductance and Frequency Range

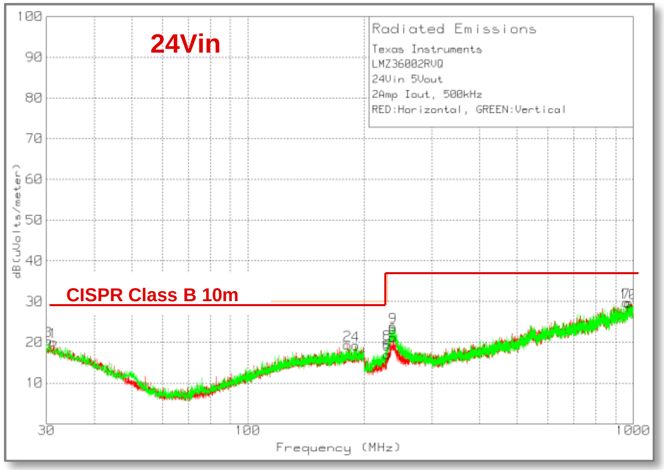


# Integrated 10uH Shielded Inductor



- 10uH selected for best balance of performance over $V_{IN}$, $V_{OUT}$, and $F_{SW}$ range
- Meets CISPR 22 Class B Radiated EMI
- Powdered iron for soft saturation



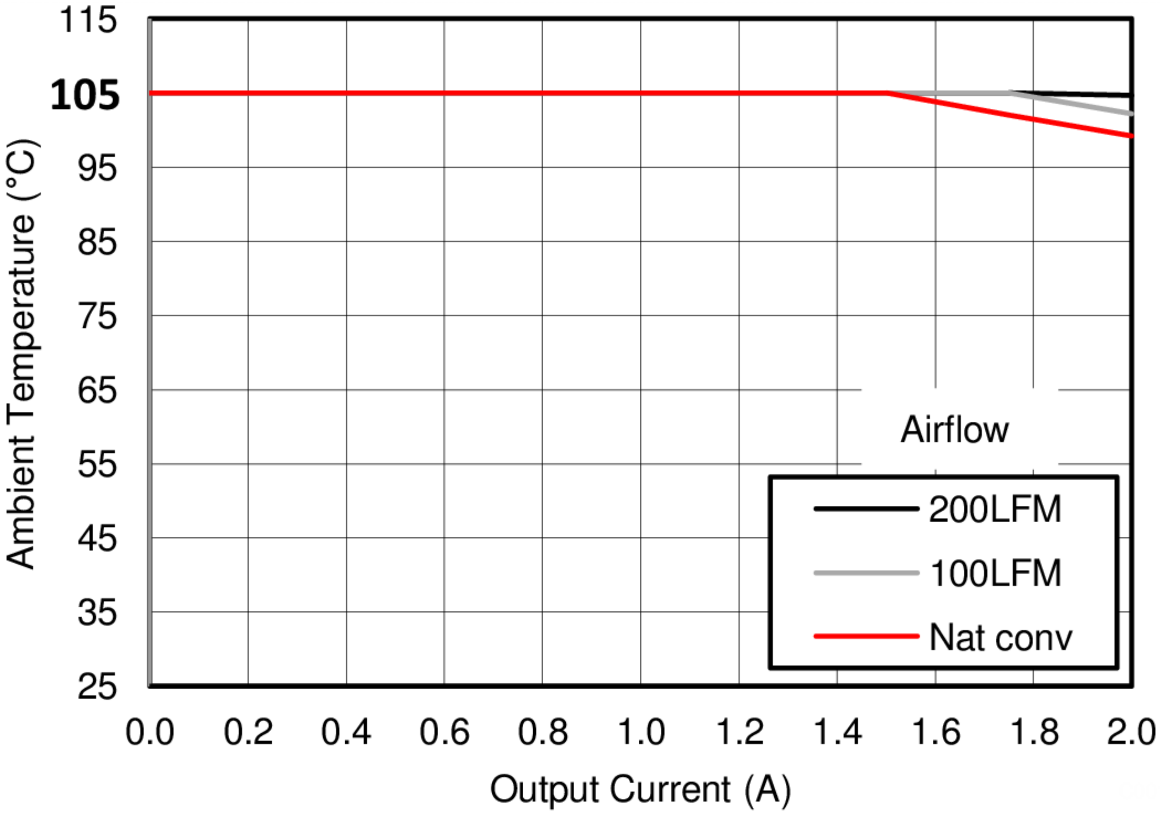
# Setting Safe Design Limits

- $V_{IN}$, $V_{OUT}$, $F_S$ Constraints
  - HS current limit
  - LS current limit
  - Slope compensation
  - Minimum Ton
  - Minimum Toff

