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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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

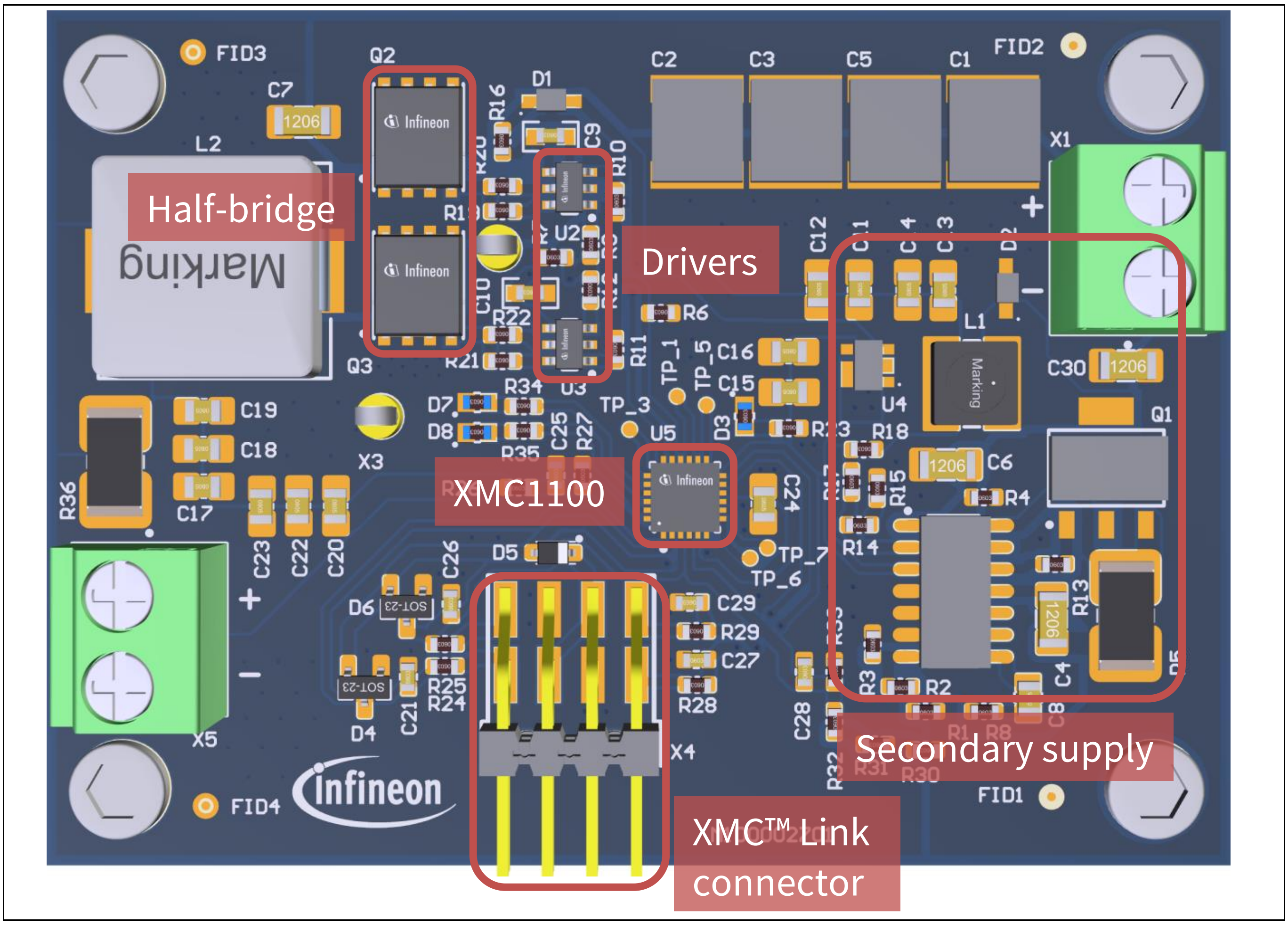


Figure 1 Component descriptions

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.

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.

