

Non-isolated bidirectional synchronous buck converter EVAL_BIDI_HB_1EDN7550B

Using 1EDN7550B with truly differential inputs

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About this document

Scope and purpose

The 1EDNx550B is the EiceDRIVER™ family of single-channel gate drivers with truly differential inputs (TDI).

The bidirectional buck converter evaluation board EVAL_BIDI_HB_1EDN7550B described in this document is designed to show the application of the 1EDNx550B in low-side (LS) and high-side (HS) drive situations.

Intended audience

This document is intended for SMPS designers and engineers interested in:

- Understanding the advantages of the driving concept with TDI
- Using the 1EDNx550B as a HS driver in low-voltage (LV) applications up to 84 V bulk voltage (full-bridge synchronous rectifiers, half-bridge (HB) and full-bridge-based brick converters)

Common abbreviations

- ADC ... Analog-to-digital converter
- UART ... Universal asynchronous receiver-transmitter
- MOSFET ... Metal-oxide-semiconductor field-effect transistor
- PWM ... Pulse width modulation

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Board description

1 Board description

This evaluation board consists of a bidirectional buck converter, which includes the following key components from Infineon:

- EiceDRIVER™ 1EDN TDI (**1EDN7550B**) with 4 V undervoltage lockout (UVLO) as HB LS and HS drivers
- OptiMOS™ 150 V 9.3 mΩ (**BSC093N15NS5**) in **SuperSO8** package as a power MOSFET
- **XMC1100** microcontroller for digital control

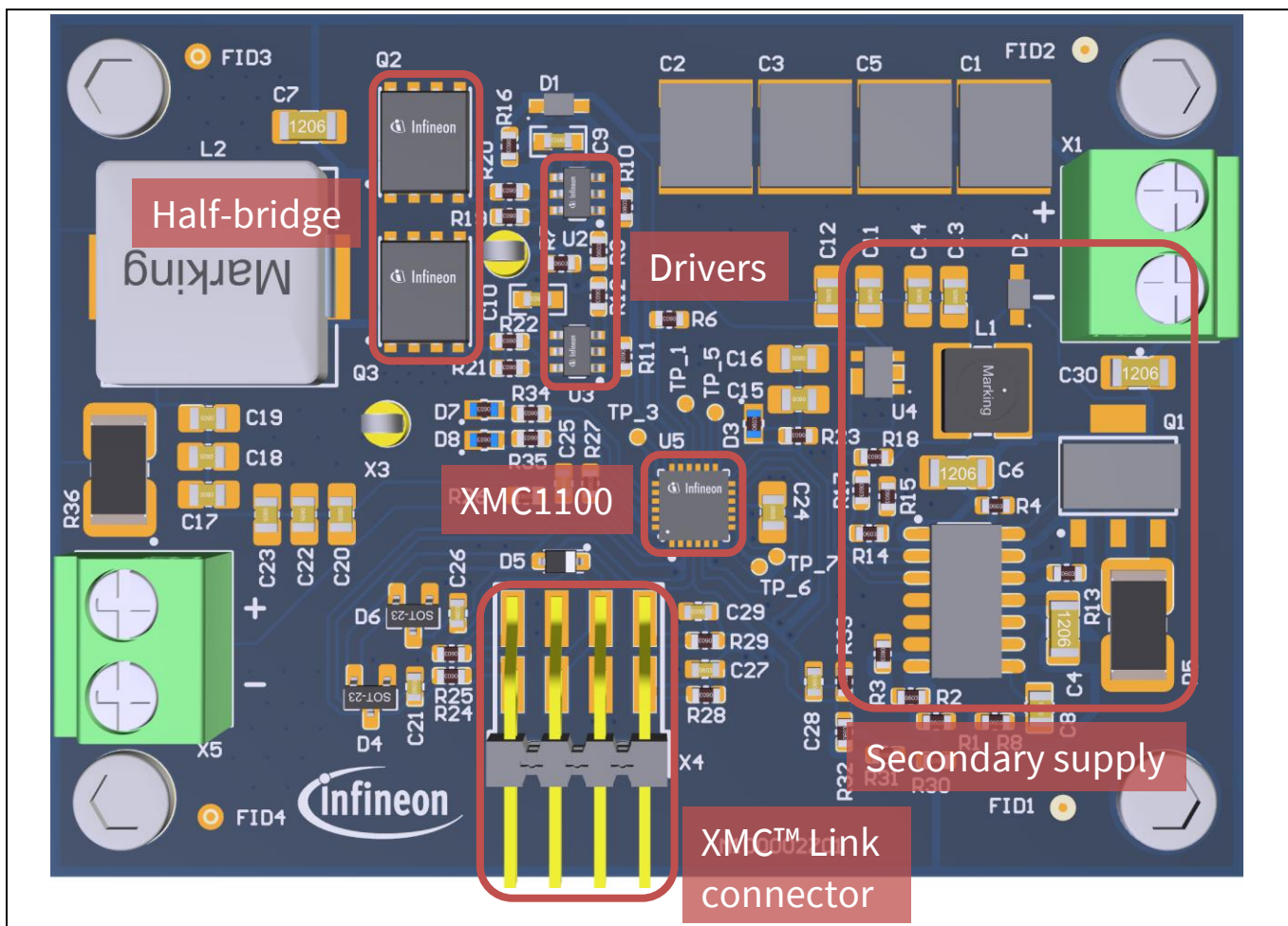


Figure 1 Component descriptions

1.1 Detailed component description

1EDN7550B EiceDRIVER™

The **1EDN7550B** driver is used to drive the LS and HS MOSFET. This is possible due to the truly differential input.

BSC093N15NS5 OptiMOS™ MOSFET

With its low $R_{DS(on)}$ and small footprint, this **BSC093N15NS5** MOSFET is ideal for this use case.

Board description

XMC1100 microcontroller

This **XMC1100** microcontroller has four 16-bit timers that are used to generate the PWM. The built-in six-channel 12-bit ADC is used for the compensation algorithm and metering. Using one USIC module, it can communicate with the UI via UART.

IFX80471SK V buck controller

The **IFX80471SK V** buck controller is used to generate 12 V out of the input voltage.

BS-channel MOSFET and BAS16-03W diode

BS-channel MOSFET and **BAS16-03W** diode are the external components needed by the IFX80471SK V controller. One of the diodes is used for the bootstrap circuit.

IFX20002MB V33

The **IFX20002MB V33** is a low-dropout (LDO) regulator that supplies the microcontroller with 3.3 V.

BAT54-04 and BAT165

BAT54-04 and **BAT165** electrostatic discharge (ESD), overvoltage and reverse voltage protection.

2 Getting started with the hardware

The intention of this section is to make the user able to power up the board.

2.1 Additional equipment

In order to turn on the board, a suitable power supply is needed. See the table below for a selection guide.

Table 1 Power supply selection guide

| Desired operation mode | Required power supply | Example |
|------------------------|----------------------------|--|
| Buck mode | 22 to 48 V DC power supply | MEAN WELL GST60A48-P1J |
| Boost mode | 12 V DC power supply | MEAN WELL GST60A12-P1J |

If control of the converter via the UI is needed, the following equipment and software is necessary.

Table 2 Required equipment for use with UI

| Required hardware | Purpose | Link |
|--------------------|--|---|
| XMC™ Link debugger | Used to connect to the converter | https://www.infineon.com/cms/en/product/evaluation-boards/kit_xmc_link_segger_v1/ |
| MicroUSB cable | Used to connect the debugger with the computer | |

Table 3 Required software for use with UI

| Required software | Purpose | Link |
|------------------------|--|---|
| Segger's J-Link driver | Enables UART communication for use with the UI | https://www.segger.com/downloads/jlink/ |
| Infineon converter UI | Set and read parameters of the converter | |

2.2 Initial operation

The board will operate in buck mode by default. This can be changed in the UI later. Depending on the desired operating mode, the board must be connected differently. In [Figure 2](#) the configuration for buck operation is shown; the one for boost mode is shown in [Figure 3](#). A power-up in the buck configuration is not necessary in order to change to boost mode.

Note: Make sure the supply and the load are connected with the right polarity before powering the board. Flipping the polarity may damage the board or the load.