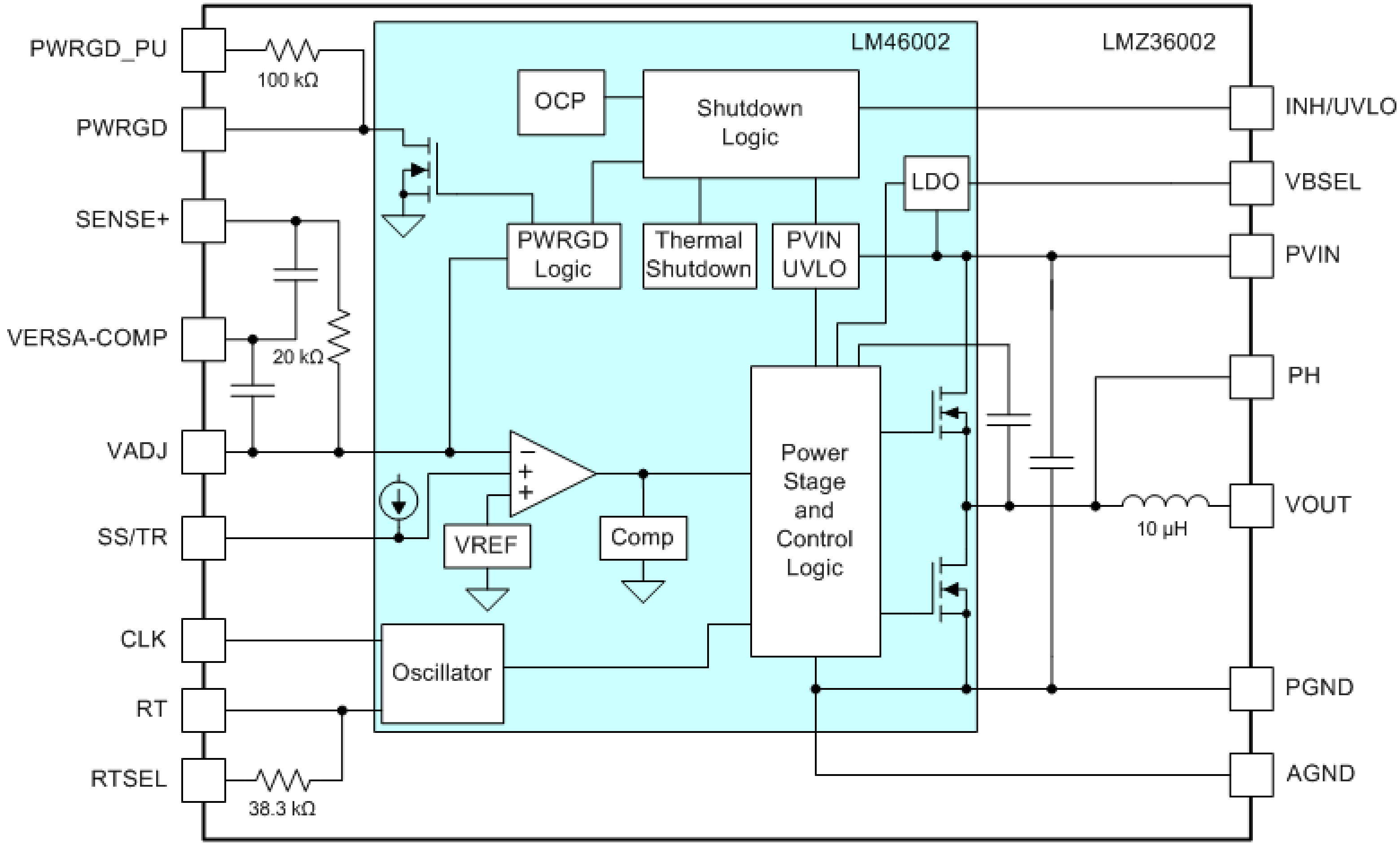
| VOUT Range (V) | Switching Frequency Range (kHz) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | PVIN = 12V | | PVIN = 24V | | PVIN = 36V | | PVIN = 48V | |
| | Min | Max | Min | Max | Min | Max | Min | Max |
| 2.5 - 3.5V | 200 | 1000 | 200 | 600 | 200 | 400 | 200 | 300 |
| >3.5V - 4.5V | 200 | 1000 | 200 | 850 | 200 | 550 | 200 | 400 |
| >4.5V - 5.5V | 200 | 1000 | 200 | 1000 | 200 | 750 | 200 | 550 |
| >5.5V - 6.5V | 300 | 1000 | 200 | 1000 | 200 | 1000 | 200 | 630 |
| >6.5V - 7.5V | 300 | 900 | 300 | 1000 | 300 | 950 | 300 | 800 |

# Thermal Safe Operating Area

- Thermal Performance
  - Based on $V_{IN}$, $V_{OUT}$, Airflow

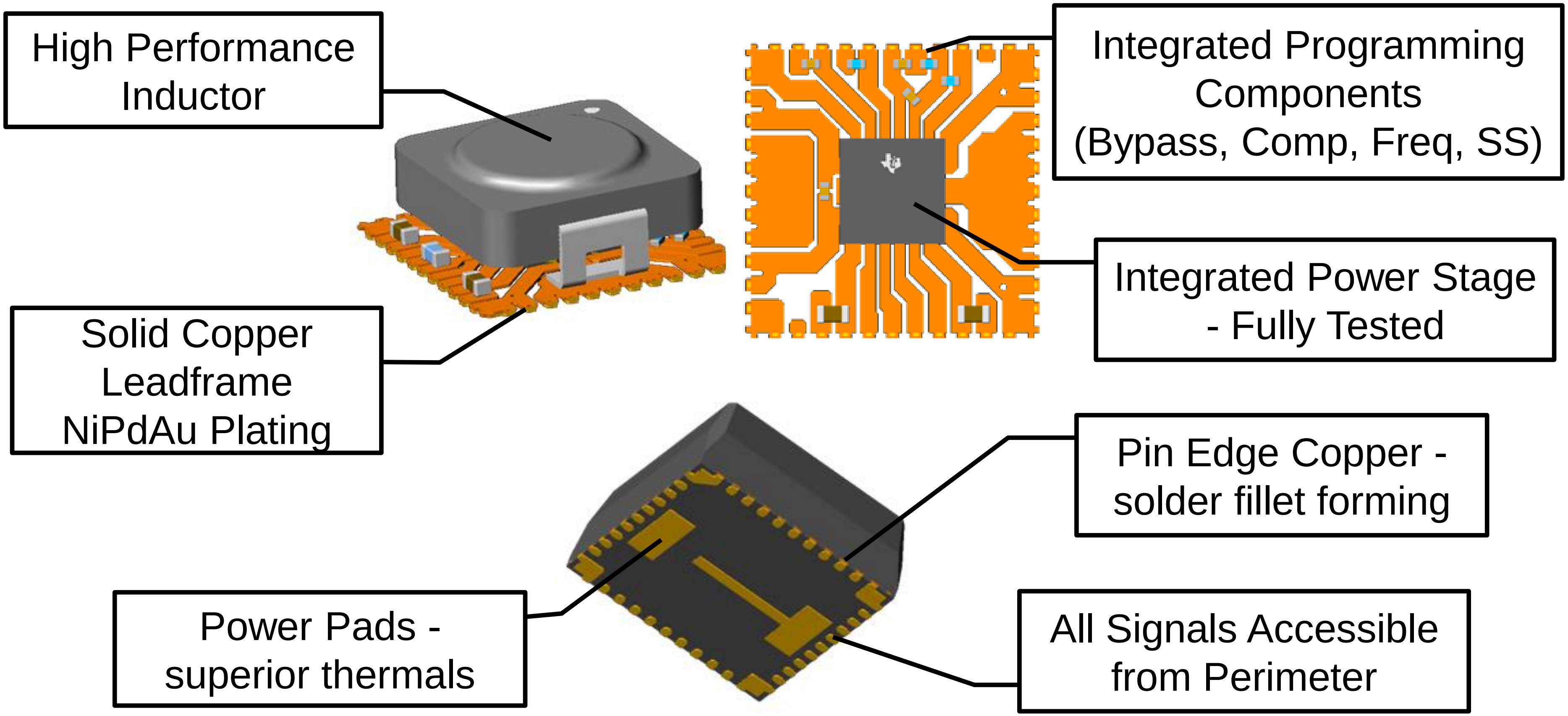


# LMZ36002 Block Diagram



# LMZ36002 Internal Tour

Thermally Enhanced Components on Copper Leadframe =
Low Temperature, Long Life Power Solution

