# LM25576 Reference Design 6-42V input, 5V 3A output

National Semiconductor
Reference Design 128
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January 2007

## 1.0 Design Specifications

| Inputs | Output #1 |
|---|---|
| vInMin=6V | vOut1=5V |
| vInMax=42V | iOut1=3A |

## 2.0 Design Description

This LM25576 reference design is based on a LM25576 demonstration board which was a assembled and tested platform to evaluate the LM25576 SIMPLE SWITCHER® step-down converter. The reference design takes a 6V-42V input and generates a regulated 5V output that can source up to 3A of current.

**Design Targets**

The primary consideration for this design was to obtain the highest efficiency LM25576 design, over it's full operating voltage input range. Cost and size of components were a secondary consideration (i.e.: using small, less expensive ceramic capacitors; a small, off the shelf inductor; etc.). The result is a design that achieves 95% peak efficiency, with a short list of necessary components. All optional features of the LM25576 can be enabled if necessary. The board layout is ideal for demonstrating the capabilities of the target design, while allowing for easy probing and adjustments.

**Product Description**

The LM25576 is an easy to use Simple Switcher buck regulator which allows design engineers to design and optimize a robust power supply using a minimum set of components. Operating with an input voltage range of 6 - 42V, the LM25576 delivers 3A of continuous output current with an integrated 170 mΩ N-Channel MOSFET. The regulator utilizes an Emulated Current Mode architecture which provides inherent line regulation, tight load transient response, and ease of loop compensation without the usual limitation on low-duty cycles associated with current mode regulators. The operating frequency is adjustable from 50 kHz to 1 MHz to allow optimization of size and efficiency. To reduce EMI, a frequency synchronization pin allows multiple IC's from the LM2557x family to self-synchronize or to synchronize to an external clock. The LM25576 guarantees robustness with cycle-by-cycle current limit, short-circuit protection, thermal shut-down, and remote shut-down. The device is available in a power enhanced TSSOP-20 package featuring an exposed die attach pad for thermal dissipation.

The LM25576 is supported by the full suite of WEBENCH® On-Line design tools

## 3.0 Features

- SIMPLE SWITCHER® regulator
- 6-42V input operation
- Synchronizeable switching frequency
- Regulated 5V output at up to 3A
- 300 kHz switching frequency
- Easily adjustable output voltage down to 1.225V
- 95% maximum efficiency
- On-board shutdown circuitry
- Also demonstrates LM5576
- Integrated WEBENCH design
- RoHS compliant
- Design was assembled and tested

**Applications**

- Step-down 36V, 24V, or 12V rail to regulated 5V output
- Robust, industrial power supply
- Automotive applications
- White goods power supplies

