

System Board 6288

## MAXREFDES98#: NON-ISOLATED 5V/2.5A POE POWERED DEVICE POWER SUPPLY

To meet the increasing demands for non-isolated Power over Ethernet (PoE) power solutions, Maxim has developed innovative, non-isolated PoE powered device (PD) power solutions. Each design was tested for load and line regulation, as well as efficiency and transient performance. As with all Maxim reference designs, the BOM, schematics, layout files, and Gerber files are all available and may be downloaded from the Design Resources tab. In addition, boards are available for purchase. These boards feature a module architecture, with through-hole pins for immediate board placement and accelerated prototyping.

MAXREFDES98# combines the PD controller and the step down converter on a 14.0mm (0.55in) x 55.9mm (2.2in) board. The module accepts input voltages ranging from 36V to 57V, and provides an output voltage of 5V with current capacity of 2.5A.

For initial evaluation, Maxim also provides an evaluation board, MAXREFDES98EV#. This board features RJ45 connectors for quick testing with sourced power.



### Features

- 36V ~ 57V input voltage
- Compact and flexible
- Minimal external components
- Robust operation in adverse environments
- 12.5W output capacity
- $\pm 3\%$  output accuracy

## Applications

- Lighting
- IP cameras
- Sensors
- Non-isolated Ethernet equipment

## Introduction

Power over Ethernet (PoE) provides power to Ethernet connected devices, through Ethernet lines, eliminating the need for connecting AC mains to the target devices. In addition to reducing cabling, PoE provides multiple advantages for many applications such as LED lighting, cameras, sensors, and additional equipment. These advantages include network management of devices, power measurement, and elimination of AC/DC circuitry.

Many PoE applications are isolated, to protect both people and systems from voltage and current transients. However, many applications do not require isolation, such as LED lighting and other equipment that is generally out of range for human touch. In these cases, eliminating the isolation circuitry further reduces cost and power dissipation at the PoE point of load. MAXREFDES98# is a unique PoE module reference design, providing 5V at 2.5A (12.5W) from a 36V to 57V input. This design can be used for evaluation, design, prototyping, and production.

MAXREFDES98# includes two function blocks: the PD controller block and the step down DC-DC power supply block. The PD controller uses the MAX5969A. The MAX5969A is an IEEE® 802.3af compliant, powered device interface controller with an integrated power MOSFET. The DC-DC power supply uses the MAX17503. The MAX17503 is a 4.5V~60V input, 2.5A output, high-efficiency synchronous step down converter with internal compensation. The entire design delivers a peak efficiency of 86% with an input of 48V.

The MAXREFDES98# features 12 through-hole pins spaced at a 2.54mm pitch standard. This modular architecture allows MAXREFDES98# to be soldered into a PCB or inserted into the MAXREFDES98EV# for evaluation.

## System Diagram

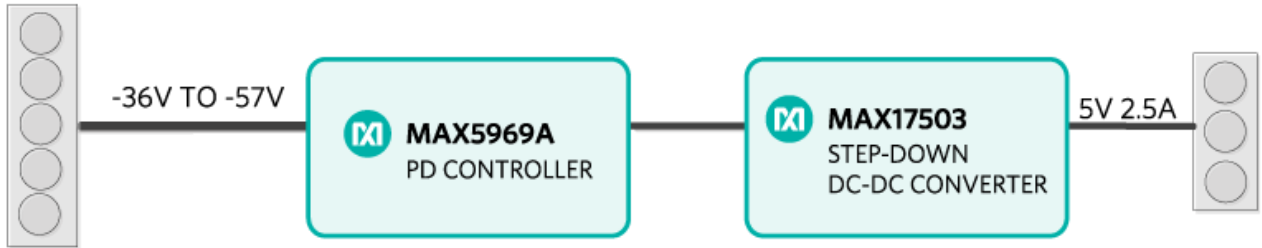


Figure 1. MAXREFDES98# reference design block diagram.

## Detailed Circuit Description

The MAXREFDES98# reference design contains all the control circuitry and electric components required for designing a 36V to 57V wide-input, 5V/2.5A (12.5W) output non-isolated step down converter power supply.

On the board, there are two 6-pin connectors. **Table 1** and **Table 2** provide the function of each pin.