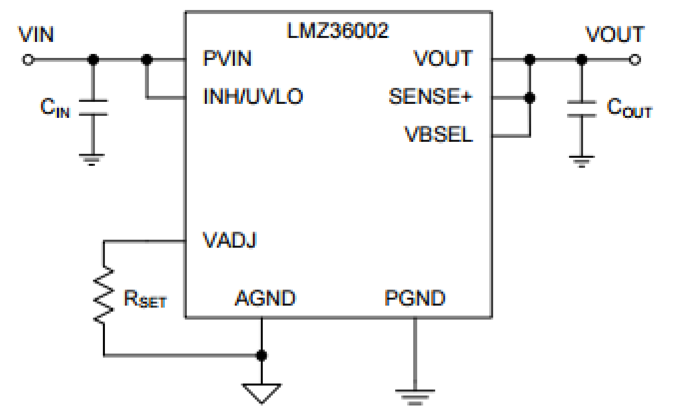


# SIMPLE SWITCHER 4.5-V to 60-V Input, 2-A Power Module

## 1 Features

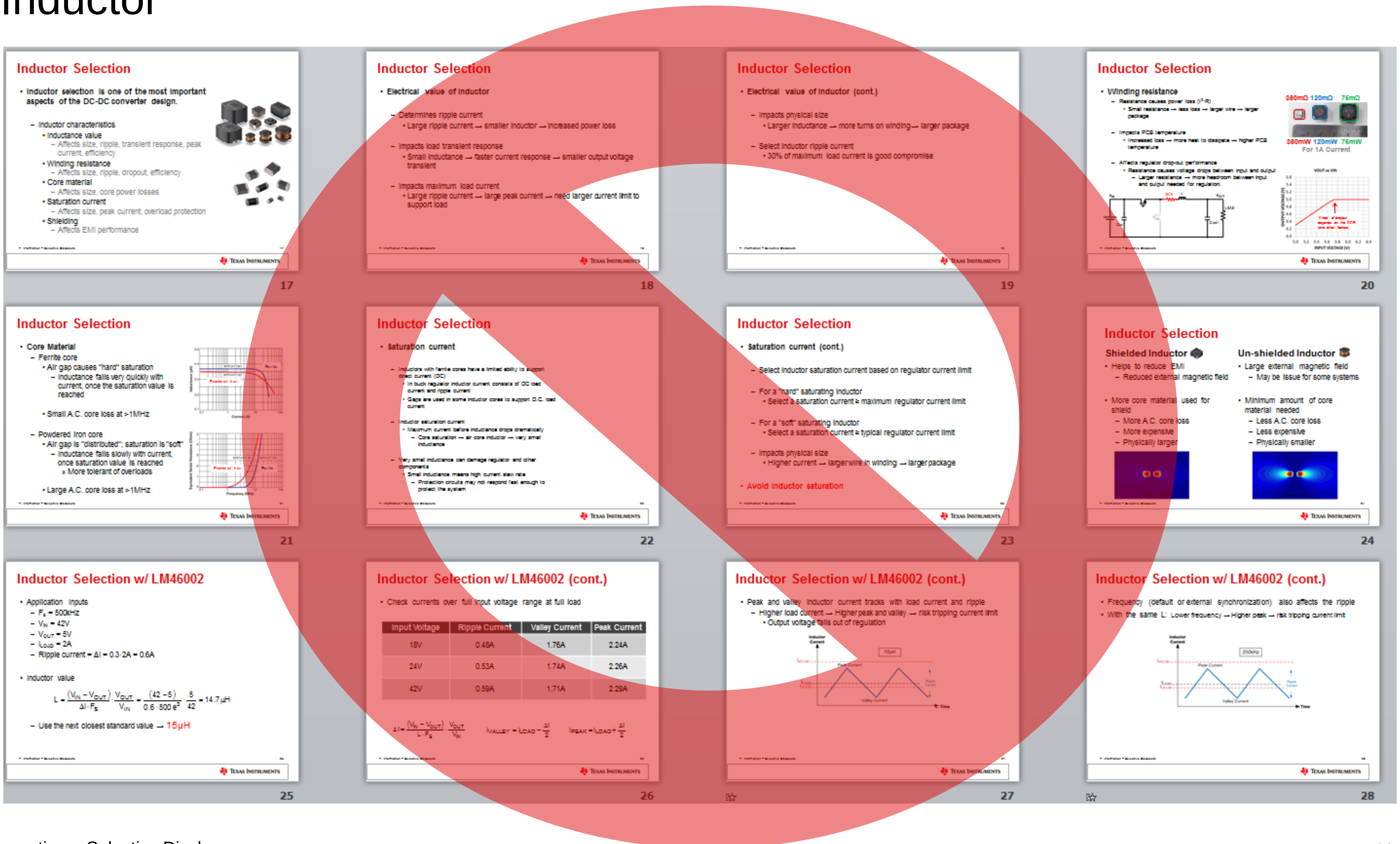
- Complete Integrated Power Solution Allows Small Footprint, Low-Profile Design
- 10 mm × 10 mm × 4.3 mm Package
- Wide-Output Voltage Adjust (2.5 V to 7.5 V)
- Adjustable Switching Frequency (200 kHz to 1 MHz)
- Synchronizes to an External Clock
- Automatic PFM Mode for Light Load Efficiency
- Adjustable Slow-start
- Output Voltage Sequencing / Tracking
- Power Good Output
- Programmable Undervoltage Lockout (UVLO)
- Over-Temperature Thermal Shutdown Protection
- Over-Current Protection (Hiccup Mode)
- Pre-Bias Output Start-Up
- Operating Temperature Range: –40°C to 105°C
- Enhanced Thermal Performance: 14°C/W
- Meets EN55022 Class B Emissions
  – Integrated Shielded Inductor