## 4.0 Schematic

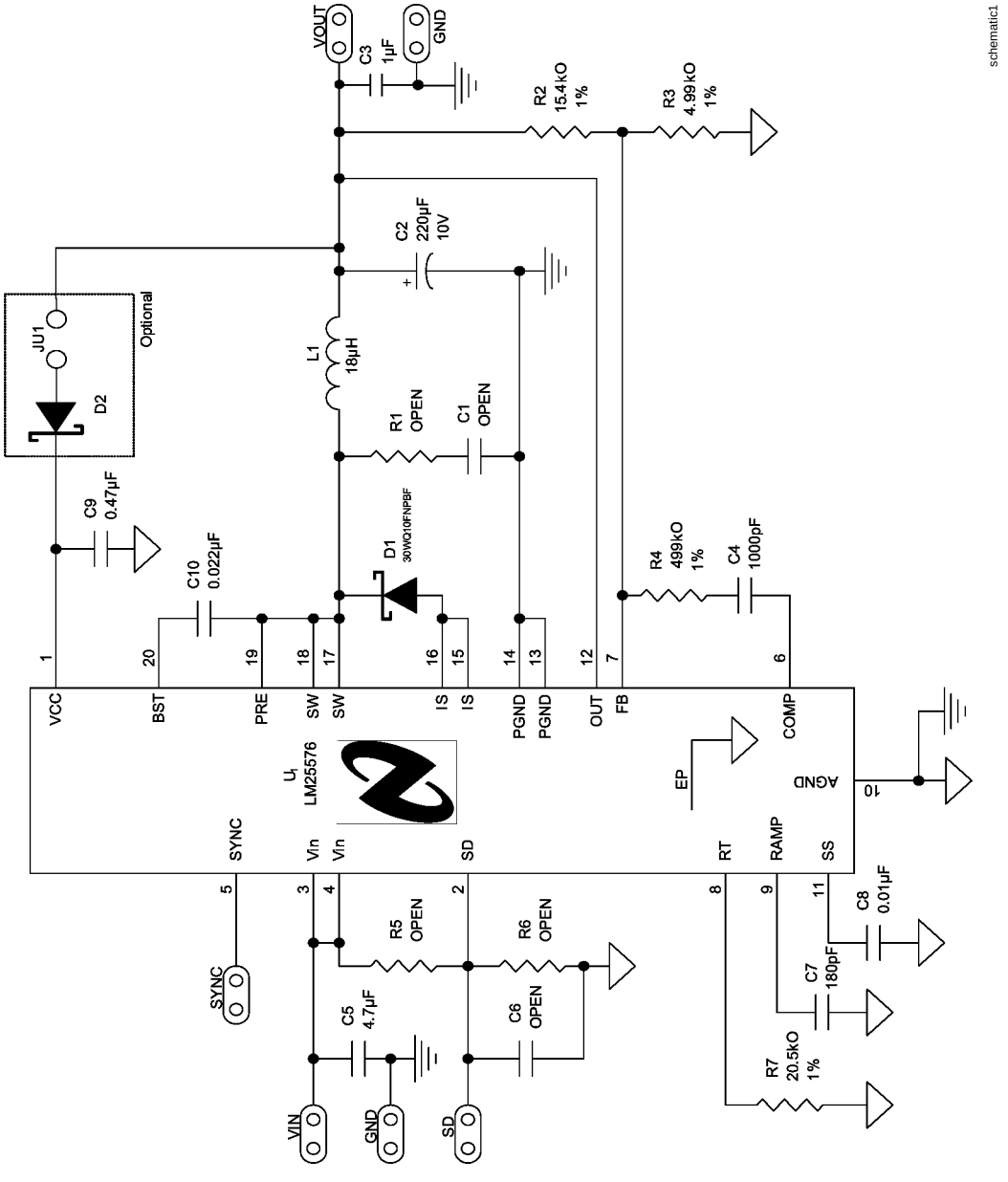



**FIGURE 1. LM25576 Demonstration Board Schematic**

# 5.0 Bill Of Materials

| Ref | Qty | Description | Supplier | Digi-Key part number |
|---|---|---|---|---|
| C1 | 0 | Not Installed (0805) | | |
| C2 | 1 | 220µF, 10V, 25mΩ tantalum capacitor (D-Case) | Kemet T520D227M010ASE025 | Digi-Key 399-3260-1-ND |
| C3 | 1 | 1.0µF, 16V, X5R 10% 0603 Ceramic capacitor | TDK C1608X5R1C105K | Digi-Key 445-1416-1-ND |
| C4 | 1 | CAP CER 1000pF 50V C0G 5% | TDK C1005C0G1E102J | Digi-Key 445-2651-1-ND |
| C5 | 1 | 4.7µF, 100V, X7R, 20% ceramic capacitor (2220) | TDK C5750X7R2A475M<br>Murata GRM55ER72A475KA01L | Digi-Key 445-1450-1-ND<br>Digi-Key 490-1934-1-ND |
| C6 | 0 | Not Installed (0603) | | |
| C7 | 1 | 180pF, 50V, C0G, 5% ceramic capacitor (0402) | TDK C1005C0G1H181J<br>Murata GRM1555C1H181JA01D | Digi-Key 445-1250-1-ND<br>Digi-Key 490-3231-1-ND |
| C8 | 2 | 0.01µF, 16V, X7R, 20% ceramic capacitor (0402) | TDK C1005X7R1C103K<br>Murata GRM155R71C103KA01D | Digi-Key 445-1262-1-ND<br>Digi-Key 490-1313-1-ND |
| C9 | 1 | 0.47µF, 16V, X7R, 10% ceramic capacitor (0805) | TDK C2012X7R1C474K<br>Murata GRM21BR71C474KA01L | Digi-Key 445-1357-1-ND<br>Digi-Key 490-3333-1-ND |
| D1 | 1 | 100V, 3.5A Schottky Diode (D-Pak) | IRF 30WQ10FNPBF | *Digi-Key 30EWQ10FN-ND |
| D2 | 1 | 40V, 30mA Shottky Diode (SOD-523) | Diodes Inc SDM03U40-7 | Digi-Key SDM03U40DICT-ND |
| L1 | 1 | 18µH, 3.9A Inductor | Sumida CDRH127-180MC<br>Toko 931BS-180M | Digi-Key 308-1080-1-ND |
| | | | | |
| R1, R5, R6 | 0 | Not Installed (0603) | | |
| R2 | 1 | 15.4kΩ, 1% Resistor (0603) | Panasonic ERJ-3EKF1542V<br>Yageo RC0603FR-0715K4L | Digi-Key P15.4KHCT-ND<br>Digi-Key 311-15.4KHRCT-ND |
| R3 | 1 | 4.99kΩ, 1% Resistor (0603) | Panasonic ERJ-3EKF4991V<br>Yageo RC0603FR-074K99L | Digi-Key P4.99KHCT-ND<br>Digi-Key 311-4.99KHRCT-ND |
| R4 | 1 | 499kΩ, 1% Resistor (0603) | Panasonic ERJ-3EKF4993V<br>Yageo RC0603FR-07499KL | Digi-Key P499KHCT-ND<br>Digi-Key 311-499KHRCT-ND |
| R7 | 1 | 20.5kΩ, 1% Resistor (0603) | Panasonic ERJ-3EKF2052V<br>Yageo RC0603FR-0720K5L | Digi-Key P20.5KHCT-ND<br>Digi-Key 311-20.5KHRCT-ND |
| U1 | 1 | Simple Switcher Step-Down Regulator (TSSOP-20EP) | National LM25576MH | |

*Digi-Key component may not be lead-free

### Component Suppliers

| SUPPLIER | PHONE | WEBSITE |
|---|---|---|
| Digi-Key | 800-344-4539 | www.digikey.com |
| Diodes INC | 805-446-4800 | www.diodes.com |
| International Rectifier | 310-726-8000 | www.irf.com |
| Kemet | 864-963-6300 | www.kemet.com |
| Murata | 770-436-1300 | www.murata.com |
| TDK | 847-803-6100 | www.component.tdk.com |

***Note:*** Please indicate that you are using the LM25576 when contacting these component suppliers.

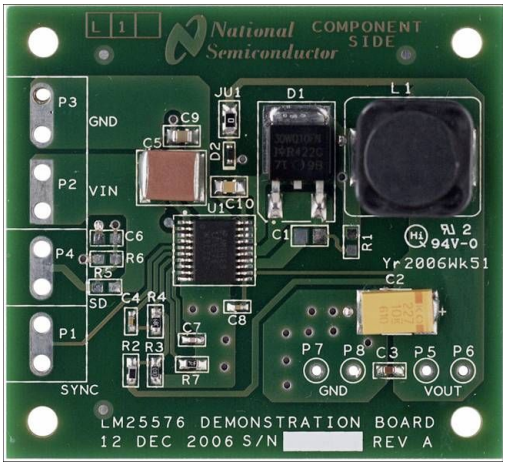
bom2

# 6.0 Other Operating Values

**Operating Values**

| Description | Parameter | Value | Unit |
|---|---|---|---|
| Modulation Frequency | Frequency | 300 | KHz |
| Total output power | Pout | 12.5 | W |
| Steady State Efficiency | Efficiency | 95 | % |
| Control scheme | Control scheme | Emulated Current Control | |
| Peak-to-peak ripple voltage | Vout p-p | 75 | mV |