Non-isolated bidirectional synchronous buck converter

EVAL_BIDI_HB_1EDN7550B

Getting started with the hardware

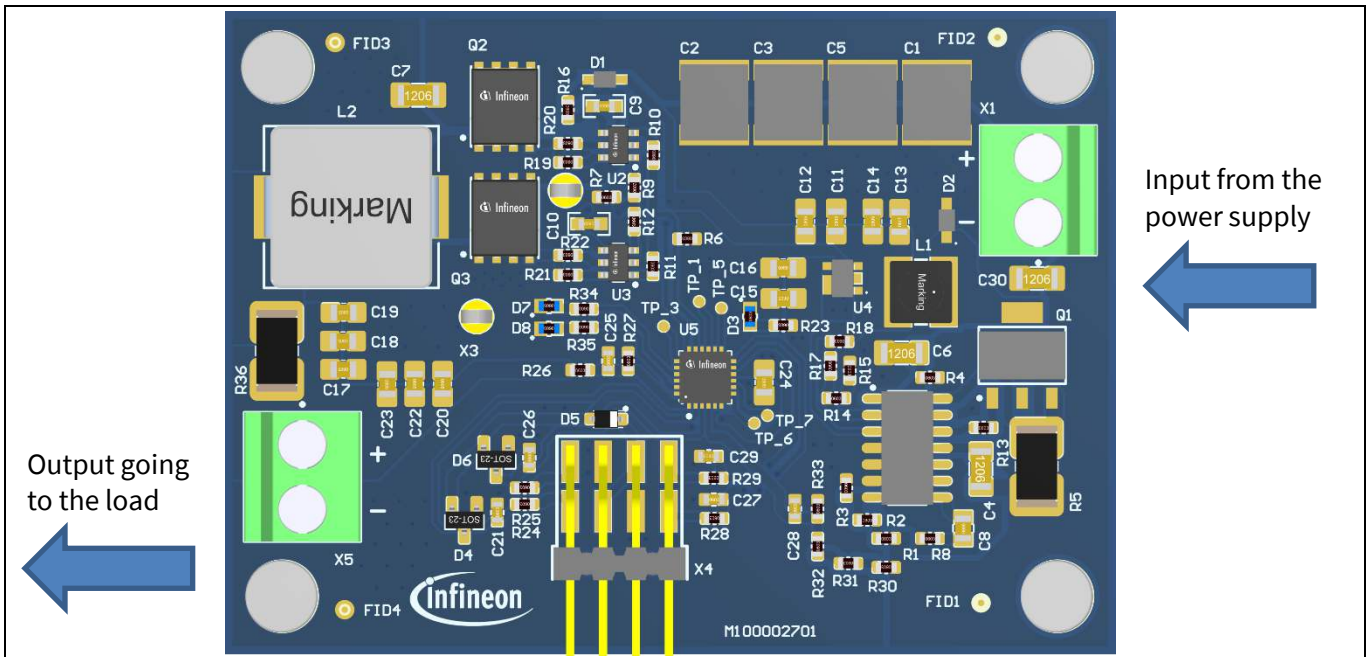


Figure 2 Converter connections in buck mode

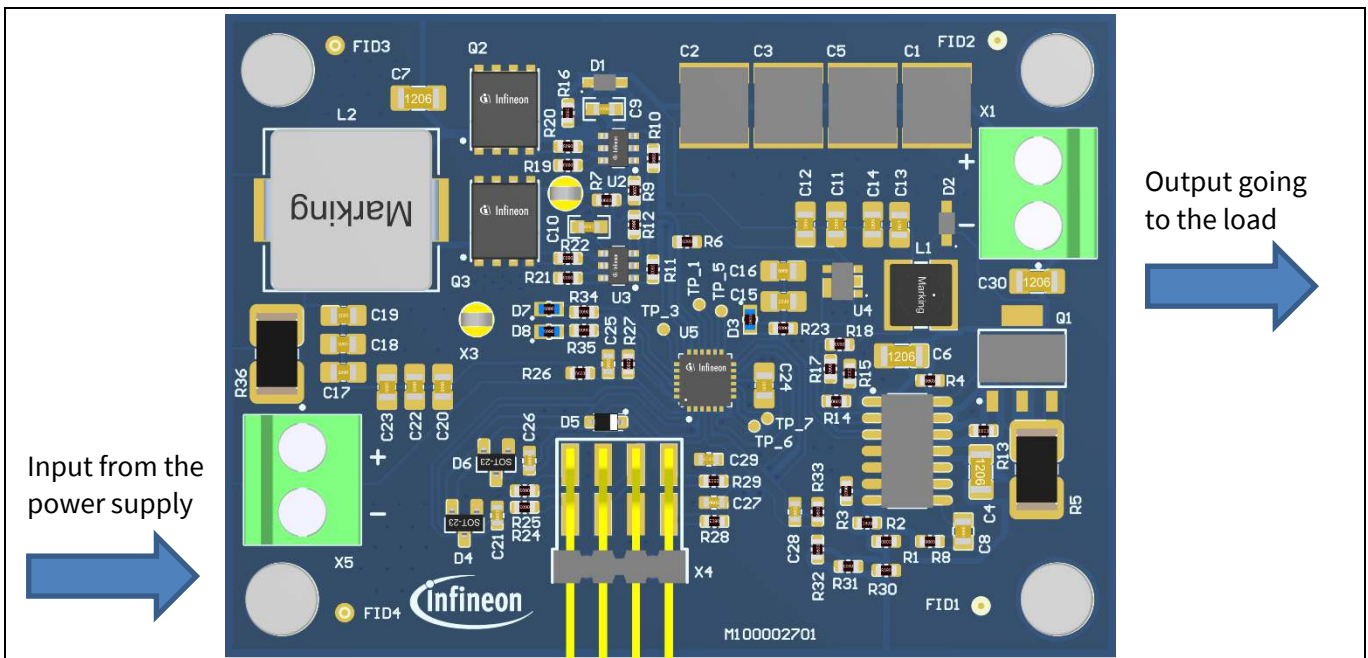


Figure 3 Converter connections in boost mode

The XMC™ Link debugger can optionally be connected to the pins at X4. The ribbon cable can only be plugged in one way with the bump facing upwards. This gives access to the UI where the parameters of the converter can be set and read.

2.3 Operating range

The following tables provide a summary of the specifications. Operating outside these specifications is not recommended.

Attention: *The input voltage must not exceed 60 V in buck mode.*

Table 4 Buck mode specification

| Parameter | Symbol | Values | | | Unit | Notes |
|---|--------------|--------|------|------|------|--|
| | | Min. | Typ. | Max. | | |
| Input voltage | V_{in} | 20 | 48 | 50 | V | - |
| Output voltage | V_{out} | 2 | - | 12 | V | - |
| Output current | I_{out} | - | - | 4 | A | - |
| Undervoltage lockout (UVLO) turn-on threshold | $UVLO_{on}$ | - | 20 | - | V | - |
| Undervoltage lockout (UVLO) turn-off threshold | $UVLO_{off}$ | - | 18 | - | V | - |
| Overvoltage protection (OVP) turn-on threshold | OVP_{on} | - | 50 | - | V | - |
| Overvoltage protection (OVP) turn-off threshold | OVP_{off} | - | 51 | - | V | - |
| Overcurrent protection (OCP) threshold | OCP | 3.5 | 5 | 6 | A | Depends strongly on the input voltage and other parameters |

Attention: *The input voltage must not exceed 25 V in boost mode.*

Table 5 Boost mode specification

| Parameter | Symbol | Values | | | Unit | Notes |
|---|--------------|--------|------|------|------|-------|
| | | Min. | Typ. | Max. | | |
| Input voltage | V_{in} | 11.5 | 12 | 12.5 | V | - |
| Output voltage | V_{out} | 20 | 32 | 32 | V | - |
| Output current | I_{out} | - | - | 0.9 | A | - |
| Undervoltage lockout (UVLO) turn-on threshold | $UVLO_{on}$ | - | 11.5 | - | V | - |
| Undervoltage lockout (UVLO) turn-off threshold | $UVLO_{off}$ | - | 11 | - | V | - |
| Overvoltage protection (OVP) turn-on threshold | OVP_{on} | - | 12.5 | - | V | - |
| Overvoltage protection (OVP) turn-off threshold | OVP_{off} | - | 13 | - | V | - |

Table 6 Timing specification

| Parameter | Symbol | Values | | | Unit | Notes |
|---|-----------------|--------|------|------|---------|-------|
| | | Min. | Typ. | Max. | | |
| Undervoltage lockout (UVLO) delay time on | $t_{UVLO(on)}$ | 80 | 82 | - | ms | - |
| Undervoltage lockout (UVLO) delay time off | $t_{UVLO(off)}$ | 200 | - | - | μ s | - |
| Overvoltage protection (OVP) delay time on | $t_{OVP(on)}$ | 80 | - | - | ms | - |
| Overvoltage protection (OVP) delay time off | $t_{OVP(off)}$ | 200 | - | - | μ s | - |

Undervoltage lockout (UVLO)

When the input voltage is below the threshold, the converter is in UVLO. In this state the power stage is switched off. However the microcontroller is still on. This means that setting parameters is possible.