**Simplified Schematic**




# External Component Considerations

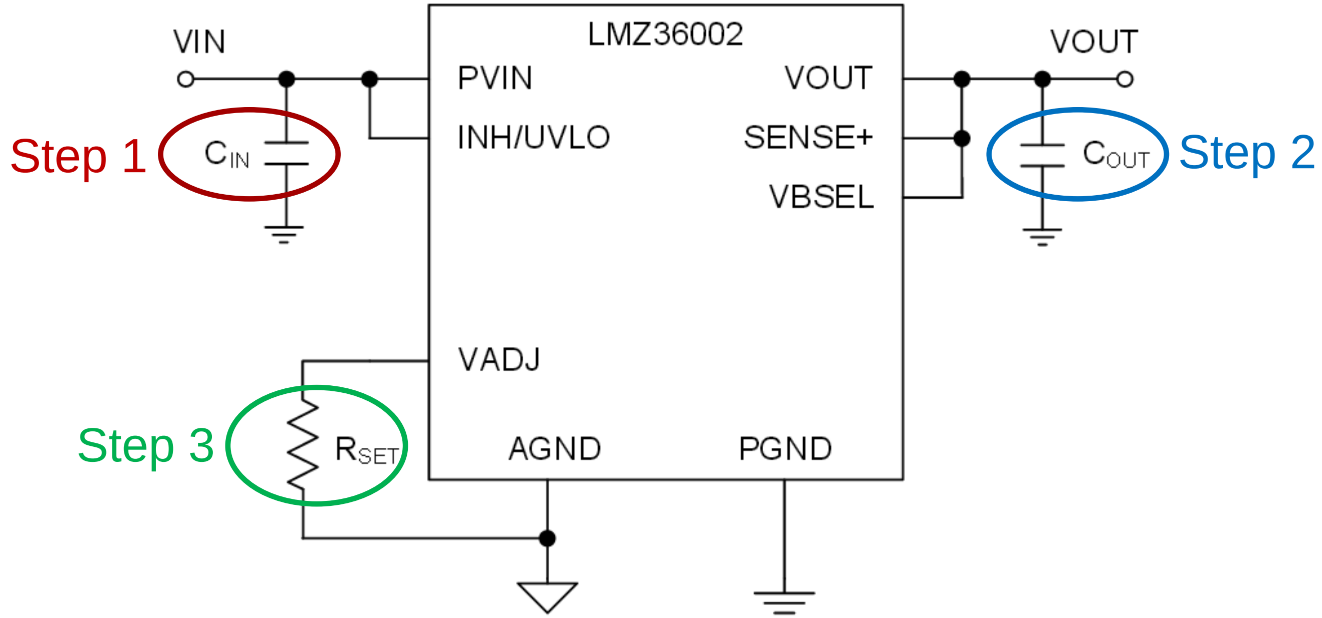
- Inductor



# External Component Considerations

| CAPACITOR CHARACTERISTICS | | |
|---|---|---|
| WORKING VOLTAGE (V) | CAPACITANCE [2] (µF) | ESR [3] (mΩ) |
| 50 | 10 | 3 |
| 50 | 10 | 2 |
| 63 | 10 | 2 |

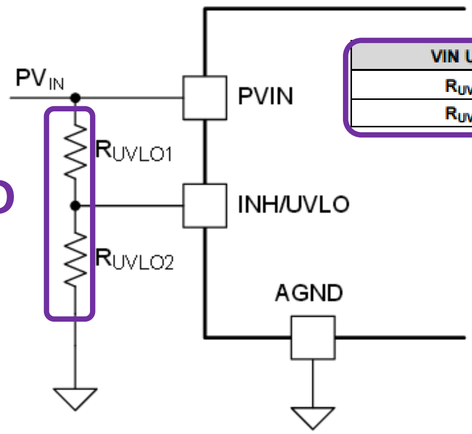
| $V_{OUT}$ (V) | MINIMUM REQUIRED $C_{OUT}$ (µF) [1] [2] | MAXIMUM $C_{OUT}$ (µF) [2] | Versa-Comp Connection |
|---|---|---|---|
| 2.5 | 64 | 350 | Leave OPEN |
| 3.3 | 64 | 350 | Connect to VADJ |
| 5.0 | 64 | 350 | Connect to VADJ |
| 6.0 | 64 | 200 | Connect to VADJ |
| 7.5 | 100 | 200 | Connect to VADJ |




| | OUTPUT VOLTAGE $V_{OUT}$ (V) | | | | |
|---|---|---|---|---|---|
| | 2.5 | 3.3 | 5.0 | 6.0 | 7.5 |
| $R_{SET}$ (kΩ) | 13.7 | 8.87 | 5.11 | 4.02 | 3.09 |

# Other, Optional Components
## (Leave Open or Tailor to Application Needs)

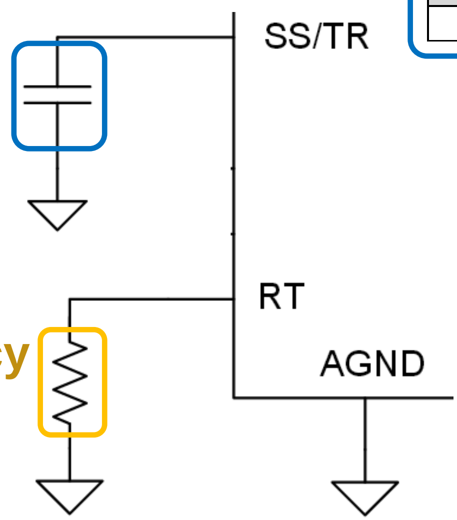
**VIN UVLO Setting**




| VIN UVLO (V) | 4.5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|---|---|
| $R_{UVLO1}$ (kΩ) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| $R_{UVLO2}$ (kΩ) | 46.4 | 21.0 | 14.0 | 10.5 | 8.45 | 6.98 | 6.04 | 5.23 | 4.64 |