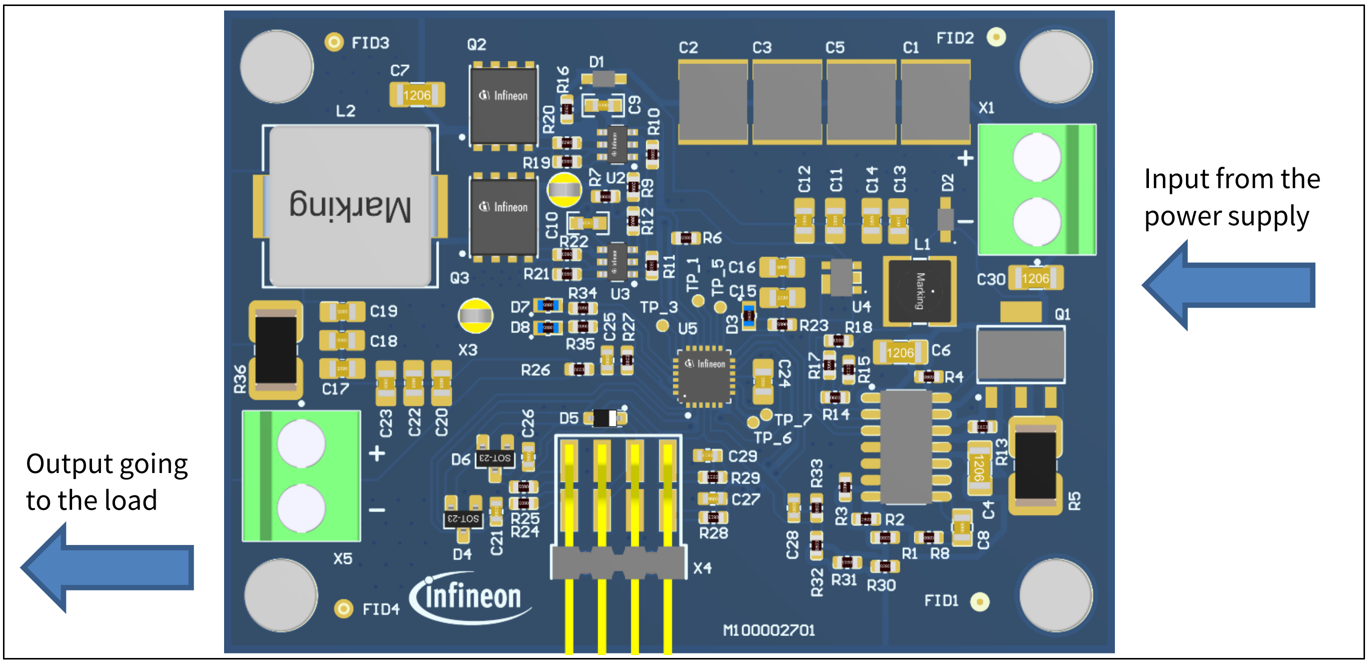


Figure 2 **Converter connections in buck mode**

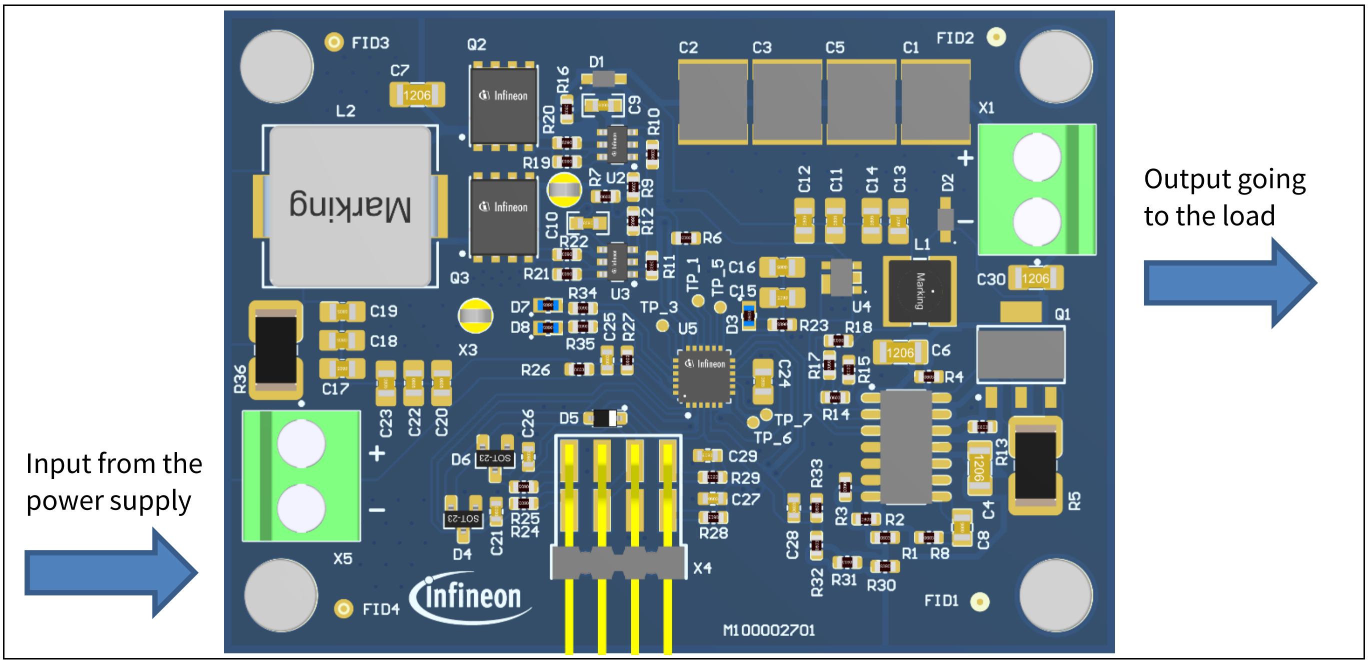


Figure 3 **Converter connections in boost mode**

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 rage

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	-	-	µs	-
Overvoltage protection (OVP) delay time on	$t_{OVP(on)}$	80	-	-	ms	-
Overvoltage protection (OVP) delay time off	$t_{OVP(off)}$	200	-	-	µs	-

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.