Pin #	Name	Function
1	VA1	Rectifier A input terminal 1
2	VA2	Rectifier A input terminal 2
3	VB1	Rectifier B input terminal 1
4	VB2	Rectifier B input terminal 2
5	CP1	PD Classification resistor terminal 1
6	CP2	PD Classification resistor terminal 2

Pin #	Name	Function
1	V <sub>OUT</sub>	5V output

2	$V_{OUT}$	5V output
3	GND	Ground
4	GND	Ground
5	NX	Not connected
6	RESET	Reset signal, active low

The MAXREFDES98# circuit consists of two function blocks: the PD controller and the step down DC-DC converter.

The PD controller section employs the MAX5969A. The MAX5969A provides a complete interface for a powered device (PD), compliant with the IEEE® 802.3af standard. The MAX5969A provides the PD with a detection signature, classification signature, and an integrated isolation power switch with inrush current control. Visit the [MAX5969A](#) product folder for more information.

When the MAXREFDES98# board is connected to PoE power sourcing equipment (PSE), the MAX5969A conducts the detection and classification process according to the IEEE 802.af/at standard. The on board classification resistor R1 (619Ω) sets the power rating to class 3, a maximum of 12.95W. On the MAXREFDES98EV# board, there is one resistor place holder that can be used to change the power class. Refer to below table to select the appropriate R3 value on the MAXREFDES98EV# board.

**Table 3. R3 value used to set PD classification class**

PD class	Maximum power consumed by PD	R3 value	Classification current
Class 0	0.4W to 12.95W	open	1.99mA
Class 1	0.44W to 3.94W	143Ω	10.8mA
Class 2	3.94W to 6.49W	75Ω	18.7mA

MAX5969A provides one Power Good (PG) signal. Only after the MAX5969 internal hot-swap MOSFET switch is fully turned on, does the PG signal become active. PG is used as the signal to enable the DC-DC converter circuit. This process reduces the inrush current and the heat generated by the MAX5969 during startup.

The MAXREFDES98# reference design uses two bridge rectifiers, which make the design compatible with most PSE types. The bridge rectifiers cause power loss since there are always two diodes conducting, at the same time when the circuit is working. To improve efficiency, MAXREFDES98# uses low forward voltage Schottky bridge rectifiers. Test data shows that by using 100V/1A Schottky rectifiers (KMB110F), peak efficiency can be improved by about 1% compared to a traditional bridge rectifier such as the HD01-T.

Following the PD controller is the step down DC-DC converter. This circuit employs the MAX17503, Maxim's high efficiency, synchronous step-down DC-DC converter with internal compensation. For more specific information about the MAX17503, refer to the [MAX17503](#) product folder. The MAX17503 circuit has been optimized for efficiency and reduction of inrush current using two different inductors. The system performs at a peak efficiency of 86% with a switching frequency to 300kHz, set with the RT resistor to 68k $\Omega$ .

For the inductor, MAXREFDES98# has been tested with the SLF12575T-150M4R7-PF from TDK and the HR320102-150 from HanRun. Test data shows these two inductors get nearly the same performance. In case you need to build your own circuit based on the MAXREFDES98# reference board, make sure the saturation current rating ( $I_{SAT}$ ) of the inductor is high enough so that saturation can occur only above the peak current-limit value of 3.7A.

The MAXREFDES98# is set to a soft-start time to 3.2ms. A soft-start reduces the inrush current from the PSE. **Figure 3** shows the soft-start waveform. The yellow trace is the enable signal (PG) from the MAX5969A, and the blue trace is the output voltage from the MAX17503.



Figure 3. Soft-start feature.

MAXREFDES98# reserves one RESET output pin (Pin 6 of J2, as described in table 2), which can be connected to the RESET pin of a microcontroller. This pin is open drain output, so users can OR (negative logic) it with another open drain signal, such as a watch dog circuit reset output, or manual reset switch. During the soft start phase, the RESET pin stays low. It goes high 3.4ms after the output voltage exceeds 4.75V. The blue trace in **Figure 4** is the RESET signal, captured with an external 10kΩ resistor pulled up to  $V_{OUT}$ . The yellow trace is the output voltage trace.



Figure 4. RESET goes high

3.4ms after  $V_{OUT}$  exceeds 4.75V.