Overvoltage protection (OVP)

This is a function where the power stage of the converter is switched off above the specified voltage. There is no hardware overvoltage protection present on the board.

Overcurrent protection (OCP)

The OCP works similar to the duty cycle current estimation (Lukic, Stupar, Prodic, & Goder, 2008). The comparison of the actual duty to a calculated duty from the input and output voltage triggers the OCP. Therefore the current is only estimated with great uncertainty. It is intended to provide protect when accidentally connecting a way to large load. For stability reasons one might disable this protection via the GUI when operating close to the current limit.

Description of UI elements

3 Description of UI elements

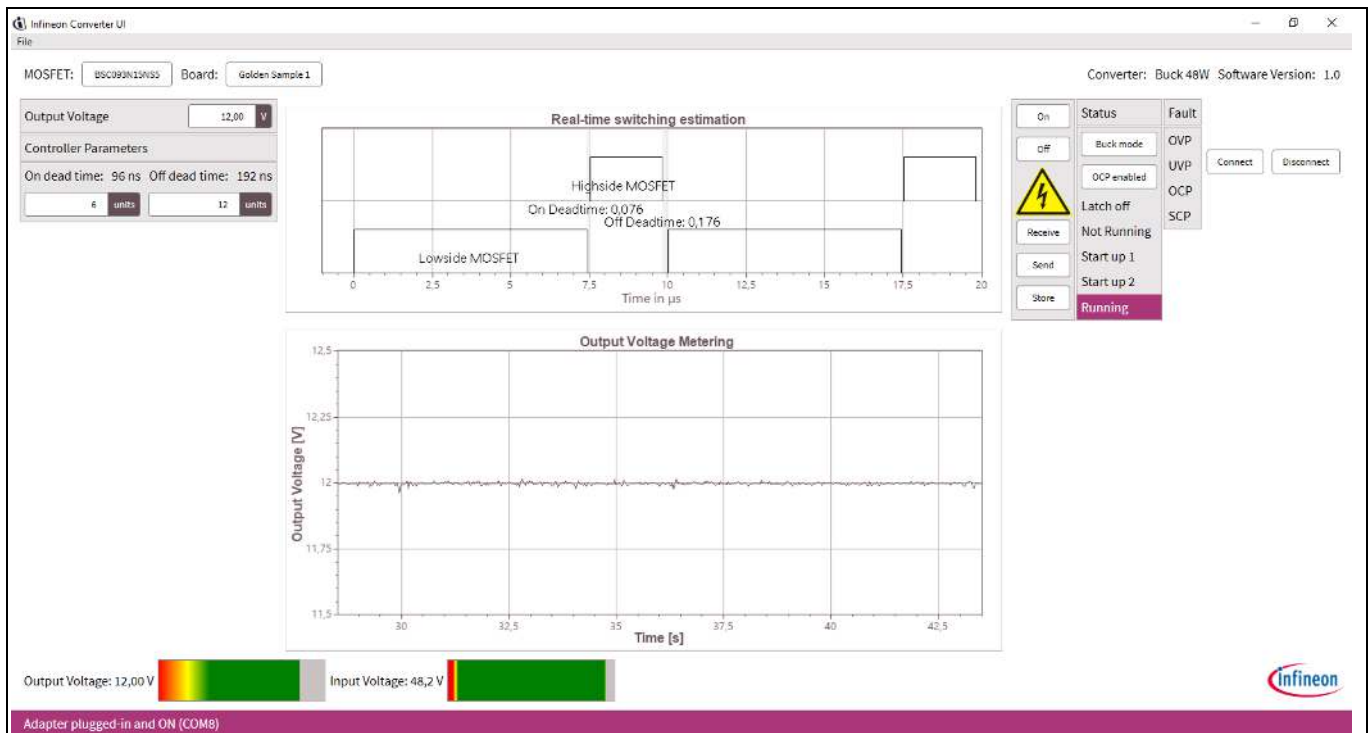


Figure 4 Screenshot of the UI

File

Store and load parameters/configurations.

MOSFET

Fill in the name of the MOSFET currently under test. This information will be saved in the parameter file.

Board

Fill in the name of the board (i.e., Golden Sample 1).

Output voltage

View or change the desired output voltage. It has a tooltip that describes the minimum and maximum values.

On dead time

Set the time between the LS MOSFET switching off and the HS MOSFET switching on. One unit is approximately 16 ns.

Off dead time

Set the time between the HS MOSFET switching off and the LS MOSFET switching on. One unit is approximately 16 ns. This dead time is when zero voltage switching (ZVS) can occur.

Real-time switching estimation

This graph displays the dead times and the estimated MOSFET switch times.

Description of UI elements

Output voltage metering

Real-time graph of the converter output voltage.

On

Switches the PWM of the microcontroller on (board starts converting voltage).

Off

Turns off the PWM of the microcontroller (board stops converting voltage).

Receive

Receive current microcontroller parameters.

Send

Send changed parameters to the microcontroller.

Store

Store the parameters of the microcontroller permanently (in the ROM).

Buck/Boost button

Switch between buck and boost mode. The current mode is visible.

Note: After changing the mode, the converter will start up when the input voltage has a correct level.

Connect

Try to connect with the debugger and the board.

Connect the GUI to the microcontroller (communication).

Disconnect

Disconnect the GUI from the microcontroller (communication).

Note: Disconnecting and then connecting may be required when the converter is not detected automatically.

3.1 Status

Latch off

Converter stops and will only turn on again if the user presses the on button.

Not running

Converter starts if the requirements (minimum input voltage) are met.

Start-up 1

First start-up phase. In this phase the converter waits a fixed amount until the input voltage is stable.

Description of UI elements

Start-up 2

Second start-up phase.

Running

Converter is converting voltage.

3.2 Fault

Overvoltage protection (OVP)

Overvoltage protection: converter switched off due to too high of output voltage (i.e., instable algorithm/parameters) or due to too high of input voltage.

Undervoltage protection (UVP)

Undervoltage protection: converter switched off due to too low of input voltage.

Overcurrent protection (OCP)

Converter switched off due to too high of current.

Short-circuit protection (SCP)

Converter switched off due to a short-circuit. This is triggered by a sudden drop of the output voltage.

Characteristics

4 Characteristics

This chapter lists some characteristics of this board.

4.1 UI vs. oscilloscope

This chapter should demonstrate the abilities and constraints of the live voltage metering. In order to test this an electronic load jumps every 200 ms from 0 A to 4 A load and back (50/50). These load transients are clearly visible in the output voltage (see [Figure 6](#)). In the UI this can also be seen. As new data is coming in only about every 70 ms this is to be expected. When load transients occur more often you can probably only see that there are many load jumps occurring.