# 7.0 Board Photos




boardphoto3

**FIGURE 2. Board Photo**

# 8.0 Quick Start

**Recommended Equipment**

— 6V-42V/3A DC power supply
— 3A electronic load
— 1 voltmeter

**Test Procedure**

The LM25576 reference design was fully assembled and tested. Follow the steps below to verify your board operation. Do not turn on the power supplies until all connections are completed.

1. Connect the 6V-42V power supply to the $V_{IN}$ and GND pads on the demonstration board.
2. Connect the electronic load to the $V_{OUT}$ and GND pads.
3. Connect the voltmeter to the $V_{OUT}$ and GND pads.
4. Set the 6V-42V power supply to output 28V.
5. Set the electronic load to draw 3.0A
6. Enable the 6V-42V power supply.
7. Enable the electronic load.
8. Verify that the voltmeter measures 5V at the power supply output.

# 9.0 Hardware Description

**Detailed Description**

The LM25576 demonstration board is a complete evaluation system for the LM25576 SIMPLE SWITCHER® step-down switching regulator.

The reference design accepts a 6V-42V input and produces a regulated 5V output that sources up to 3A of current. Multiple LM25576 reference design are easily synchronized to each other via on-board connection points. An analog shutdown input, and capacitor programmable soft-start functions are also available.

The LM25576 reference design is also able to demonstrate the LM5576 (6V-70V) input.

Additional design support is available via the WEBENCH design tool.

**Powering $V_{CC}$ From The Output Voltage**

The LM25576 reference design features additional circuitry that powers the IC internals from the power output. This optional circuitry (D1, JU1) is included to improve efficiency when the input voltage is high. Buck regulators operating with high input voltage can dissipate an appreciable amount of power for the bias of the IC. The internal $V_{CC}$ regulator must step-down the input voltage $V_{IN}$ to a nominal $V_{CC}$ level of 7V.

This large voltage drop across the $V_{CC}$ regulator translates into large power dissipation within the $V_{CC}$ regulator. This power dissipation becomes a dominant portion of the circuit efficiency when the load current is light.

Jumper JU1 connects the output voltage to the LM25576's $V_{CC}$ input via diode D2. Since this design is configured for a 5V output voltage, the diode is back biased and the output voltage is not connected. When you alter the design such that the output voltage is in the range of ~8V to <14 V, the internal $V_{CC}$ will shut off, and the overall design power consumption will be reduced. Please see the "BIAS POWER DISSIPATION REDUCTION" section of the datasheet for more details.

**Setting the Output Voltage**

By default the LM25576 demonstration board is designed to generate a 5V output. The output voltage of the LM25576 reference design can be changed via resistors R2 and R3. If the output voltage is changed significantly, recalculate components L1, C2, and loop compensation components R4 and C4. Refer to the LM25576 datasheet for details on how to calculate component values. If only moderate output voltage changes are made, the loop gain will remain more or less constant if only R3 is changed. R2, in conjunction with C4 and R4, sets the error amplifier gain. R3 only sets the loop's DC operating point. Calculate R3's value using the equation shown in Figure 10 (in the appendix):

*where,*
*R2 = 15.4 kΩ*
*$V_{OUT}$ = desired output voltage*
*$V_{FB}$ = 1.225V*

If the output voltage is raised above 10V be sure and replace output capacitor C2 (220 µF, 10V) with an appropriately rated device.

**Modifying the Switching Frequency**

The internal oscillator frequency (switching frequency) of the LM25576 is determined by the value of R7. By default, the reference design is designed to operate at a nominal 300 kHz switching frequency. Change the frequency by calculating a new resistor value using the equation shown in Figure 8 (in the appendix):

*where,*
*f = switching frequency in hertz*

Changing the switching frequency of the demonstration board will affect performance of the board. Recalculate inductor L1 and capacitor C2, after the new frequency is determined. Refer to the LM25576 datasheet for equations relating to inductor and capacitor calculations.

# 10.0 Layouts

**Soft-Start**

The soft-start feature of the LM25576 gradually ramps the output voltage of the regulator over a pre-determined amount of time. By default, capacitor C8 configures the LM25576 reference design for a soft-start time of approximately 1.2 ms. Modify the soft-start time, by calculating a new value for capacitor C8 using the following equation shown in Figure 9 (in the appendix):

*where,*
*tss = desired soft-start time*
*$V_{SS}$ = 1.225V*

**On-Board Snubber Circuitry**

The LM25576 reference design features place-holders for a snubber circuit. The snubber circuit is used to dampen large transient voltages that may appear across schottky diode D1. Selecting the values for the snubber network is best accomplished through empirical methods. Install the selected components at locations R1 and C1 if desired.

**Shutdown Control**

The LM25576 features a tri-level shutdown input. Control the shutdown feature by driving the SD pad of the LM25576 reference design with an external voltage source. Refer to Table 2 for a description of the voltage input.