3 Description of UI elements

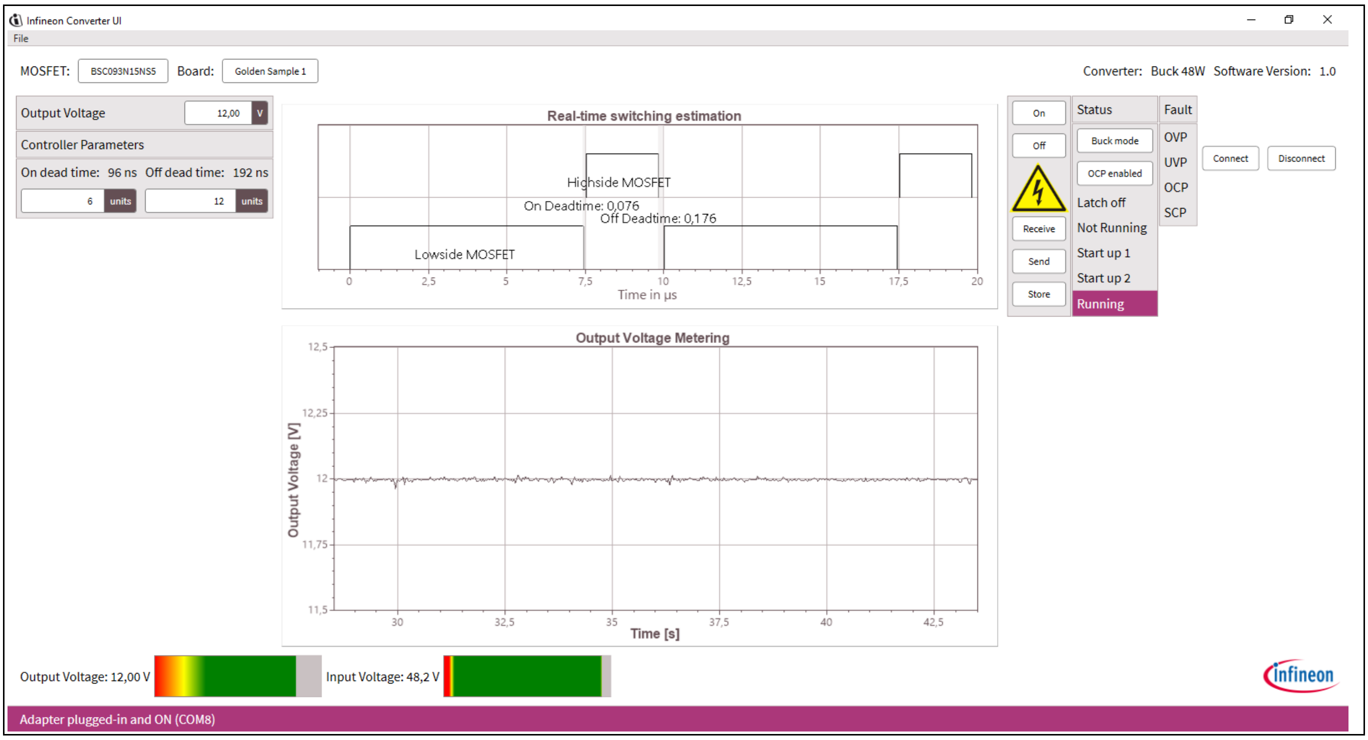


Figure 4 Screenshot of the UI

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.

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.

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.