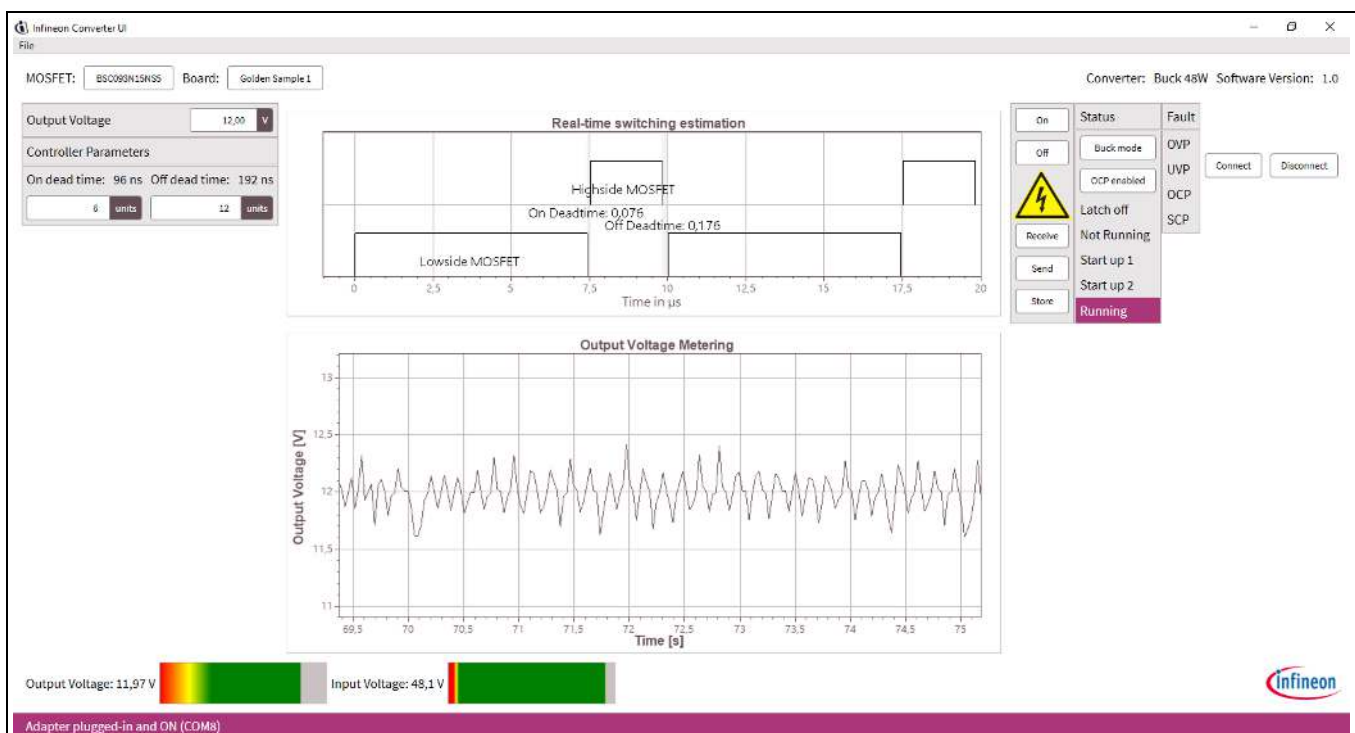


Figure 5 UI while applying load jumps every 100 ms

Characteristics

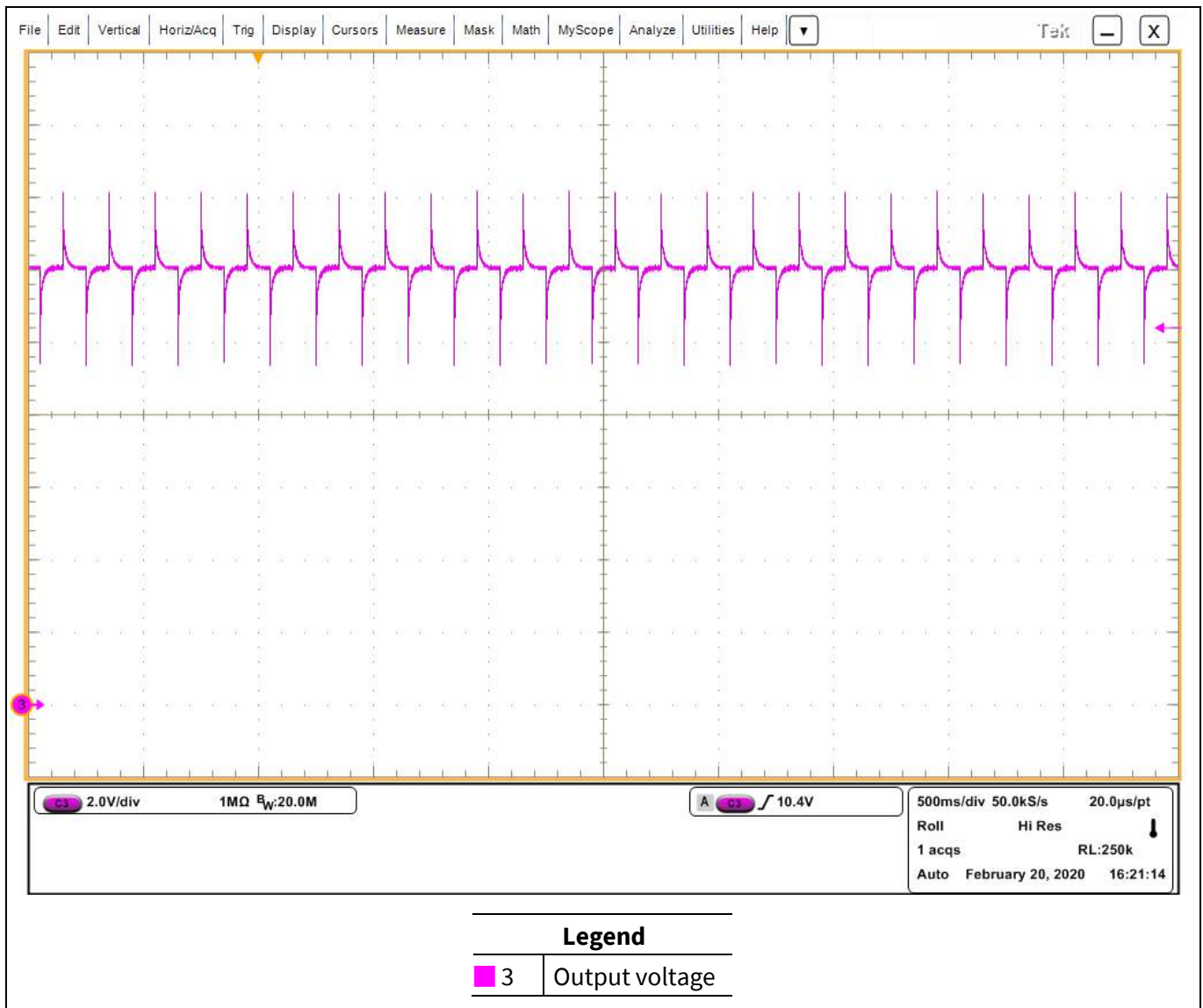


Figure 6 Output waveform during load jumps

4.2 Efficiency

This efficiency curve was measured at room temperature. The converter operates in buck mode and has either a 48 V or 24 V input and a 12 V output voltage. The shunt resistor R36 is replaced with a bridge in order to increase the overall efficiency.

Measures that can be taken to improve the efficiency:

- Decrease the inductor equivalent series resistor (ESR). This is the part that is responsible for most of the power lost.
- Choose MOSFETs that have a lower $R_{DS(on)}$ and a lower voltage rating, such as the [BSC026N08NS5](#).