**Table 2. Shutdown Control**

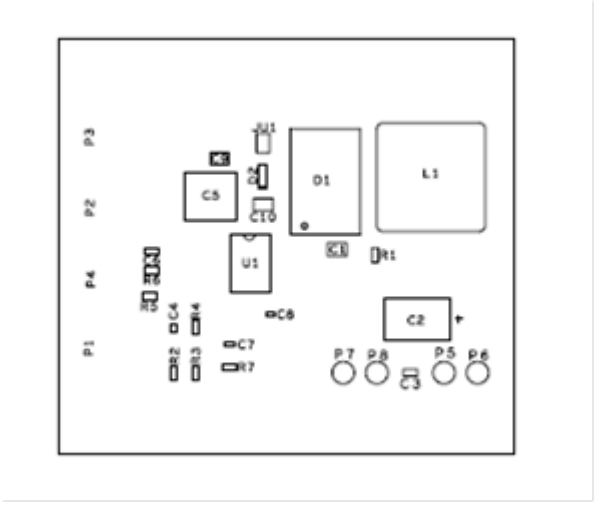
| Vmin | Vmax | DESCRIPTION |
|---|---|---|
| 0 | 0.7 | Shutdown |
| 0.7 | 1.225 | Standby |
| 1.255 | 8.0 | Standard Operating Mode |

Additionally, resistors R5 and R6 can be set to enable the LM25576 at a predetermined input voltage ($V_{IN}$) level. Calculate the resistor values using the equation shown in Figure 11 (in the appendix):

*Where,*
*R6 = 100 kΩ*
*$V_{IN}$ = minimum input voltage*
*$V_{SD}$ = 1.225V*

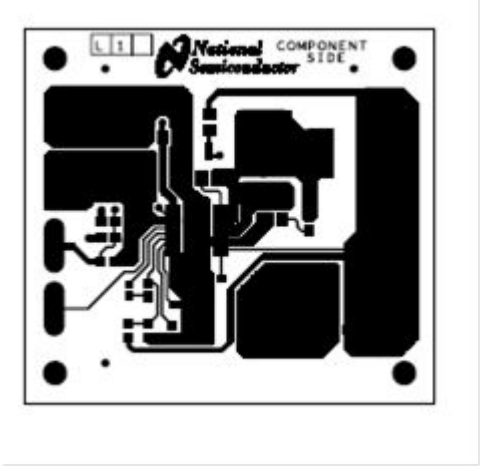
**Change the design to use the LM5576**

The LM25576 reference design can also demonstrate the LM5576 (6V-70V input voltage). When using the LM5576, remove the LM25576 (U1) and replace it with a LM5576MH. Order a free sample of the LM5576MH through online samples at www.national.com.