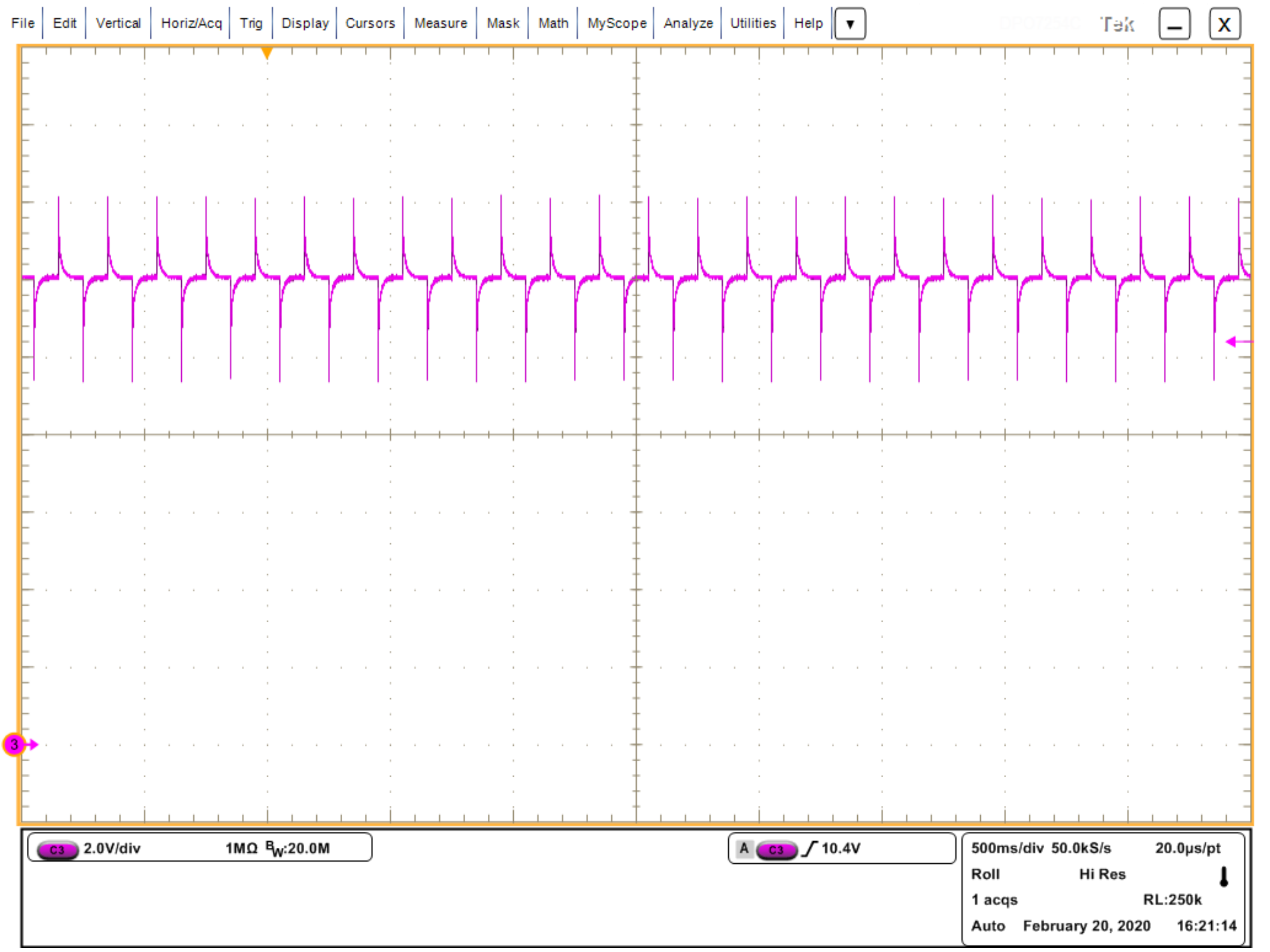
4 Characteristics

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



Legend	
3	Output voltage

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**.