**Softstart Setting**

**Frequency Setting**

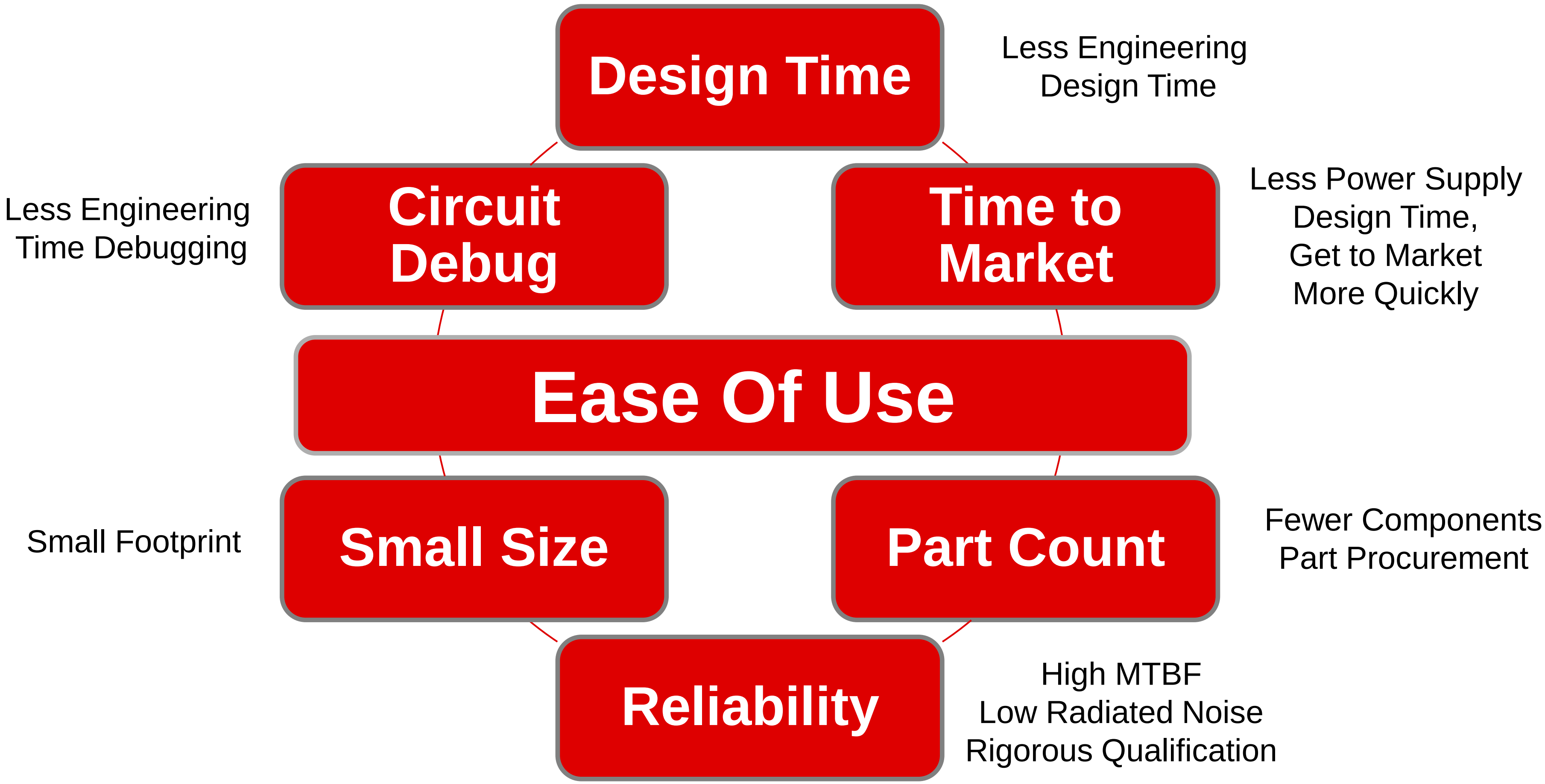



| $C_{SS}$ (nF) | open | 15 | 22 | 33 | 47 |
|---|---|---|---|---|---|
| SS Time (ms) | 4.1 | 7 | 10 | 15 | 20 |

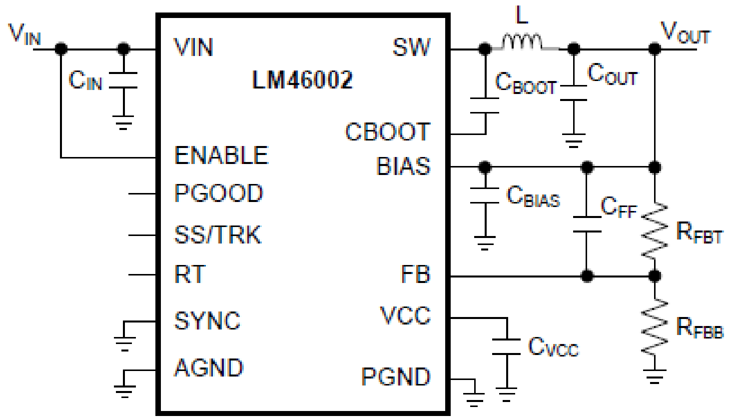
| Switching Frequency | $R_{RT}$ (kΩ) |
|---|---|
| 250 kHz | 158 |
| 500 kHz | 78.7 or (RT pin OPEN, RTSEL pin OPEN) |
| 750 kHz | 53.6 |
| 1 MHz | 38.3 or (RT pin OPEN, RTSEL pin to AGND) |

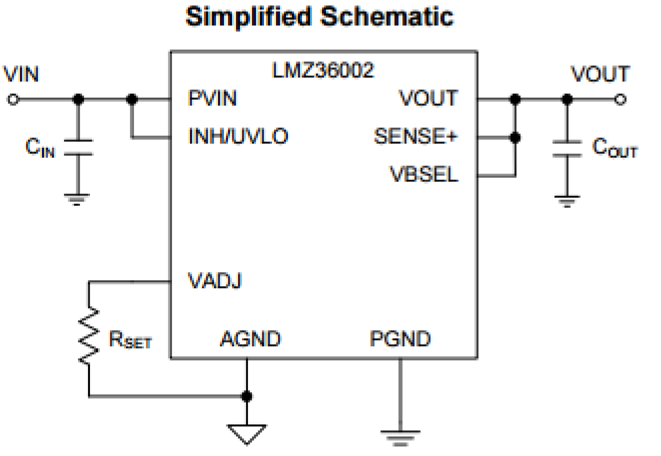
# PCB Layout example for LMZ36002

# Hidden Advantages of Modules

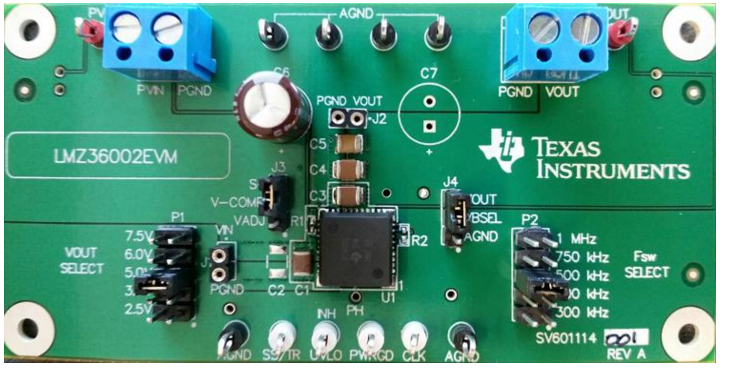


# LM46002 vs LMZ36002

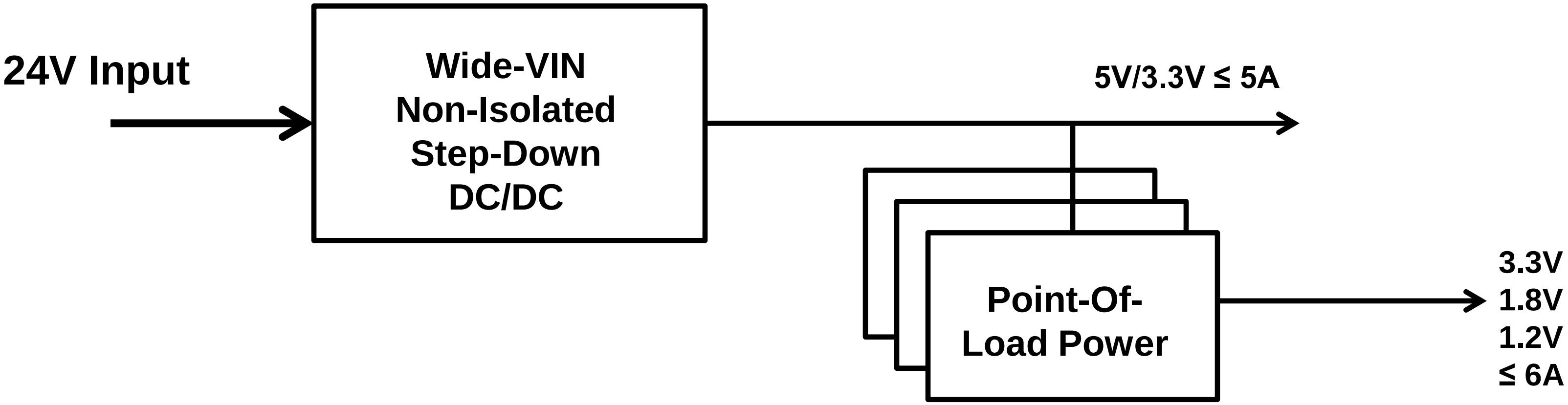


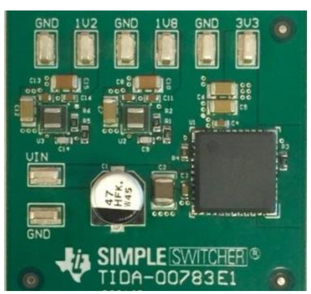







# Typical Line Powered Industrial System




**TIDA00783**
4.5V-40V → 3.3V, 1.8V, 1.2V, 6W total
38x38mm solution size


**PMP9483**
7V-36V → 5V, 2.5V, 1.8V, 15W total
20x30mm solution size

Design Challenges
- Small Solution Size
- High Efficiency
- Low BOM cost
- Fast Solution