Characteristics

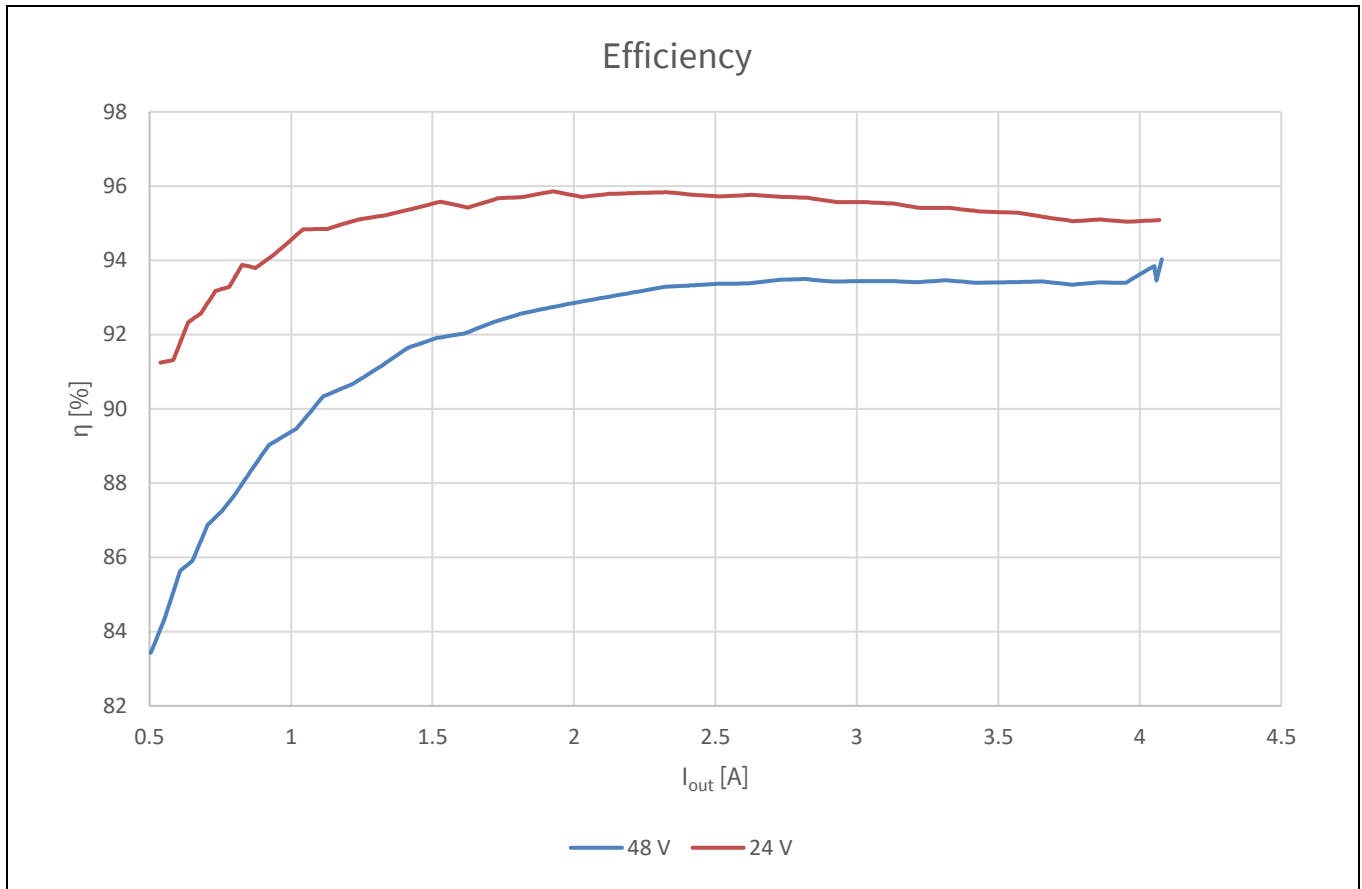


Figure 7 Efficiency at 12 V output in buck mode (R36 has been bridged)

4.3 Start-up in buck mode

The following capture shows the start-up waveform when connected to a MEAN WELL GST60A48-P1J power supply. No load is connected.

Characteristics

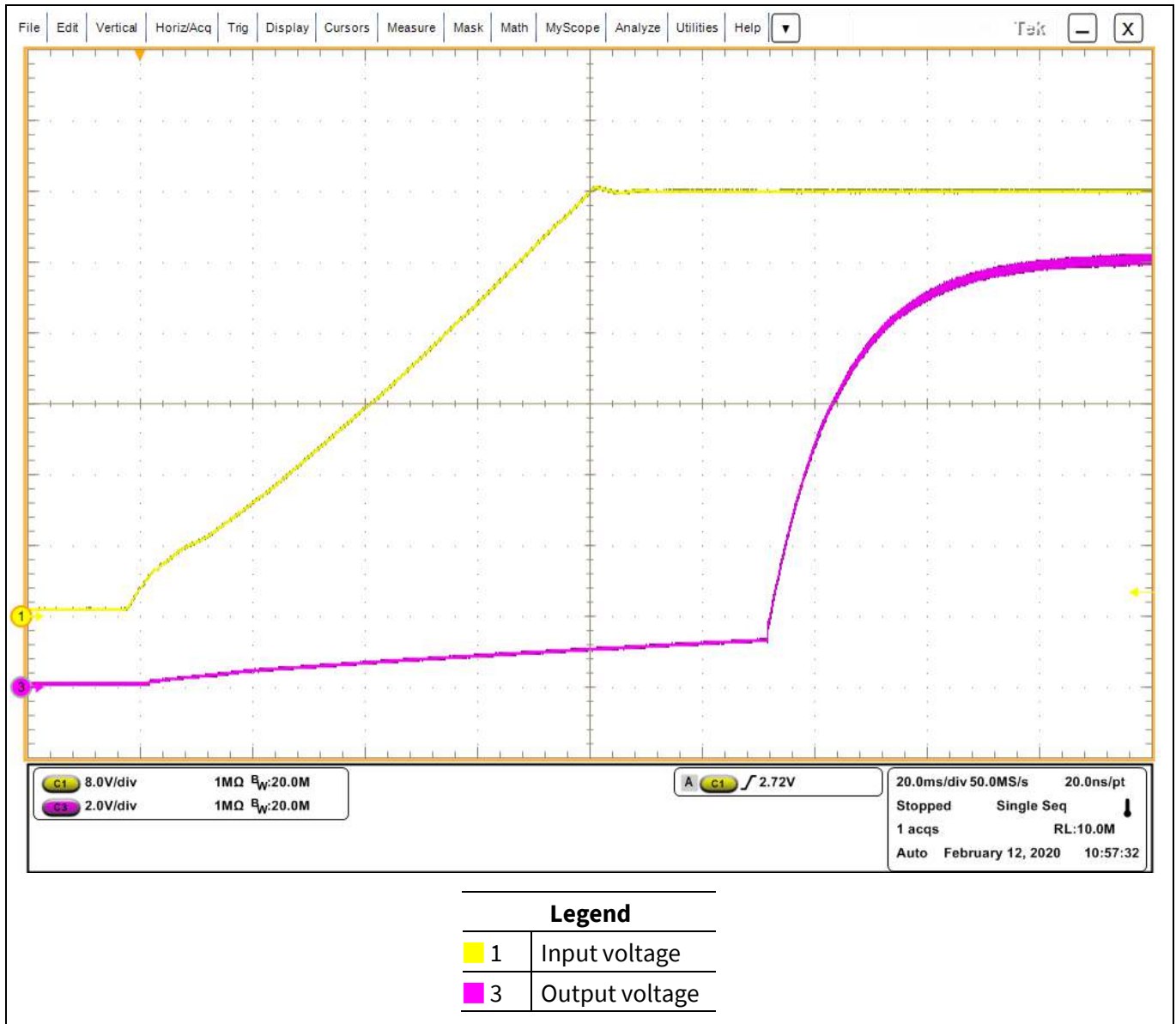


Figure 8 Start-up in buck mode with 48 V input and 12 V output voltage

A start-up under full load (that is 4 A) is shown below.