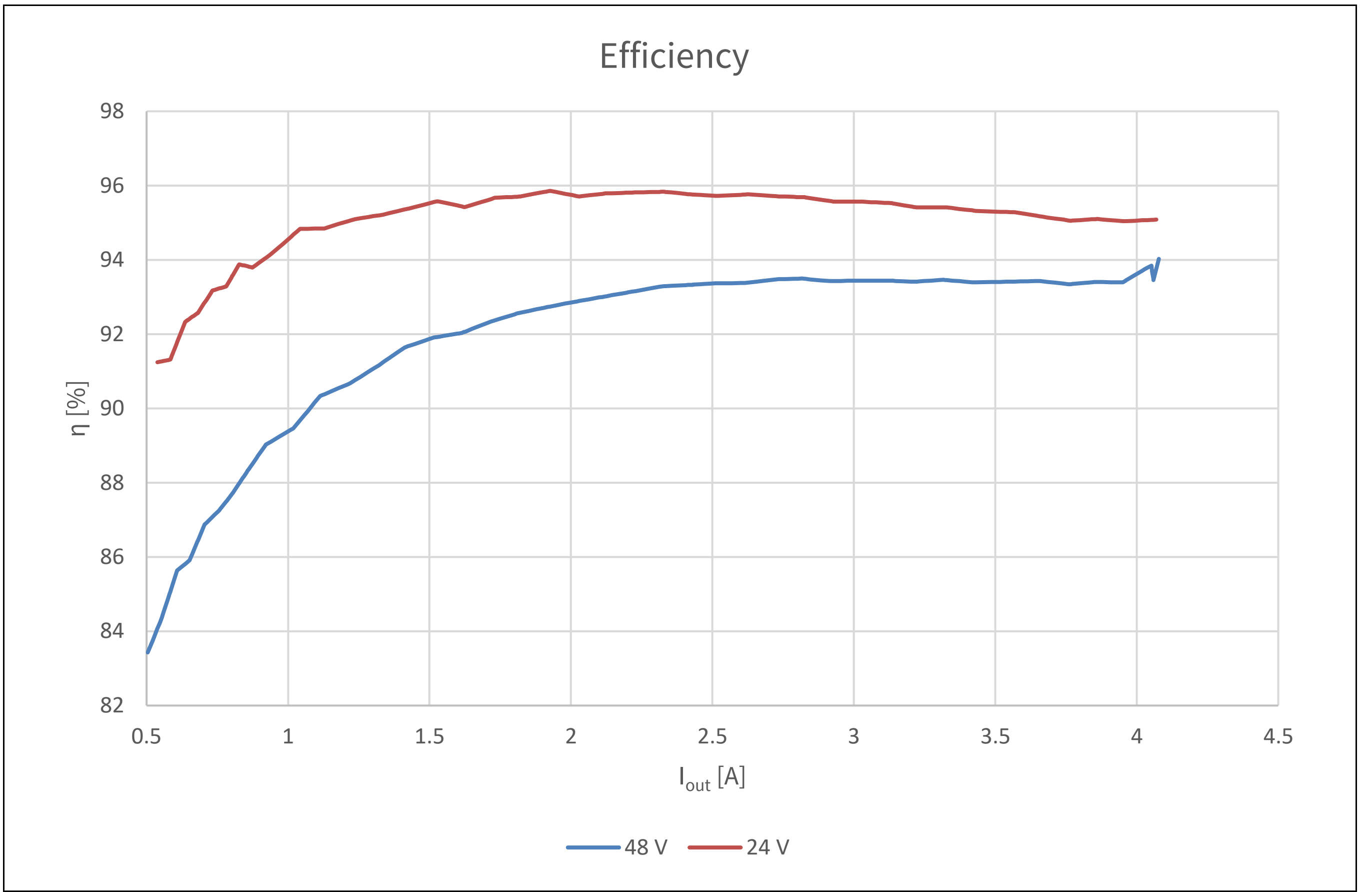
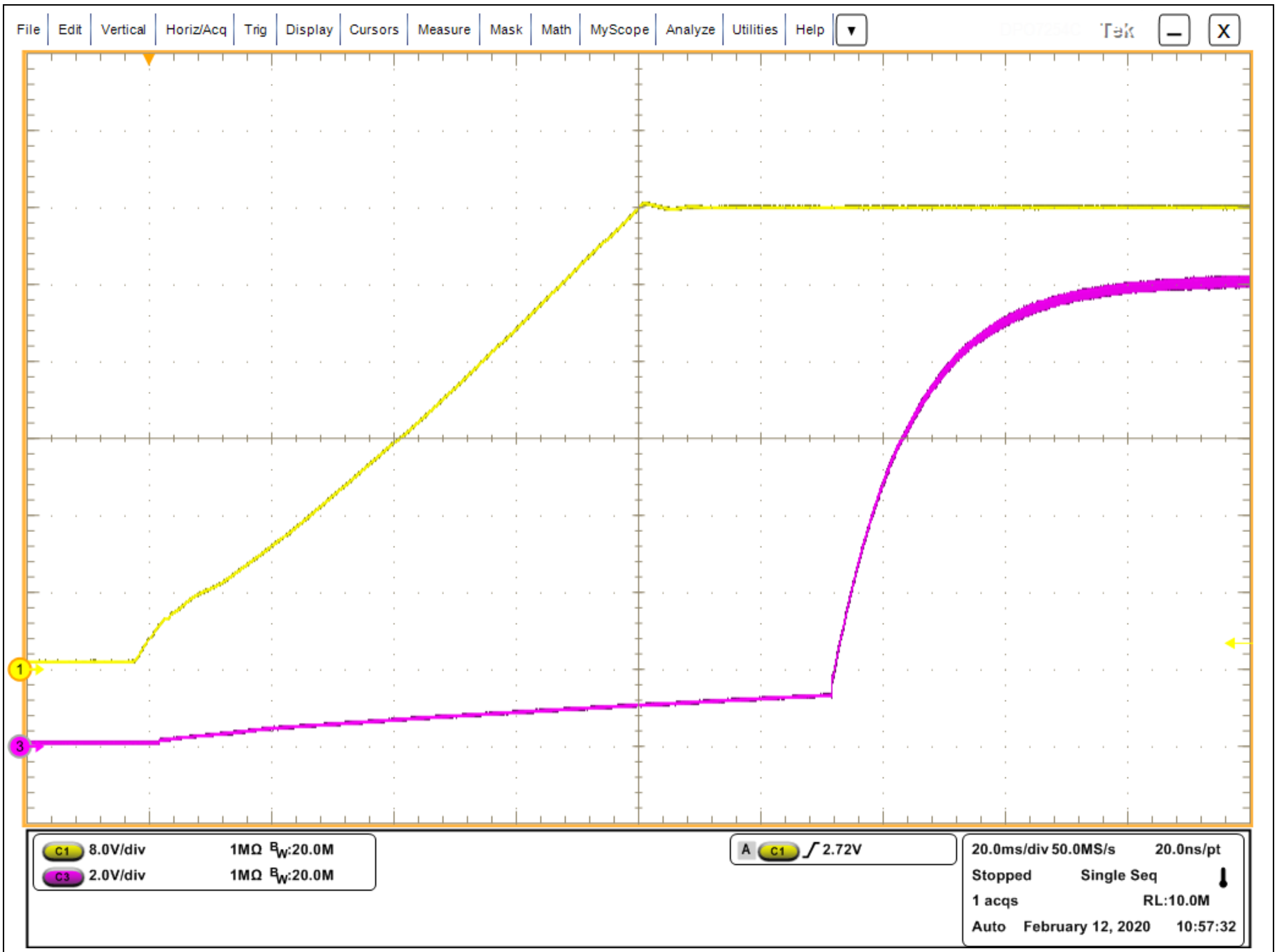