# Wide $V_{IN}$ Power Quick Reference Guide

## 24V Non-Isolated DC/DC Converter ($V_{IN}$ max 36-42V)

| Key Power Requirement | 1. Small footprint<br>2. BOM cost<br>3. High efficiency | 1. BOM cost<br>2. Small footprint<br>3. High efficiency | 1. High efficiency<br>2. Small footprint<br>3. BOM cost | 1. Fast design<br>2. Small footprint<br>3. High efficiency |
|---|---|---|---|---|
| ≤1A | LMR23610* | LMR14006<br>LMR14020 | LM43600<br>LM43601 | LMZ14201<br>LMZ35003 |
| 2A | LMR23625* | LMR14020 | LM43602 | LMZ14202<br>LMZ35003 |
| 3A | LMR23630* | LMR14030 | LM43603 | LMZ14203<br>LMZ23603 |
| 5A | LMR14050 | LMR14050 | LM73605* | LMZ23605 |

**Non-Synchronous**
**Synchronous**
**Module**

***Sampling now**

# Wide $V_{IN}$ Power Quick Reference Guide

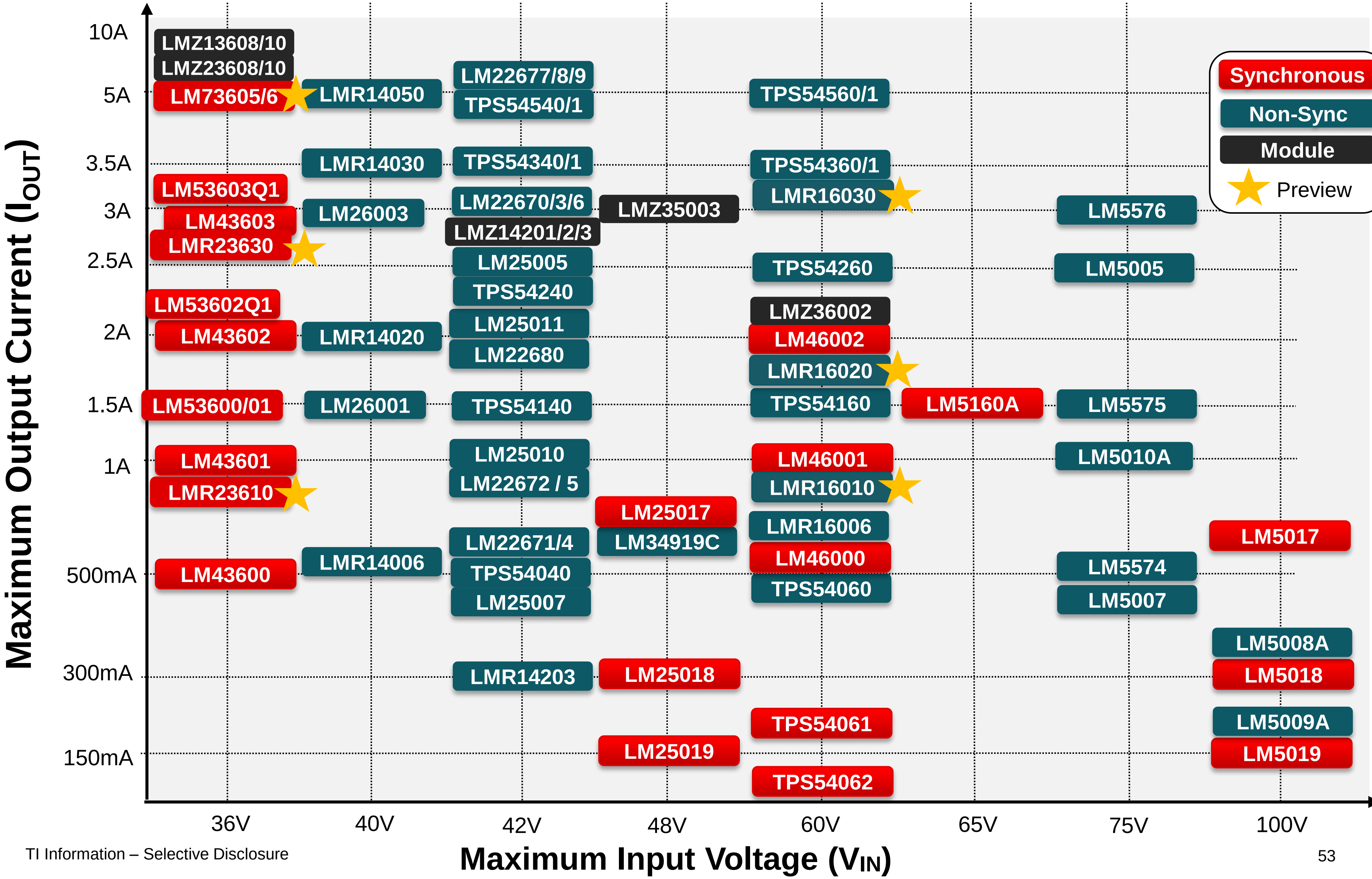
## 24V Non-Isolated DC/DC Converter ($V_{IN}$ max >42V)

| Key Power Requirement | 1. Small footprint<br>2. BOM cost<br>3. High efficiency | 1. BOM cost<br>2. Small footprint<br>3. High efficiency | 1. High efficiency<br>2. Small footprint<br>3. BOM cost | 1. Fast design<br>2. Small footprint<br>3. High efficiency |
|---|---|---|---|---|
| ≤1A | TPS54062<br>TPS54061<br>LMR16010* | TPS54060<br>TPS54161 | LM46000<br>LM46001 | LMZ36002<br>LMZ35003 |
| 2A | TPS54260<br>LMR16020* | TPS54260 | LM46002 | LMZ36002<br>LMZ35003 |
| 3A | TPS54361<br>LMR16030* | TPS54361 | TPS54561 | |
| 5A | TPS54561 | TPS54561 | TPS54560 | |