Quick Start

## Required equipment:

- MAXREFDES98# board
- MAXREFDES98EV# board
- RJ45 cable and one PSE RJ45 socket capable of delivering PoE, or one DC power supply adjustable to 57V
- One electronic load
- One voltmeter

## Procedure

The MAXREFDES98# board is fully assembled and tested. Use the following steps to verify board operation.

1. Insert the MAXREFDES98# board into the MAXREFDES98EV# board, as shown in **Figure 5**.



*Figure 5.*

*MAXREFDES98# connected to the MAXREFDES98EV#.*

2. Insert one end of the RJ45 cable to the PSE RJ45 socket, then insert the other end to J1 on MAXREFDES98EV# board, as shown in **Figure 6**. The "PWR" LED on right bottom corner should light up continuously or flash slowly, depending on the PSE.

In case the "PWM" LED does not light up, the RJ45 socket likely does not have the POE feature. In this case, connect the power supply (37V~57V) to VA1/VA2, or VB1/VB2. There is no polarity requirement when the power is connected, since there are bridge rectifiers following these connectors. When the power supply is turned on, the "PWM" LED should light up continuously.



Figure 6. When

*the MAXREFDES98# board works, the PWR LED on the MAXREFDES98EV# board lights up.*

3. Connect the  $V_{OUT}$  and PGND terminals on the MAXREFDES98# board to the electronic load.
4. Set the electronic load to a constant current up to 2.5A.
5. Connect the voltmeter to the VDC and GND, to verify the output voltage reading is  $5V \pm 0.15V$ .
6. Set the electronic load to "short," and turn off the PWR LED. When the "short" is released, the PWR led should light up again, and the voltage should read  $5V \pm 0.15V$ .

On the MAXREFDES98EV# board, a current sense amplifier, [MAX9643](#), measures the output current of the MAXREFDES98# board, and similar boards, such as the MAXREFDES108#. To get the actual current, divide the voltage measured by 1.6. For example, if  $I_{OUT}$  is measured at 1.6V, the actual current drawn from MAXREFDES98# board is 1A. The  $I_{OUT}$  is designed to measure steady state current. If it is used to capture the transient current waveform, there will be distortion on the waveform due to MAX9643's signal bandwidth and pulse response. For more information, refer to the [MAX9643 data sheet](#). **Figure 7** shows the error curve of the current measurement circuit. Error increases as measured current decreases, as is consistent with any current measuring system.



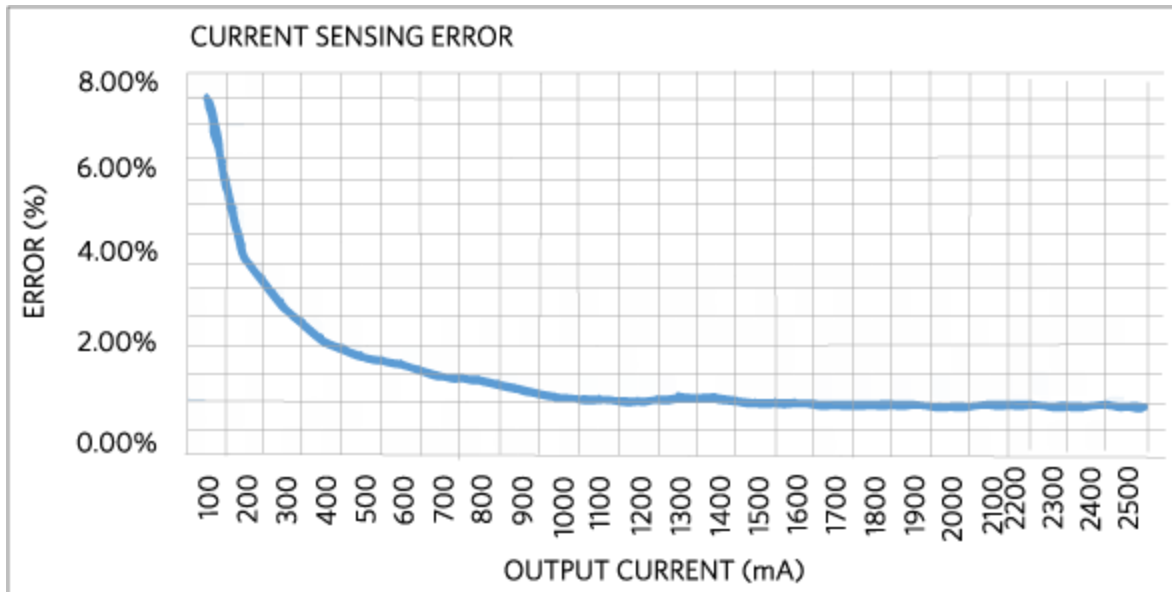


Figure 7. Current error of the current measurement circuit (tested on 5 samples).