Figure 7 **Efficiency at 12 V output in buck mode (R36 has been bridged)**

4.3 Start-up in buck mode

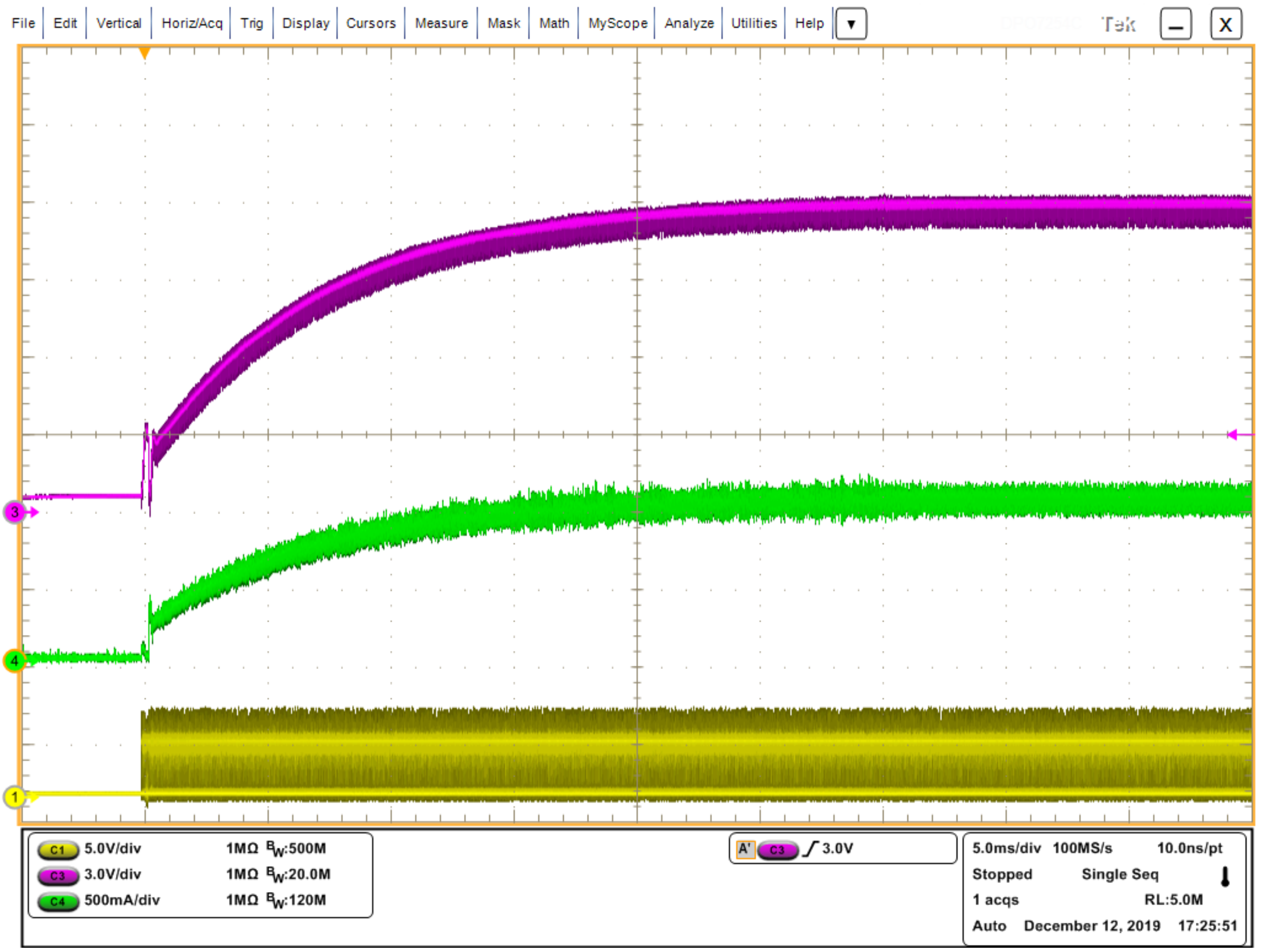
The following capture shows the start-up waveform when connected to a MEAN WELL GST60A48-P1J power supply. No load is connected.



Legend	
1	Input voltage
3	Output voltage

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.