Characteristics

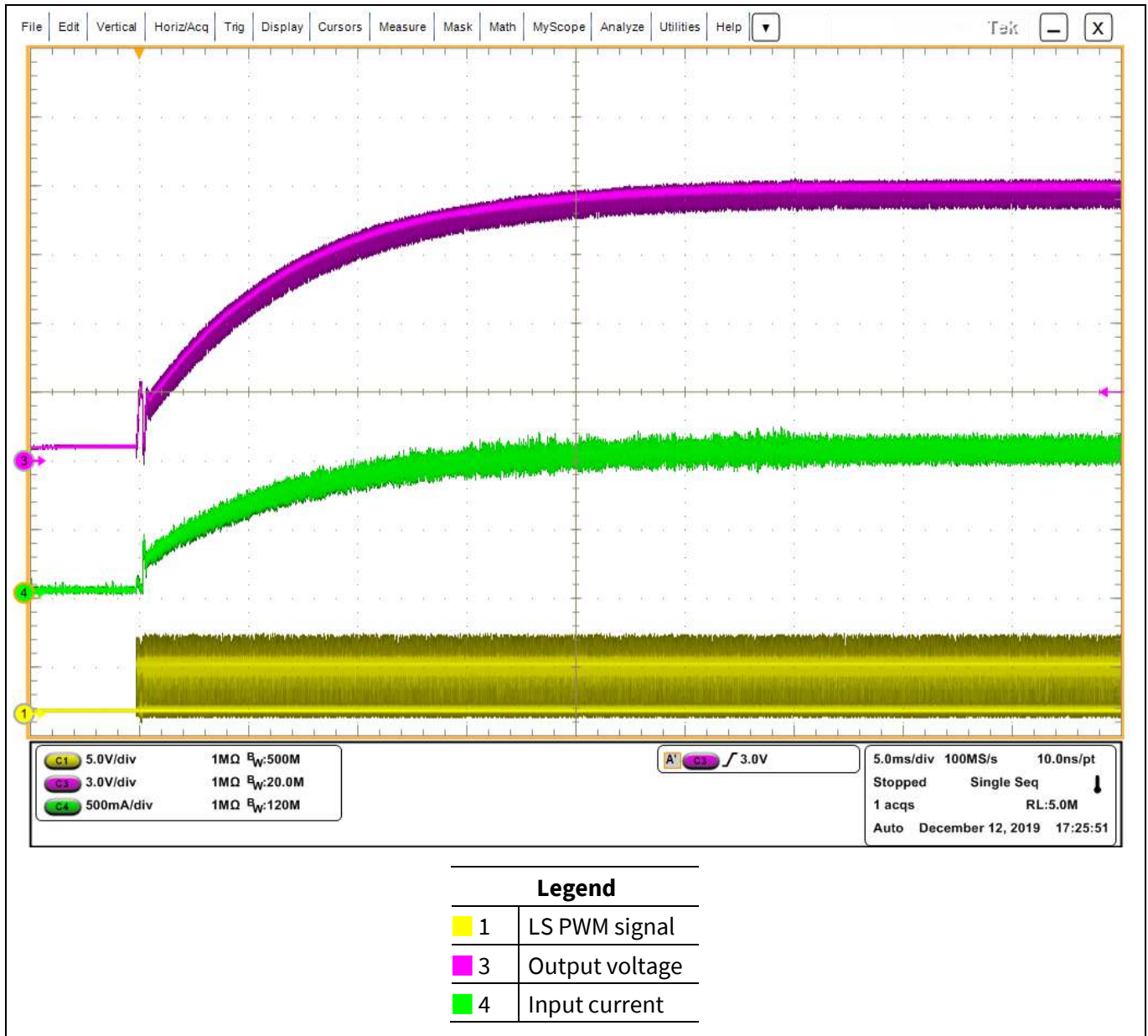


Figure 9 Start-up in buck mode with 48 V input, 12 V output voltage and 4 A load

4.4 Start-up in boost mode

In the figure below, the start-up waveform can be seen. The output voltage has a little overshoot (48.68 V).

Note: Such a large load is not feasible over a long period of time (more than 2 minutes) due to thermal constraints.

Characteristics

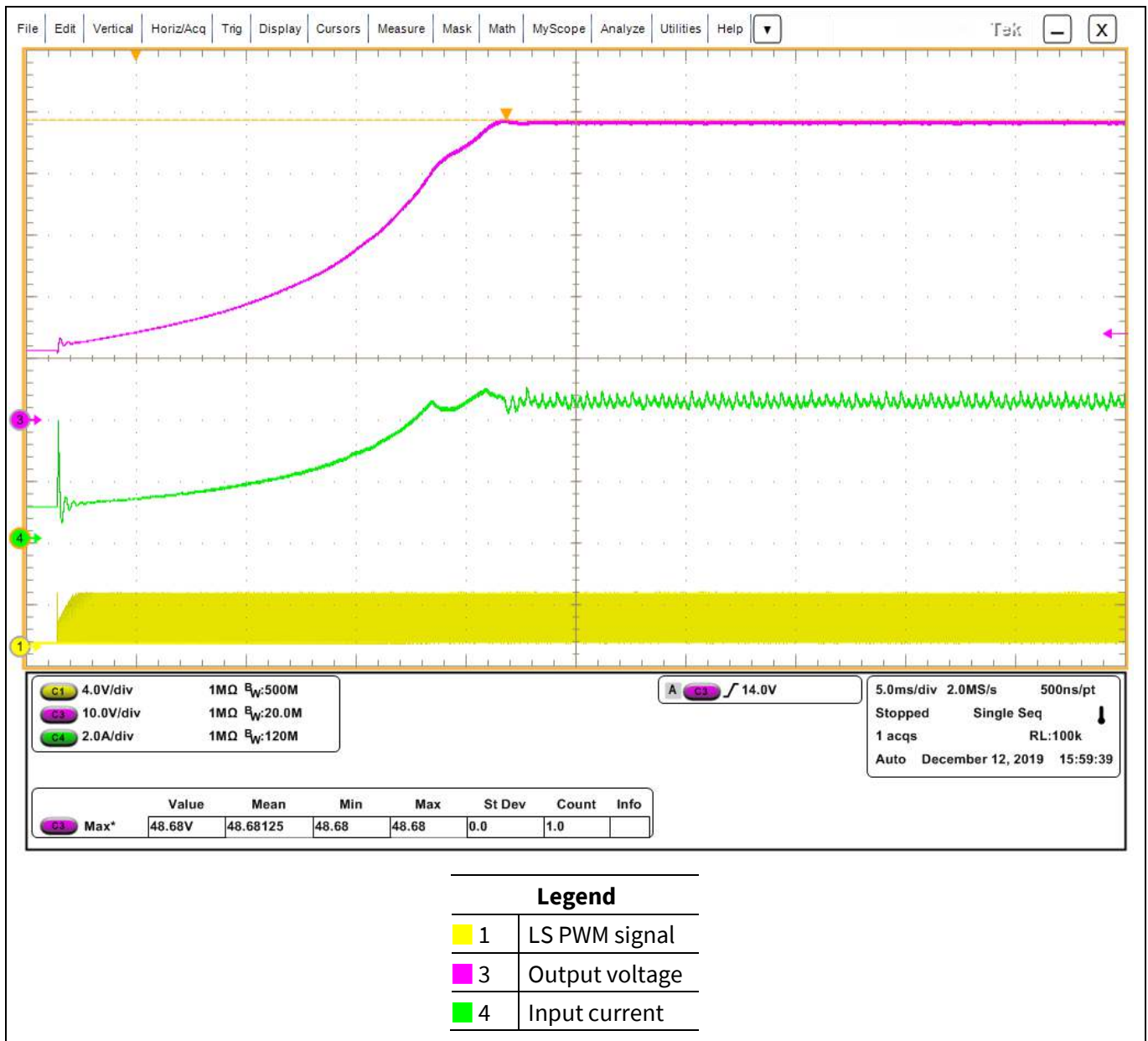


Figure 10 Start-up in boost mode with 12 V input, 48 V output voltage and 1 A load

4.5 Thermal measurements

The figure below show the temperature of different parts under full load. The converter was operating in buck mode with a 48 V input voltage and 12 V output voltage. It operated at the maximum current of 4 A. The main limiting factor thermally is the coil. Changing the coil to one that has better DC resistance could improve the thermal performance of this board significantly in buck mode under full load. Please note that the drivers are both cooler than 80°C. The hotter of the two is also shown below. Be careful when handling the board after it has been in operation for a long time under a certain amount of load. The rest of the board does not get significantly hot.