### Lab Measurements Data

The MAXREFDES98# design was verified and tested under the full input range and different output load conditions.

### Power efficiency vs. load current

MAXREFDES98# performs with high efficiency, across a range of input voltages. Peak efficiency is 86%, and efficiency is high across a wide output current range.

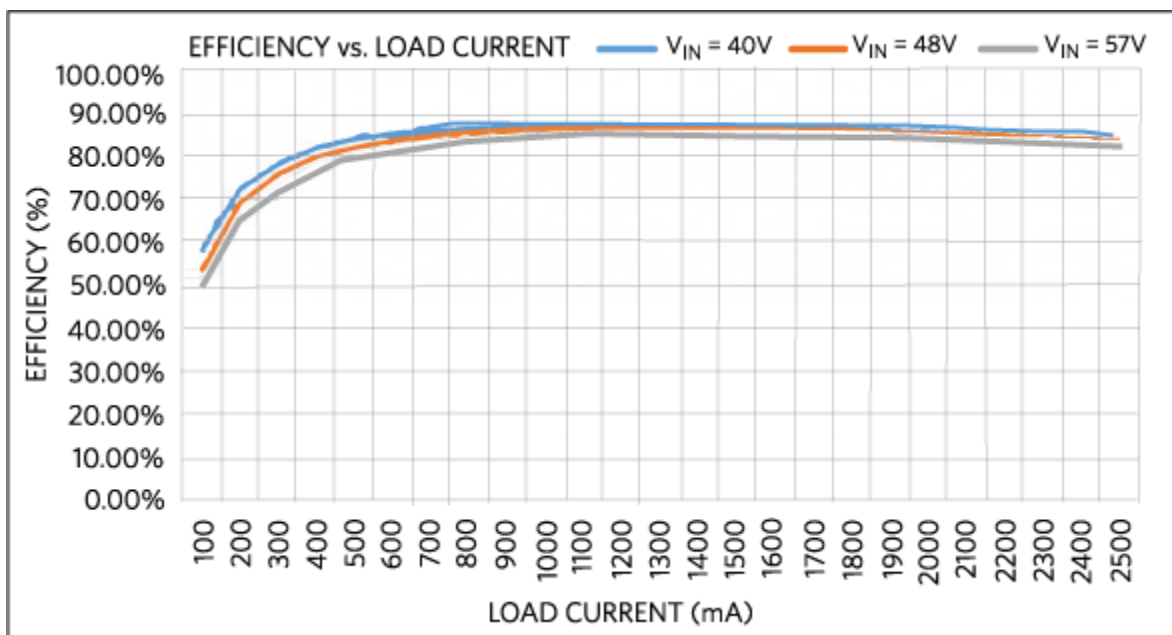


Figure 8. Power efficiency vs. load current.

### Load regulation:

Load regulation (**Figure 9**) was measured for input voltages of 40V, 48V, and 57V. The output voltage remains well regulated across the range of output current, deviating by less than 1.5%. Line regulation (**Figure 10**) is completely solid across the entire range of input voltages. Output ripple was measured at 5mA output (**Figure 11**) and is less than 100mV. At a current output of 2.5A, output ripple is also less than 100mV (**Figure 12**). Transient responses were measured from 5mA to 1000mA and back (**Figure 13**) and from 1500mA to 2500mA and back (**Figure 14**). In both cases, system response is around 100mV.