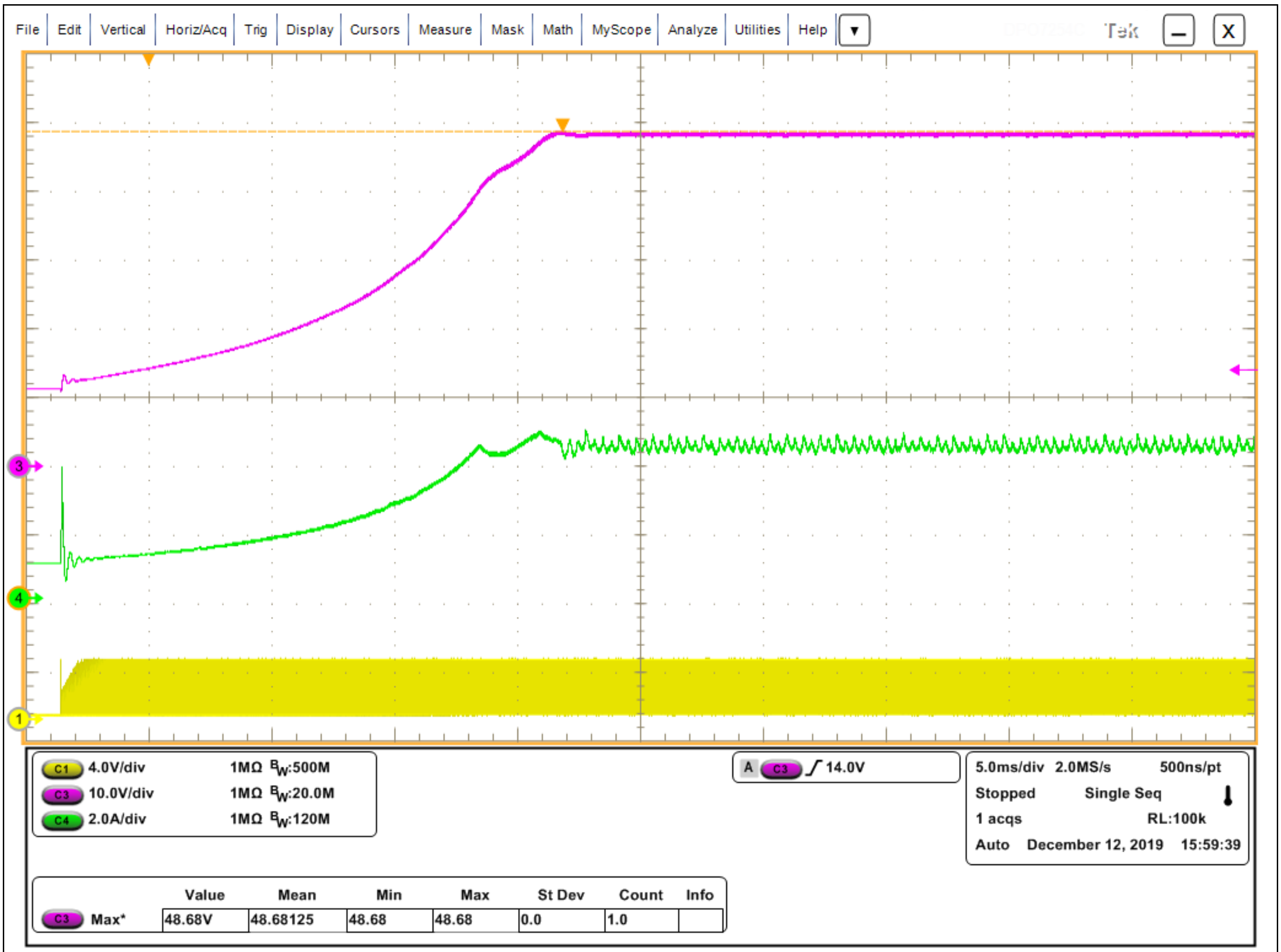
Legend	
1	LS PWM signal
3	Output voltage
4	Input current

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.*



Legend	
1	LS PWM signal
3	Output voltage
4	Input current

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.