Characteristics

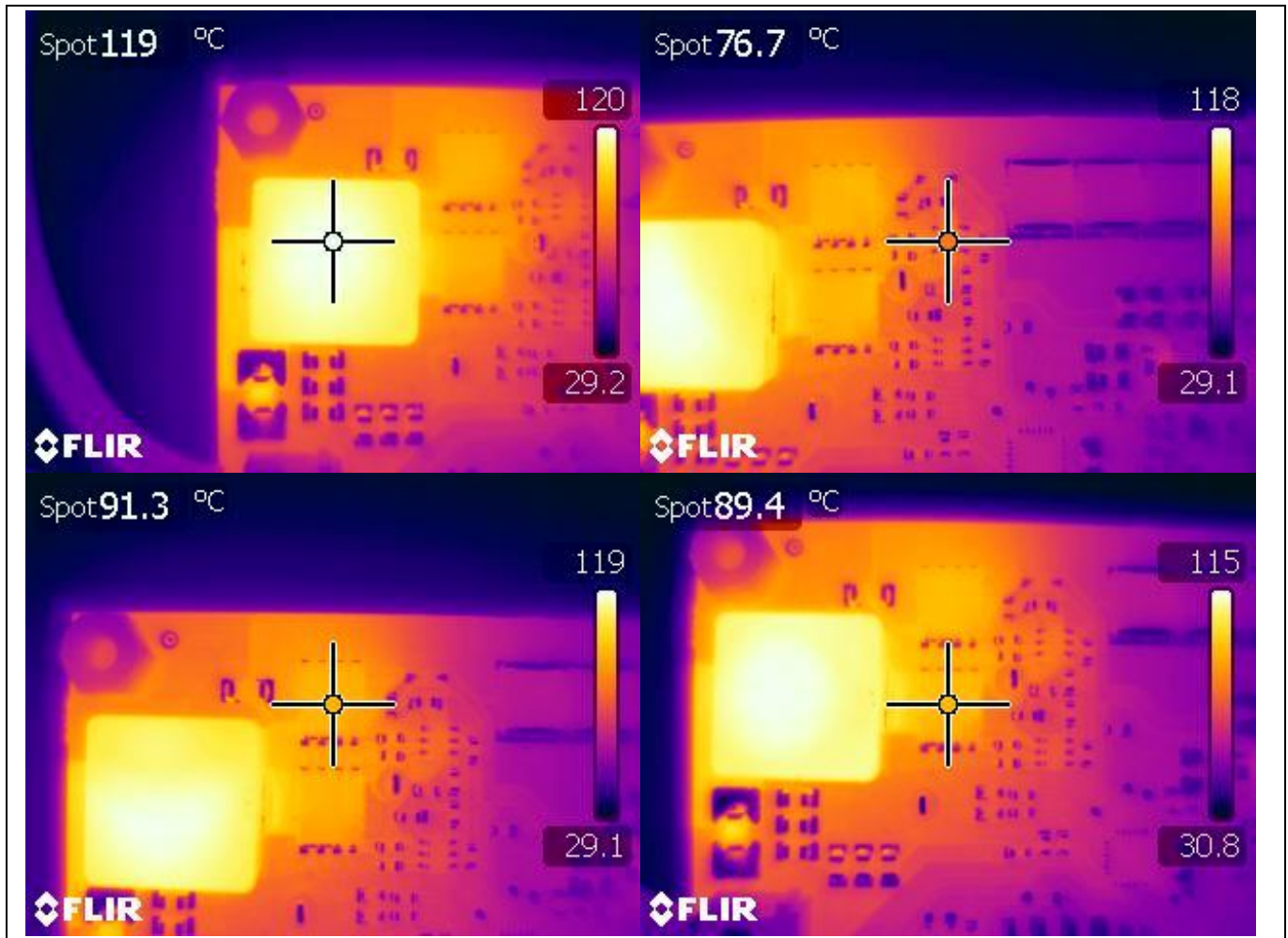


Figure 11 MOSFET and coil temperatures in buck mode with 4 A load

Non-isolated bidirectional synchronous buck converter EVAL_BIDI_HB_1EDN7550B



Addendum

5 Addendum

5.1 Schematic

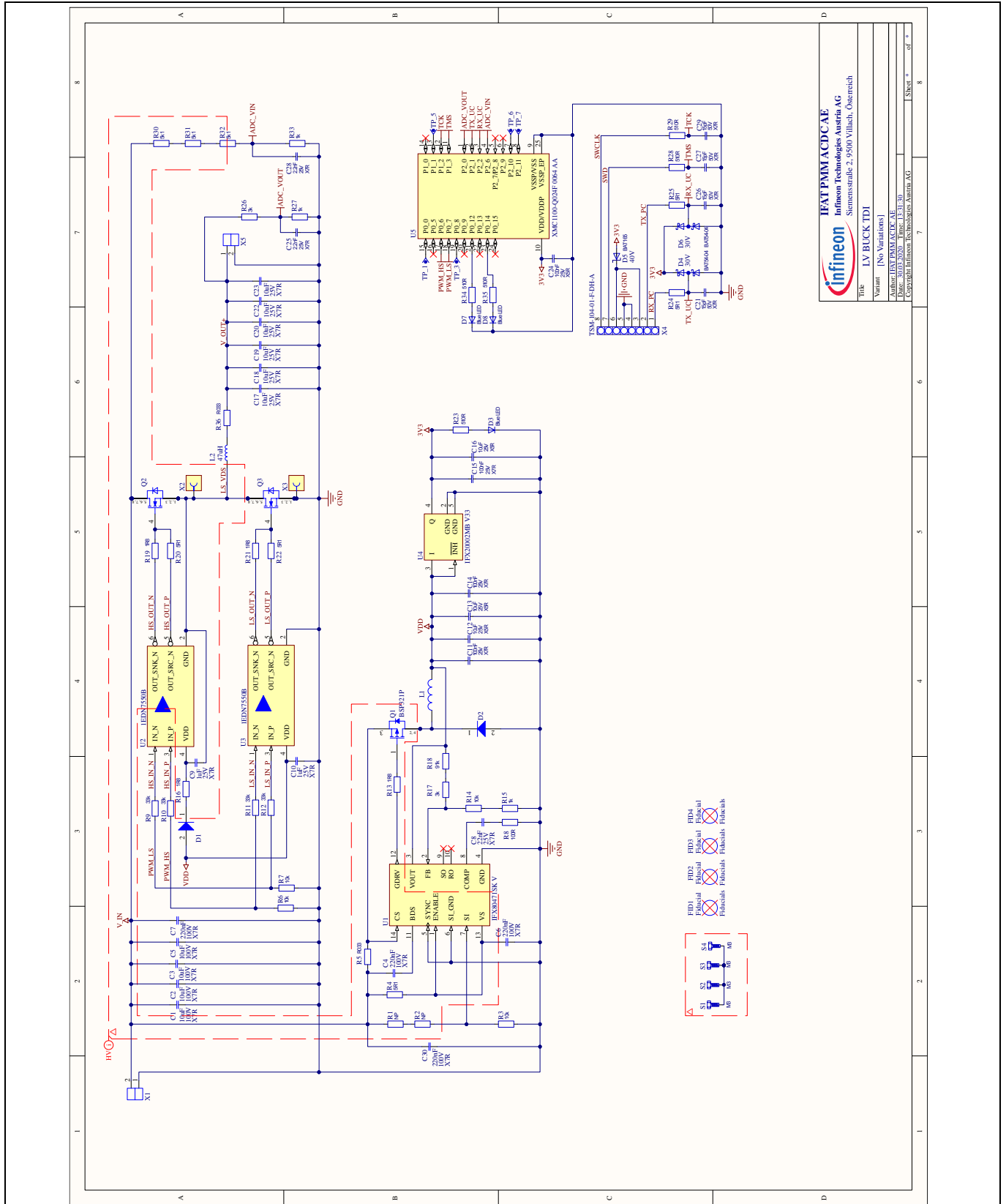


Figure 12 Schematic

5.2 PCB layout

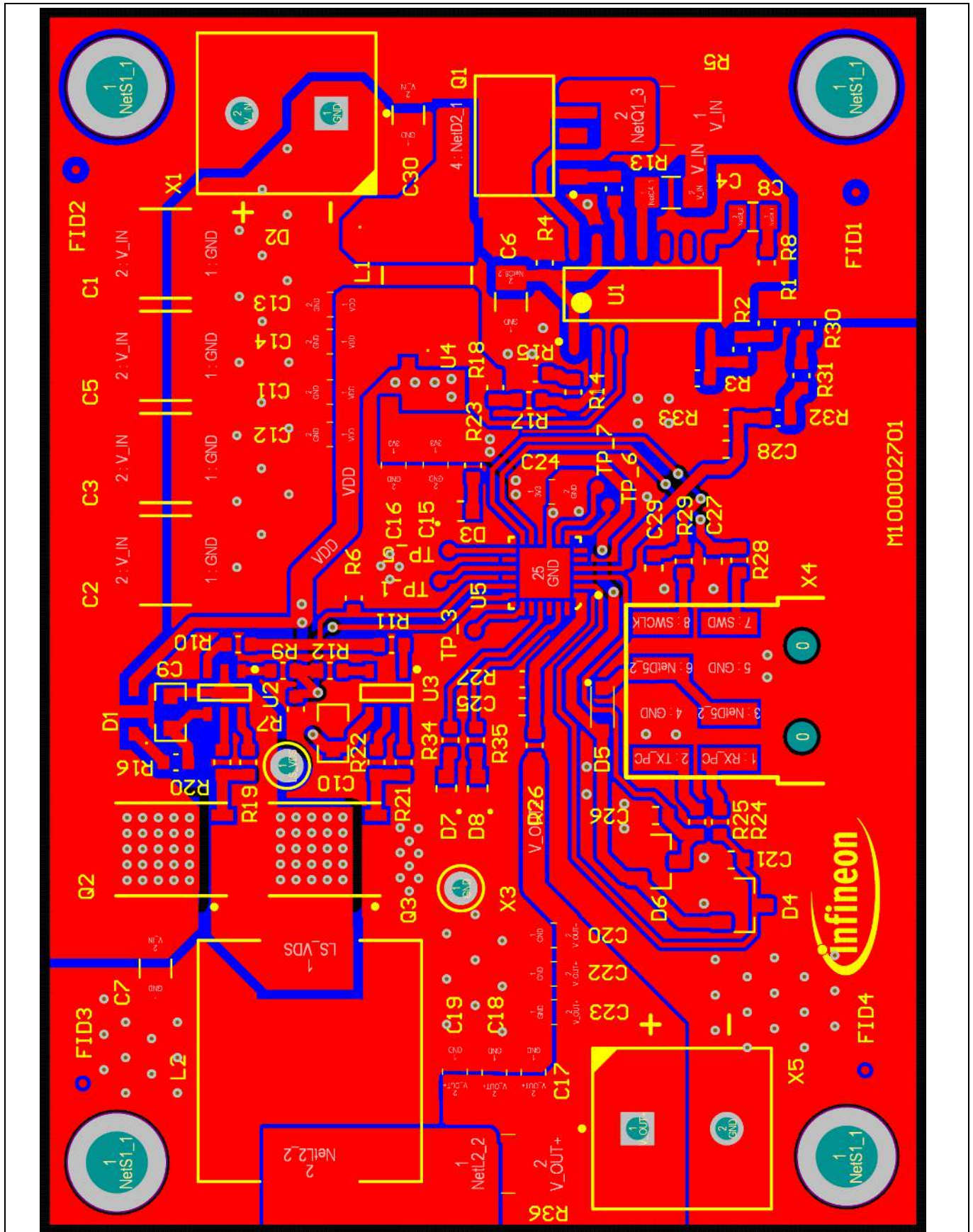


Figure 13 PCB layout

5.3 Bill of materials (BOM)

Table 7 Bill of materials

| Quantity | Designator | Value | Description | Footprint | Supplier 1 | Supplier part number 1 |
|----------|------------|-----------------------|--|---|------------|------------------------|
| 1 | X4 | TSM-104-01-F-DH-A | Female header, eight contacts | Pin header double row 2x4c SMD mounting holes | Digi-Key | TSM-104-01-F-DH-A-ND |
| 2 | X1, X5 | | Pin header, two contacts | CON-TER-THT-1935776 | Farnell | 1641934 |
| 2 | X2, X3 | 5004 | Test point THT, yellow | CON-THT-TP-5004 | Farnell | 1533290 |
| 1 | C8 | 22 nF | Unpolarized capacitor | CAP0805R | | |
| 1 | D5 | BAT165 | Schottky diode | SOD323 | | |
| 1 | L1 | 100 μ H | SMT shielded tiny power inductor WE-TPC, size 4828, 100 μ H, 0.51 A | WE-TPC_4828 | Digi-Key | 732-1111-1-ND |
| 1 | L2 | 47 μ H | WE-LHMI SMD power inductor | INDM135125X650N | Farnell | 2434080 |
| 1 | Q1 | BSP321P | P-channel SiPMOS small-signal-transistor, -100 V V_{DS} , -0.98 A I_D , -55 to 150°C, PG-SOT223 (SC-73), reel, green | INF-PG-SOT223_SC-73_N | Infineon | BSP321P |
| 1 | R8 | 100 R | Resistor | RES0603R | | |
| 1 | R18 | 91 k | Resistor | RES0603R | | |
| 1 | U1 | IFX80471S-K V | Step-down DC-DC controller, 2300 mA I_q , -40 to 125°C, PG-DSO-14-1, reel, green | INF-PG-DSO-14-1_N | | |
| 1 | U4 | IFX20002M B V33 | Low-dropout voltage regulator, 4.5 to 45 V operating, 30 mA, -40 to 125°, PG-SCT595, reel, green | INF-PG-SCT595_V | | |
| 1 | U5 | XMC100-Q024 F 0064 AA | 32-bit XMC1000 industrial microcontrollers ARM® Cortex®-M0/PG-VQFN-24-19 | QFN50P400X400X90-25N | Infineon | |
| 2 | C9, C10 | 1 μ F | Unpolarized capacitor | CAP0603W | | |
| 2 | C25, C28 | 2.2 nF | Ceramic capacitor | CAP0603R | | |
| 2 | D1, D2 | BAS16-03W | Silicon switching diode, SOD323, reel, green | INF-SOD323_V | Infineon | BAS16-03W |

Non-isolated bidirectional synchronous buck converter