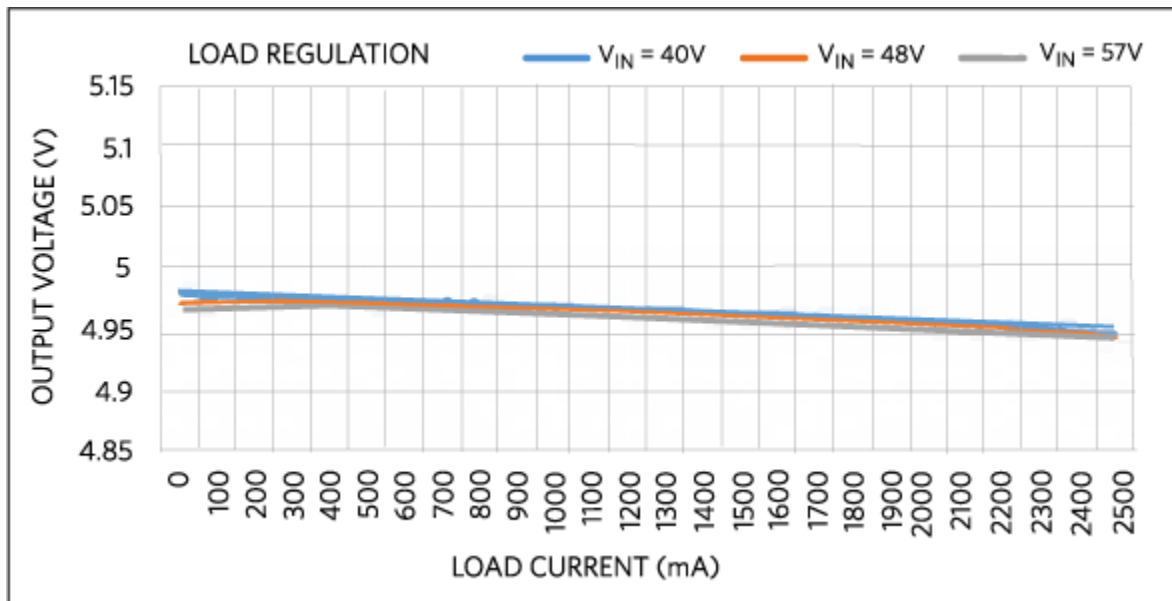


Figure 9. Load regulation.

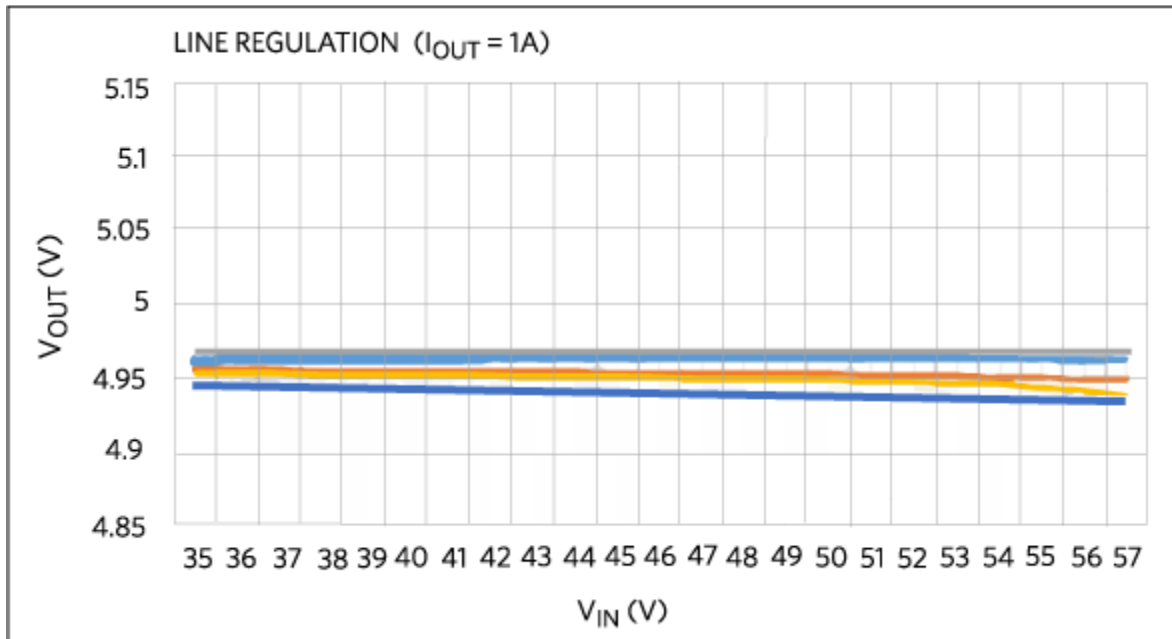


Figure 10. Line regulation when output current is 1A.