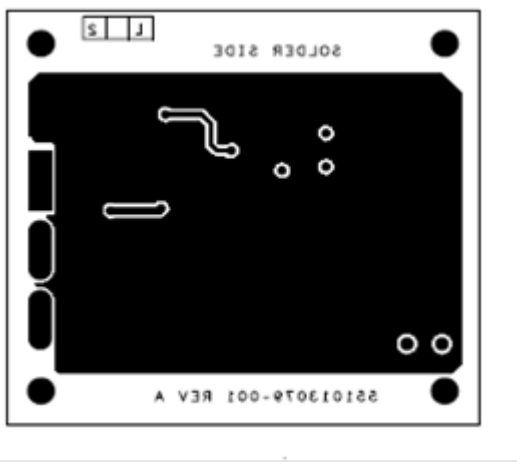

layout

**FIGURE 3. LM25576 Reference Board Component Placement Guide Component Side (551013079-001)**



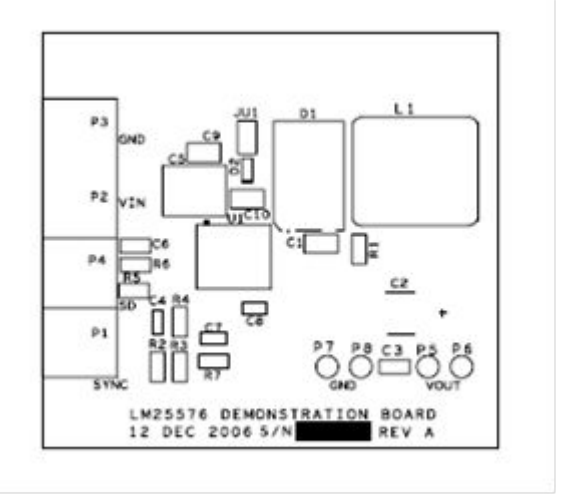

layout1

**FIGURE 4. LM25576 Reference Board PC Board Layout Component Side (551013079-001)**




layout2

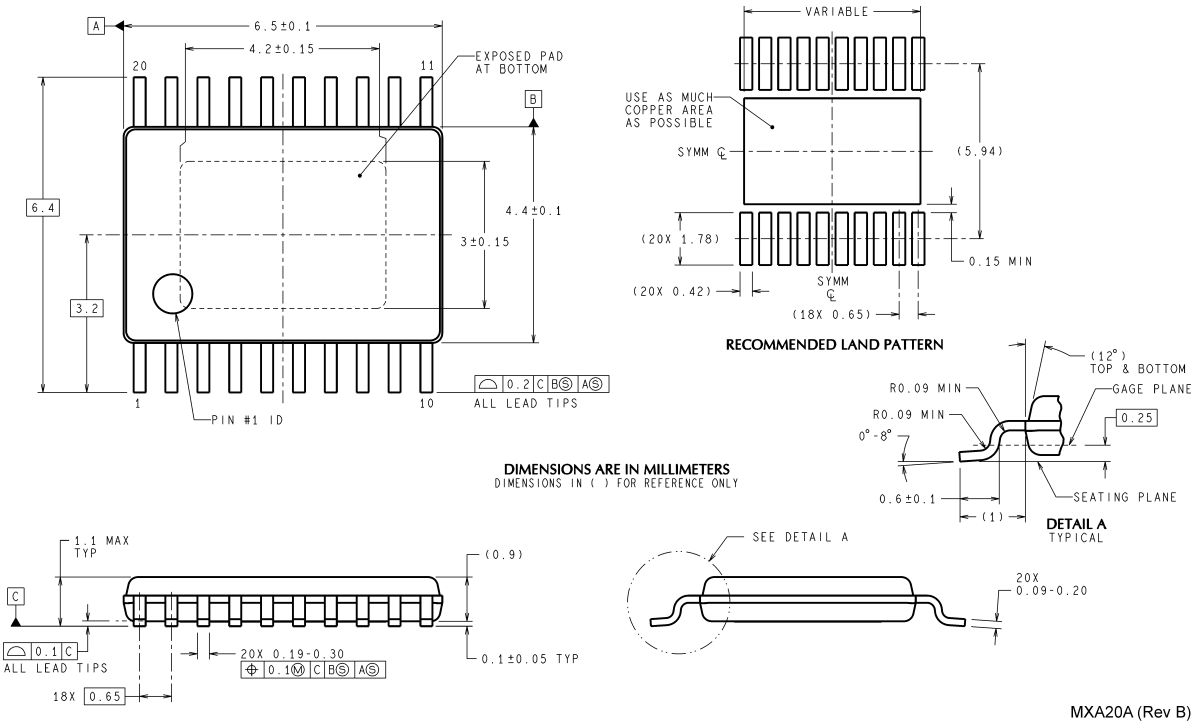
**FIGURE 5. LM25576 Reference Board PC Board Layout Solder Side (551013079-001)**




layout3

**FIGURE 6. LM25576 Reference Board PC Silkscreen Component Side (551013079-001)**

## 11.0 Physical Dimensions inches (millimeters) unless otherwise noted




MXA20A (Rev B)

## 12.0 Appendix

$$R7 = \frac{\frac{1}{F} - 580 \times 10^{-9}}{135 \times 10^{-12}}$$

image

**FIGURE 7. R7 Equation**

$$C8 = \frac{10\mu A \times t_{ss}}{V_{SS}}$$

image1

**FIGURE 8. C8 Equation**

$$R3 = R2 / \left( \frac{V_{OUT}}{V_{FB}} - 1 \right)$$

image2

**FIGURE 9. R3 Equation**

$$R5 = \frac{(V_{IN} - V_{SD}) \times R6}{V_{SD} - R6 \times 5\mu A}$$

image3

**FIGURE 10. R5 Equation**

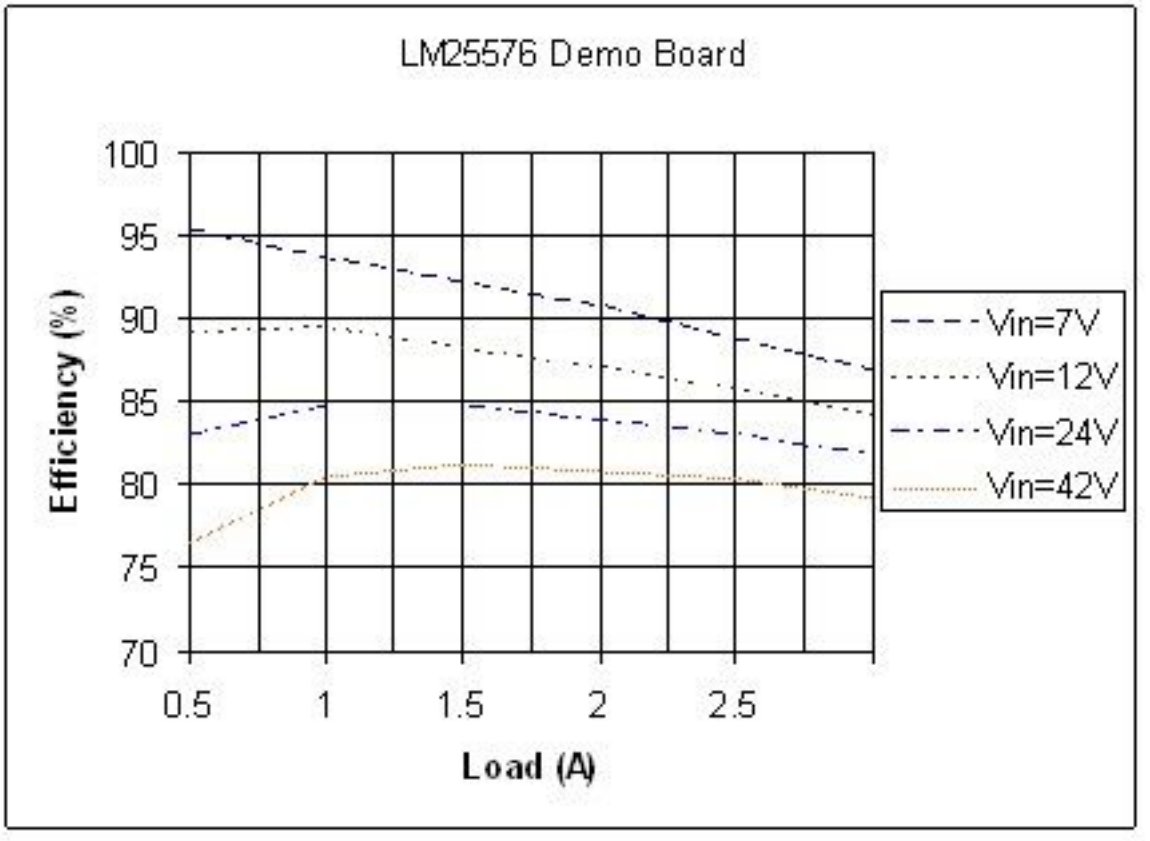



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**FIGURE 11. Efficiency Measurements**