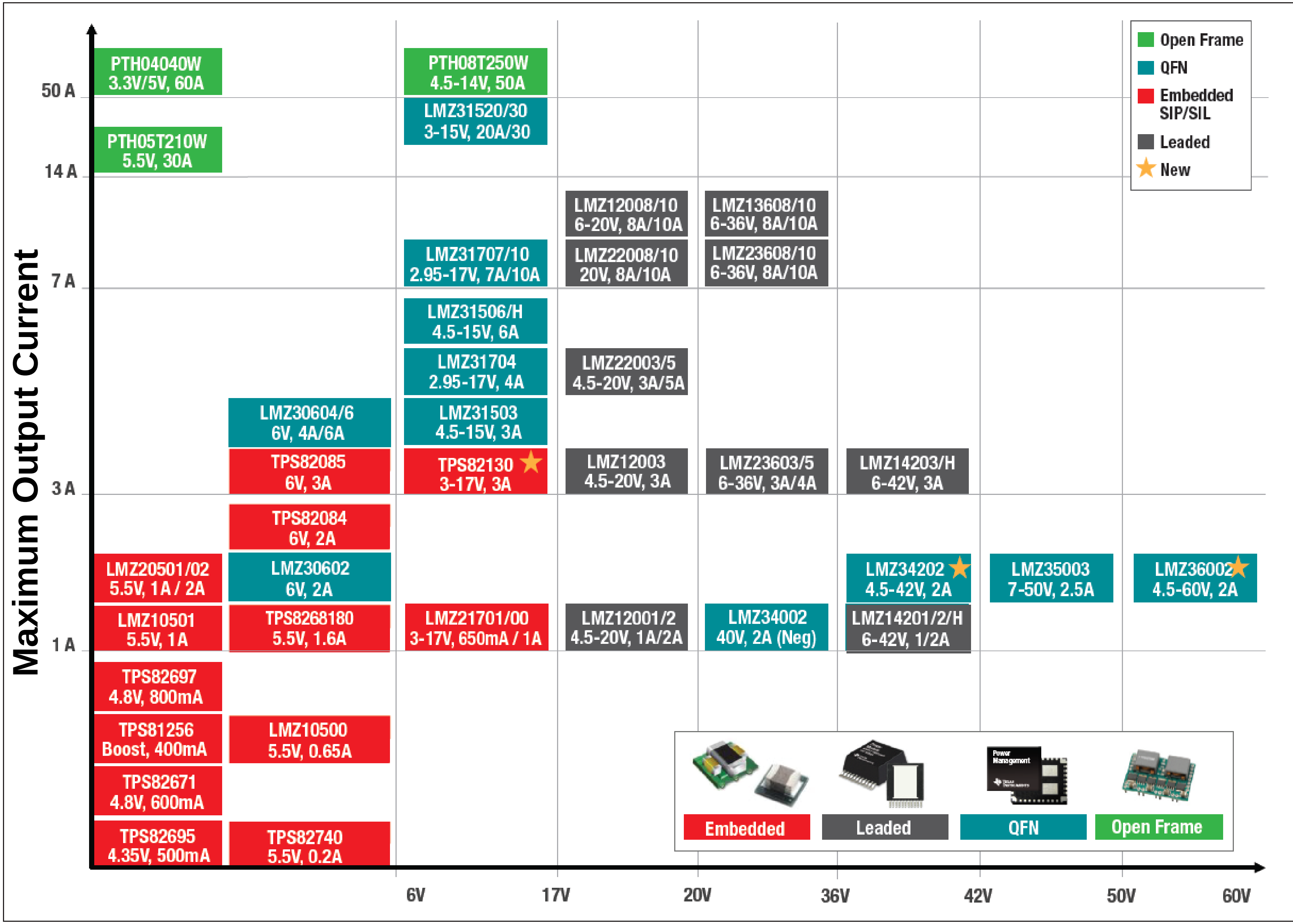
**Non-Synchronous**
**Synchronous**
**Module**

***Sampling now**

# TI Wide $V_{IN}$ DC/DC Step-Down Portfolio



# TI's Power Module Portfolio




**Maximum Input Voltage**

TEXAS INSTRUMENTS

# Module or Discrete Regulator?

## Module Solution

Pro
- Lower total cost of ownership
- Fewer components for procurement
- Less engineering time debugging
- IC, inductor, and passives in module qualified to TI's standard
- Small solution size

Con
- Narrower operating range
- Higher BOM cost


LMZ36002

## Discrete Solution

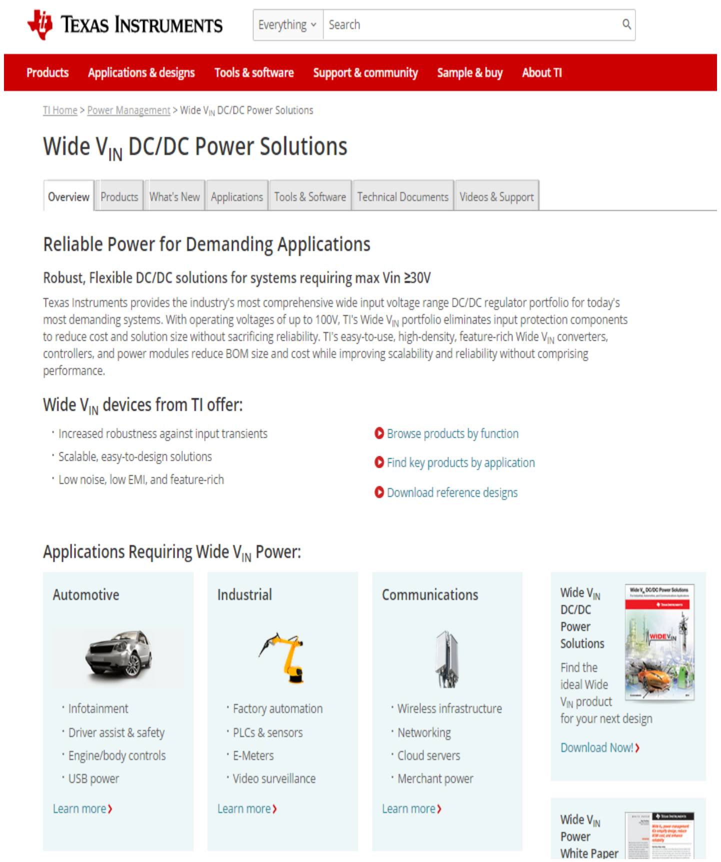
Pro
- More design flexibility
- Optimize to your design conditions
- Lower total solution cost
- Spread heat over larger area
- Small size with optimized layout