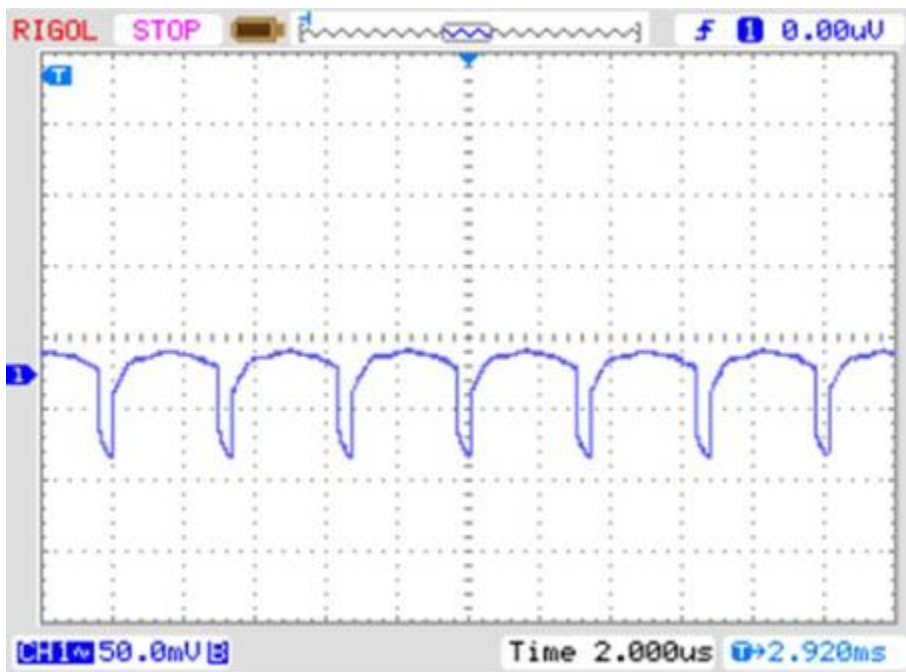


Figure 11. Output ripple at 5mA load.

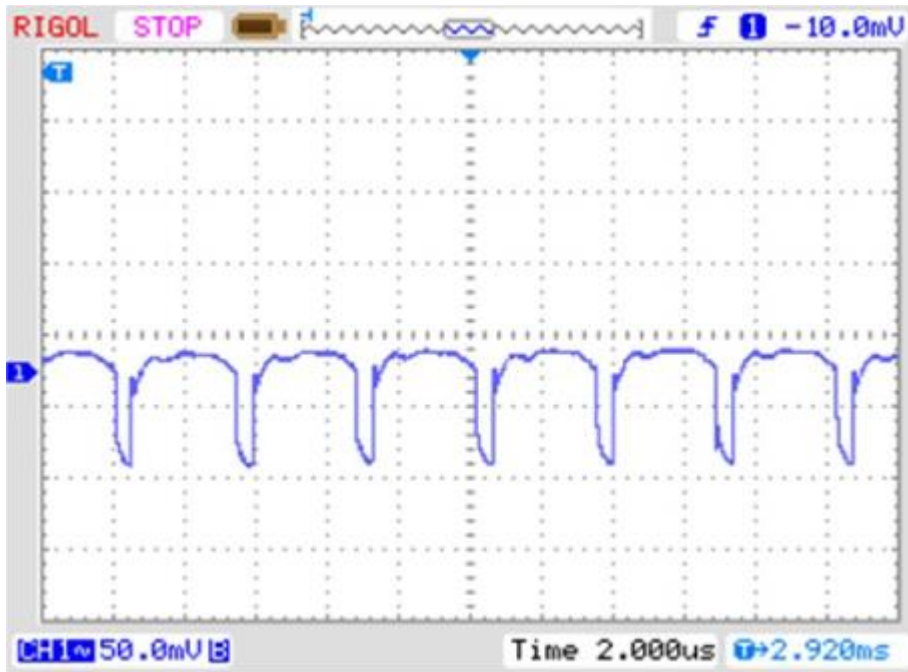


Figure 12. Output ripple at full load (2500mA).