EVAL_BIDI_HB_1EDN7550B



Addendum

| | | | | | | |
|---|---|----------------------|---|--------------------------|----------|-------------------|
| 2 | D4, D6 | Bat5 4-04 | Schottky diode | SOT23R | Infineon | BAT54-04 |
| 2 | Q2, Q3 | BSC0 93N1 5NS5 | OptiMOS™ 5 power transistor, 80 V | INF-PG- TDSO8-8-FL | Infineon | BSC093N 15NS5 |
| 2 | R1, R2 | NP | Resistor | RES0603R | | |
| 2 | R5, R36 | R033 | Resistor | RES2512R – shunt | Farnell | 2828210 |
| 2 | R17, R26 | 3 k | Resistor | RES0603R | | |
| 2 | U2, U3 | 1EDN 7550 B | EiceDRIVER™, single-channel LS gate driver IC for MOSFETs and IGBTs, 4.2 V UVLO | SOT95P280X1 45-6N-7-V | | |
| 3 | D3, D7, D8 | Blue LED | LED | LED-0603R | Farnell | 1685096 |
| 3 | R15, R27, R33 | 1 k | Resistor | RES0603R | | |
| 3 | R30, R31, R32 | 5k1 | Resistor | RES0603R | | |
| 4 | C1, C2, C3, C5 | 10 µF | Unpolarized capacitor | 2220 | Digi-Key | 445-5212- 1-ND |
| 4 | C4, C6, C7, C30 | 220 nF | Unpolarized capacitor | CAP1206R | Digi-Key | 399-8177- 1-ND |
| 4 | C11, C14, C15, C24 | 100 nF | Ceramic capacitor | CAP0805-IFX | | |
| 4 | C21, C26, C27, C29 | 15 pF | Ceramic capacitor | CAP0603R | | |
| 4 | R3, R6, R7, R14 | 10 k | Resistor | RES0603R | | |
| 4 | R9, R10, R11, R12 | 33 k | Resistor | RES0603R | | |
| 4 | R13, R16, R19, R21 | 1R8 | Resistor | RES0603R | | |
| 5 | R4, R20, R22, R24, R25 | 5R1 | Resistor | RES0603R | | |
| 5 | R23, R28, R29, R34, R35 | 510 R | Resistor | RES0603R | | |
| 9 | C12, C13, C16, C17, C18, C19, C20, C22, C23 | 10 µF | Ceramic capacitor, unpolarized capacitor | CAP0805-IFX | | |

6 References

- [1] Lukic, Z., Stupar, A., Prodic, A., & Goder, D. (2008). Current Estimation and Remote Temperature Monitoring System for Low Power Digitally Controlled DC-DC SMPS. *39th IEEE Annual Power Electronics Specialists Conference*, (pp. 1139-1143). Rhodes. Retrieved February 28, 2020, from http://www.ele.utoronto.ca/power_management/cp29.pdf

Revision history

Revision history

| Document version | Date of release | Description of changes |
|-------------------------|------------------------|----------------------------------|
| V 1.0 | 2021-12-03 | First release |
| V 1.1 | 2022-06-13 | Description of Figure 11 updated |
| | | |

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