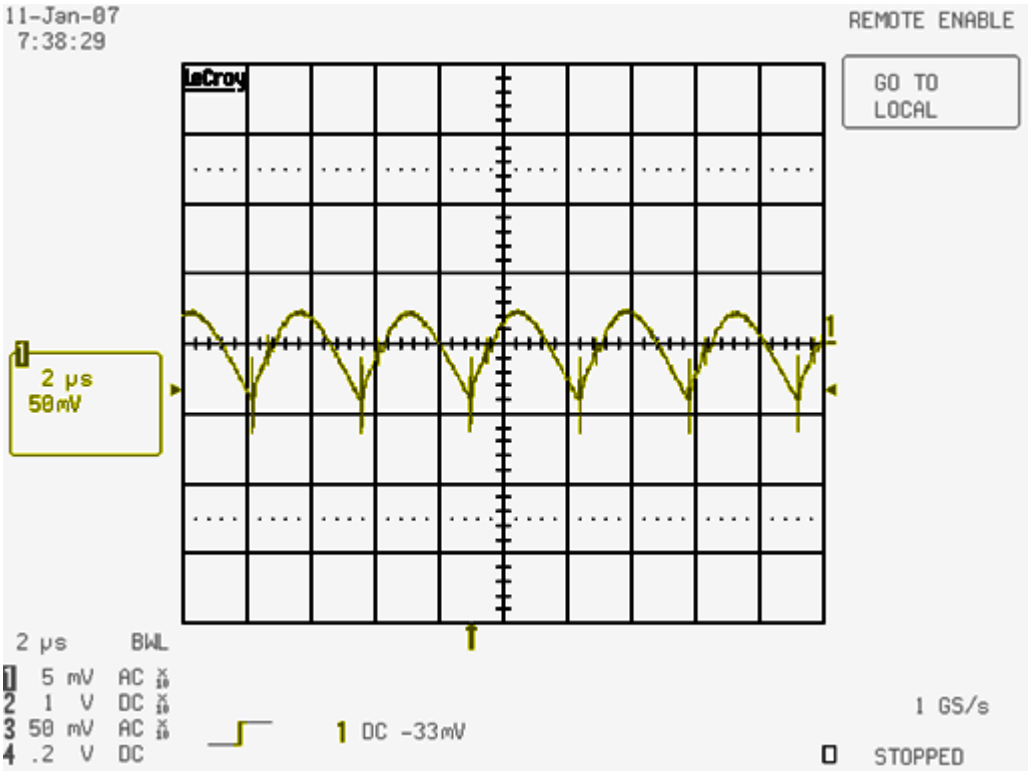


image5

**FIGURE 12. Output Ripple - Vin 42V, Iout 3A (Vout 50 mV/Div)**

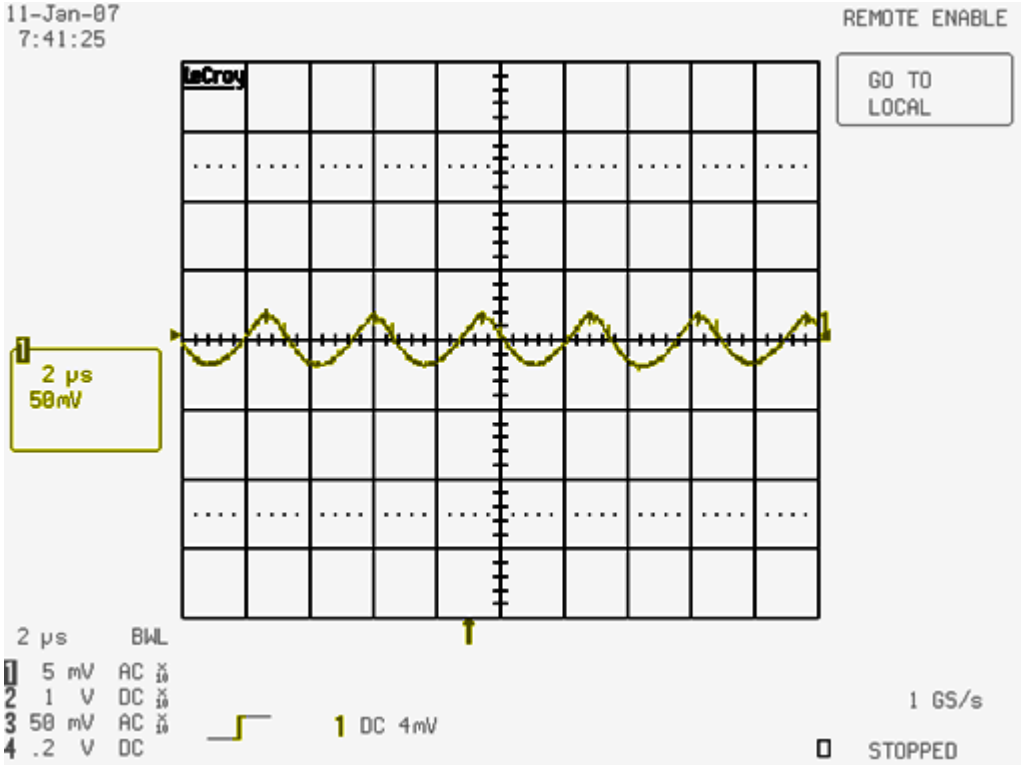


image6

**FIGURE 13. Output Ripple - Vin 7V, Iout 