Con
- Requires more design time
- Higher BOM count

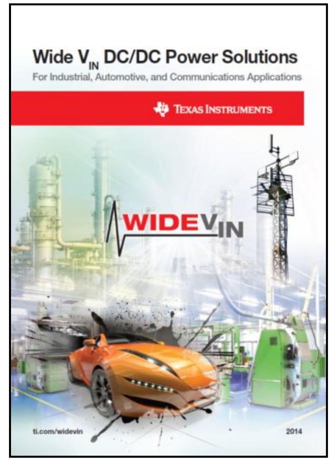
LM46002

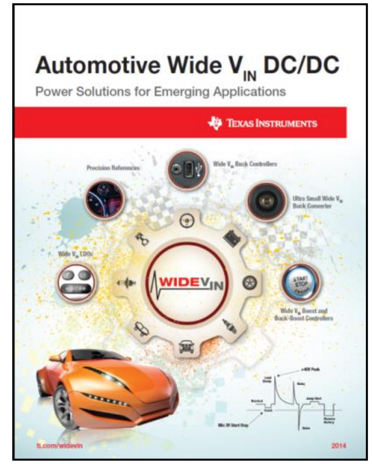
# TI.com/WideVin

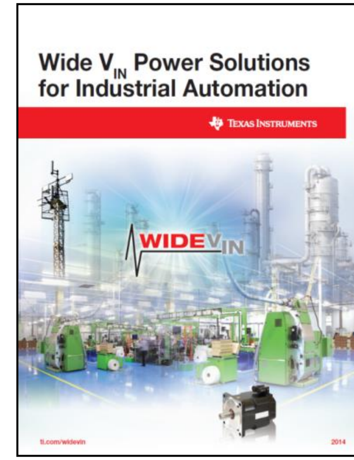
## Wide Vin Landing Page: www.ti.com/widevin




## Wide Vin Selection Guides

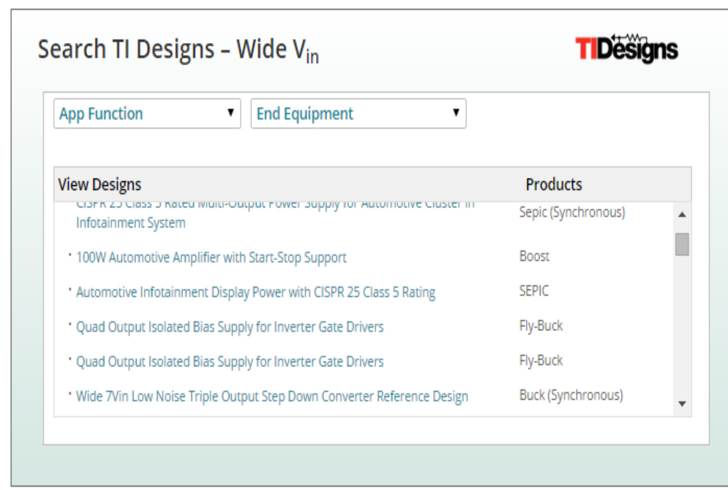



## Wide Vin TI Designs

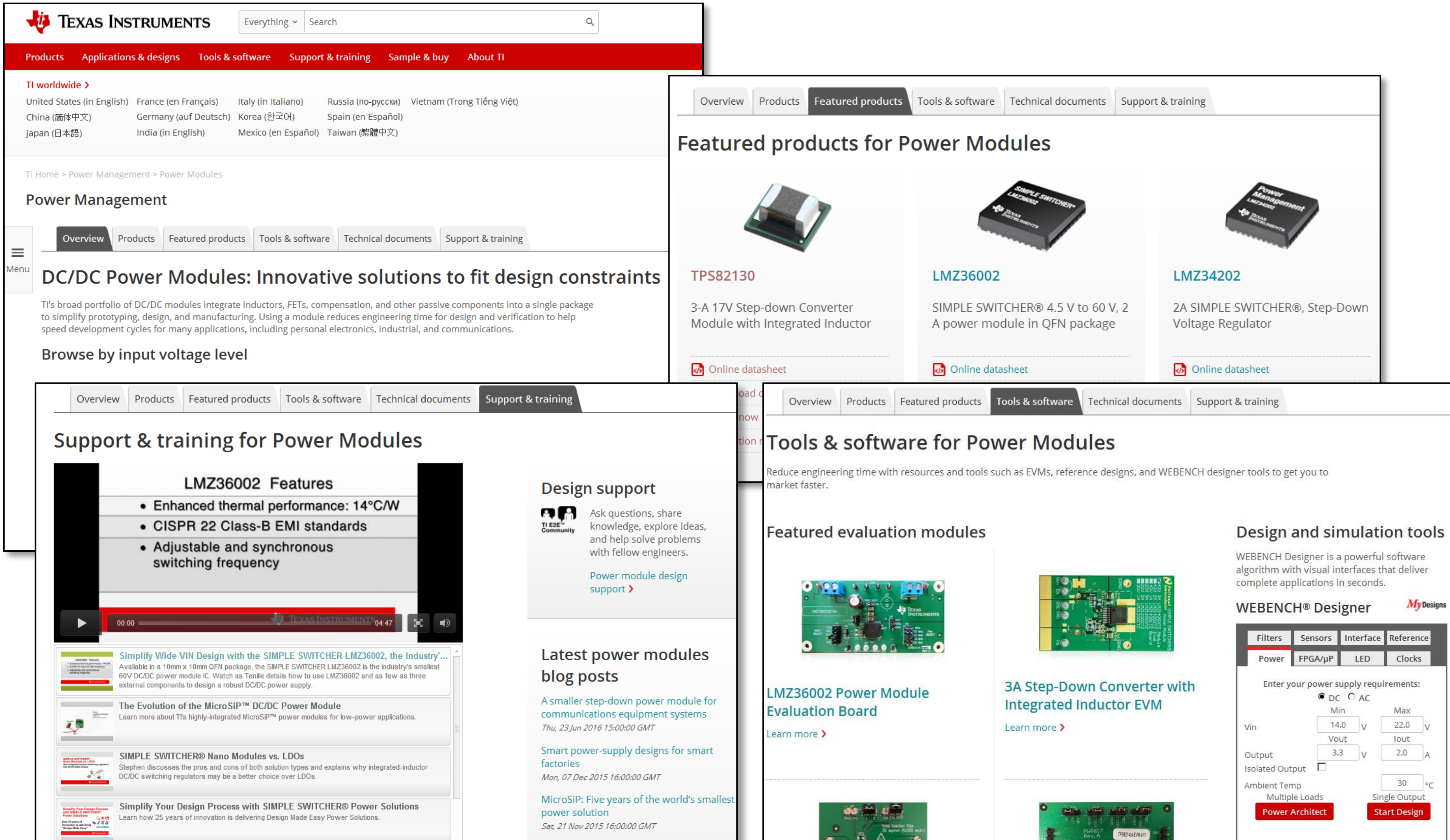
( Designs, searchable by application & end equipment)




TI Information – Selective Disclosure

# TI.com/PowerModules

**Power Modules Landing Page: www.ti.com/powermodules**



# Thank You!

**ti.com/WideVin**

**ti.com/PowerModules**