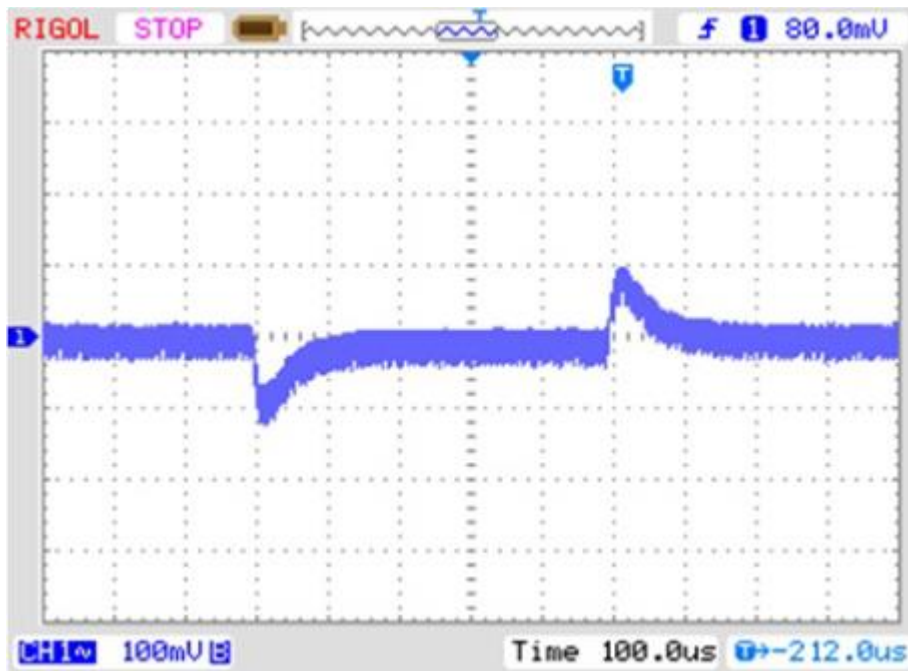


Figure 13. Load transient response when load steps between 5mA and 1000mA.

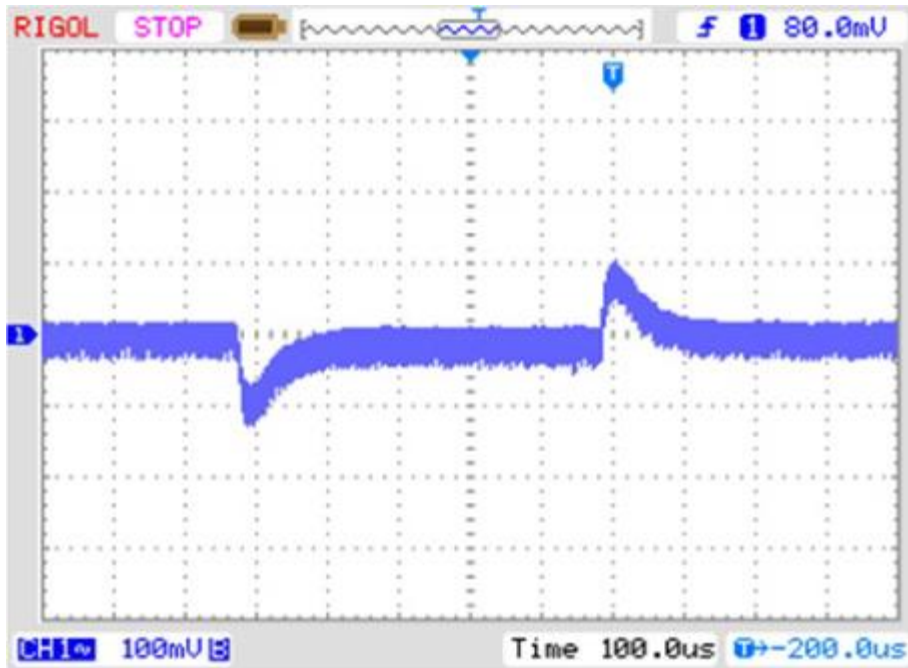


Figure 14. Load

*transient response when load steps between 1500mA and 2500mA.*

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## Quick Start

### Required equipment:

- MAXREFDES98# board
- MAXREFDES98EV# board
- RJ45 cable and one PSE RJ45 socket capable of delivering PoE, or one DC power supply adjustable to 57V
- One electronic load
- One voltmeter

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