3A (Vout 50 mV/Div)**

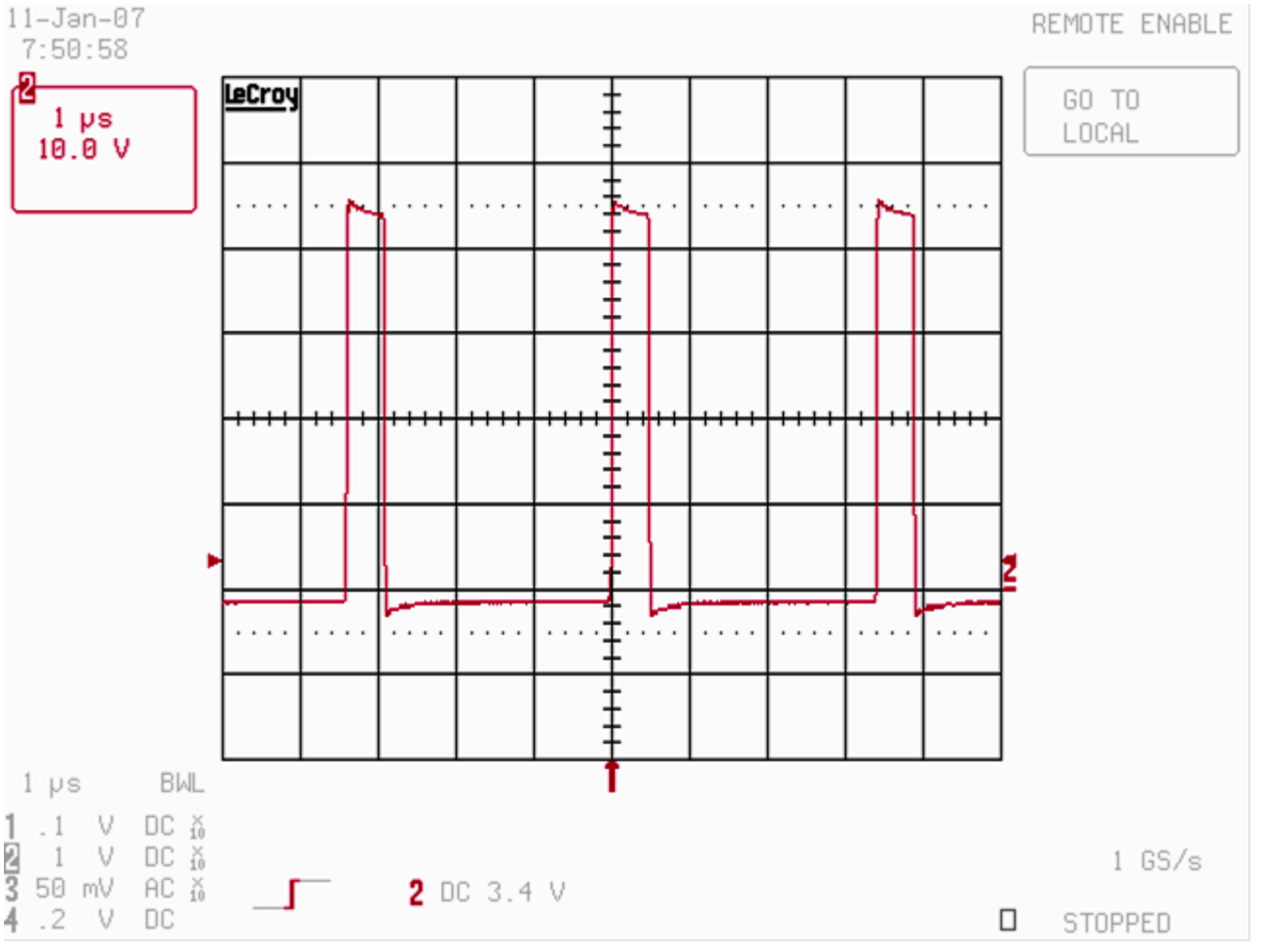


image7

**FIGURE 14. Switch Node Voltage Vin = 42V**

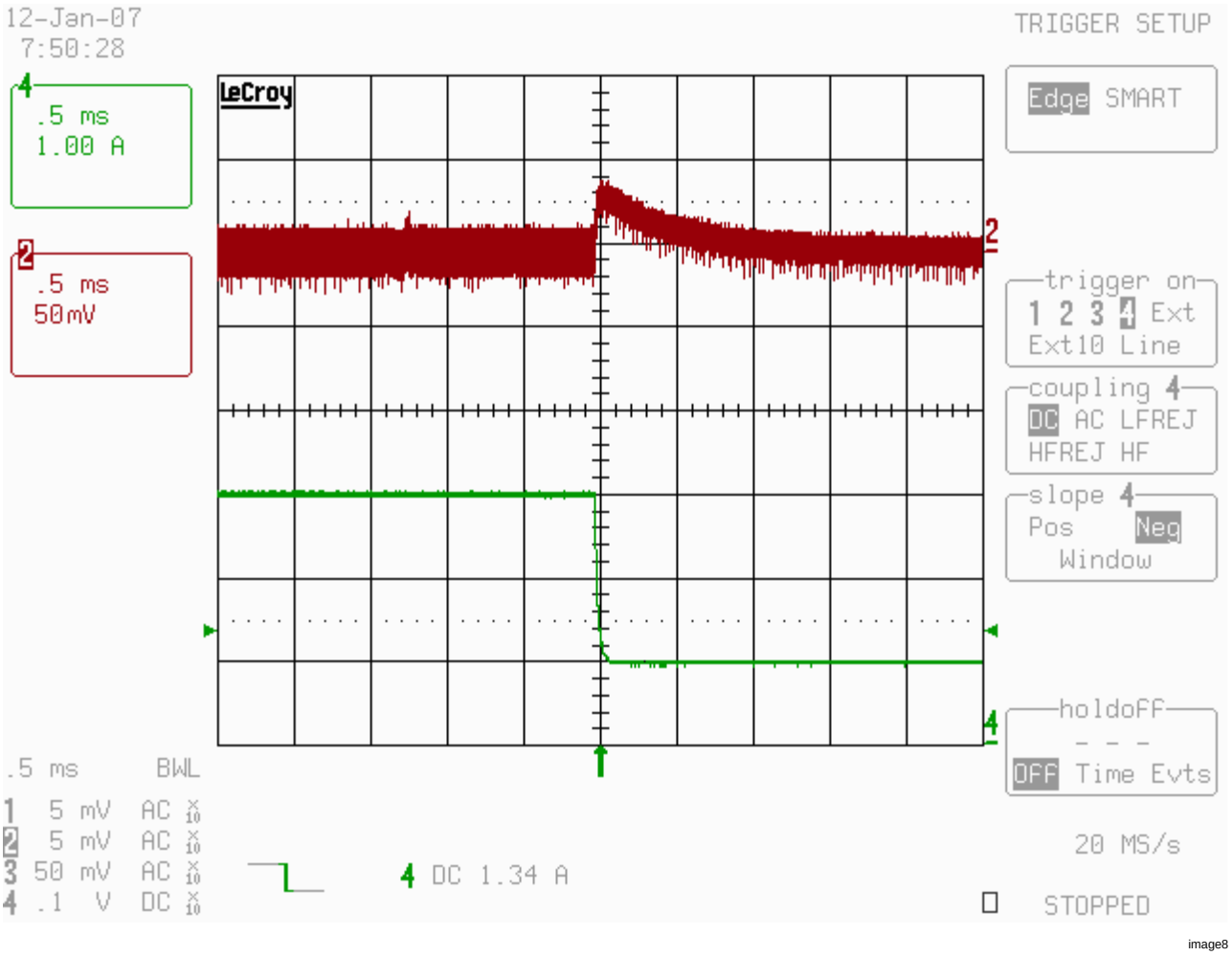


**FIGURE 15. Transient Response, Vin = 12V, ΔI = 1A to 3A Load On**

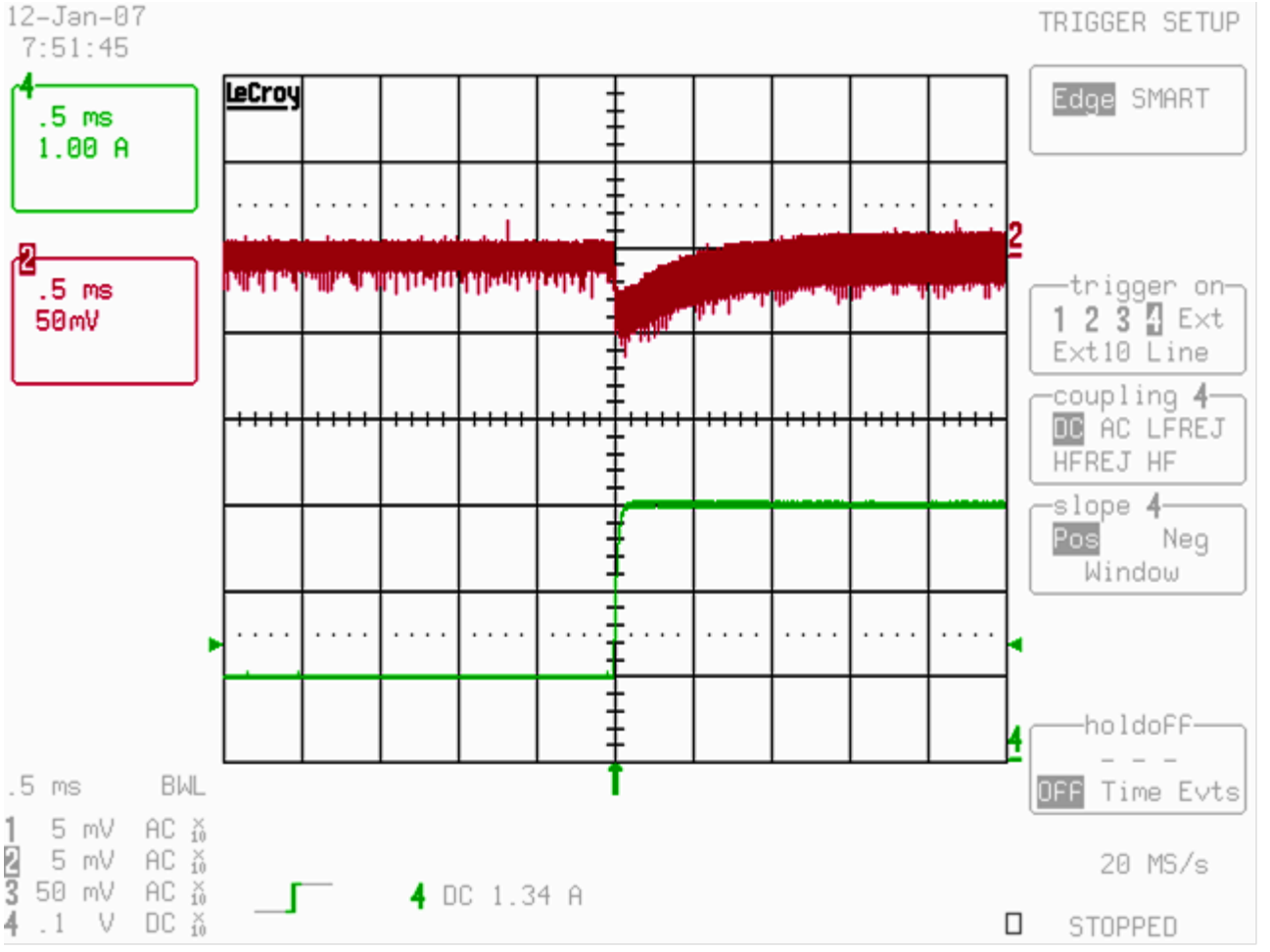


image9

**FIGURE 16. Transient Response, Vin = 12V, ΔI = 1A to 3A Load Off**

# Notes



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