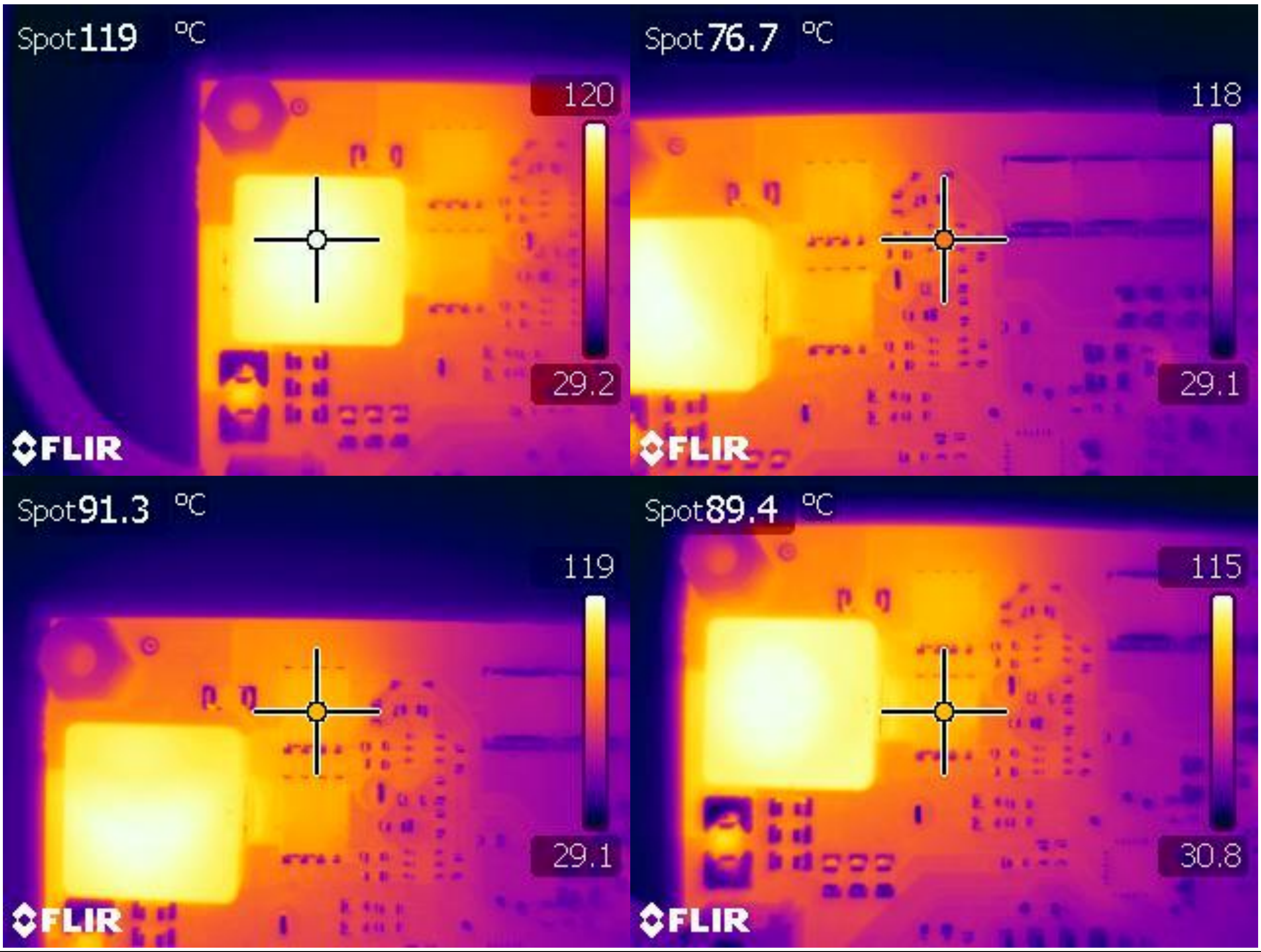


Figure 11 **MOSFET and coil temperatures in buck mode with 4 A load**

5 Addendum

5.1 Schematic

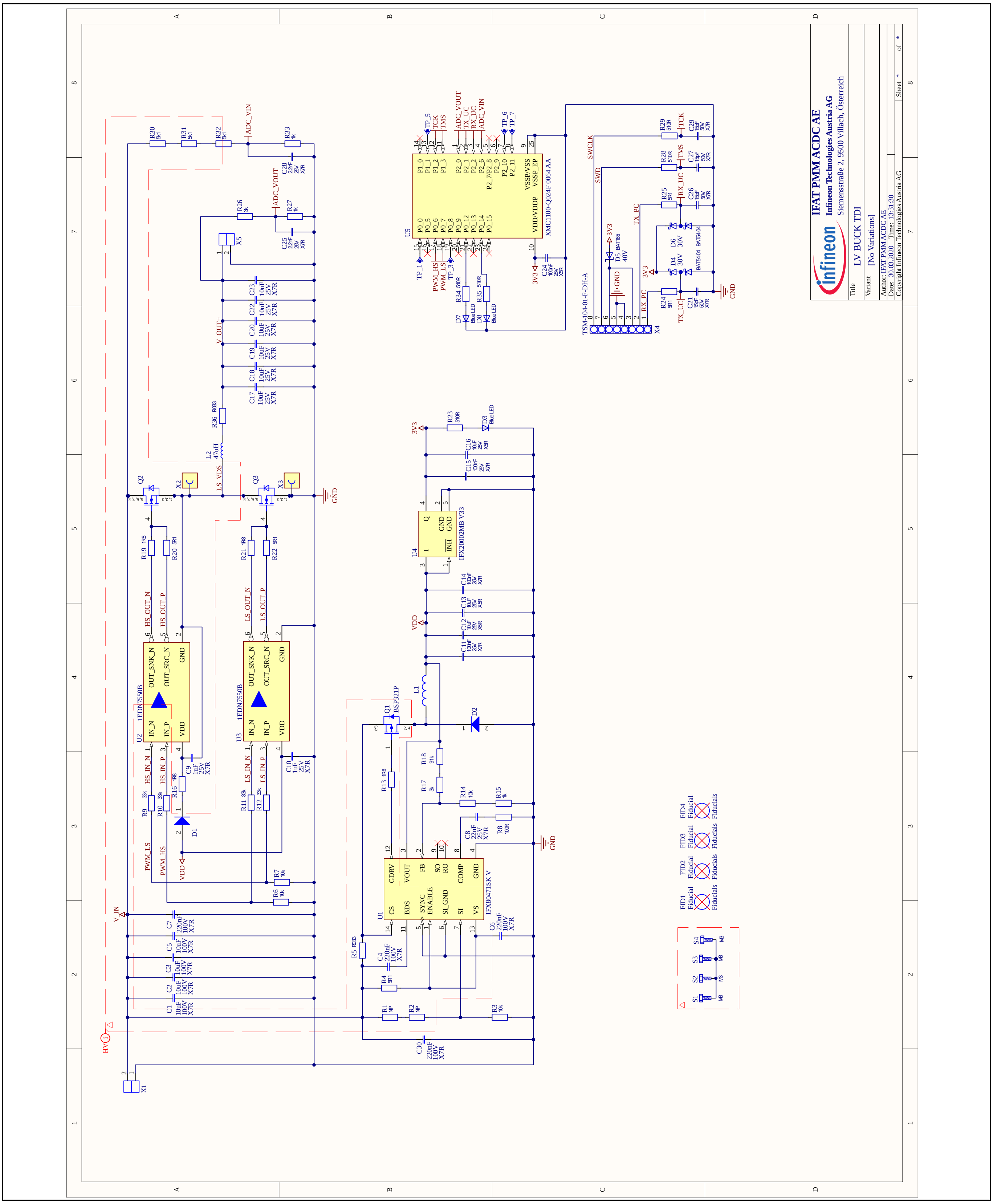


Figure 12 Schematic

5.2 PCB layout

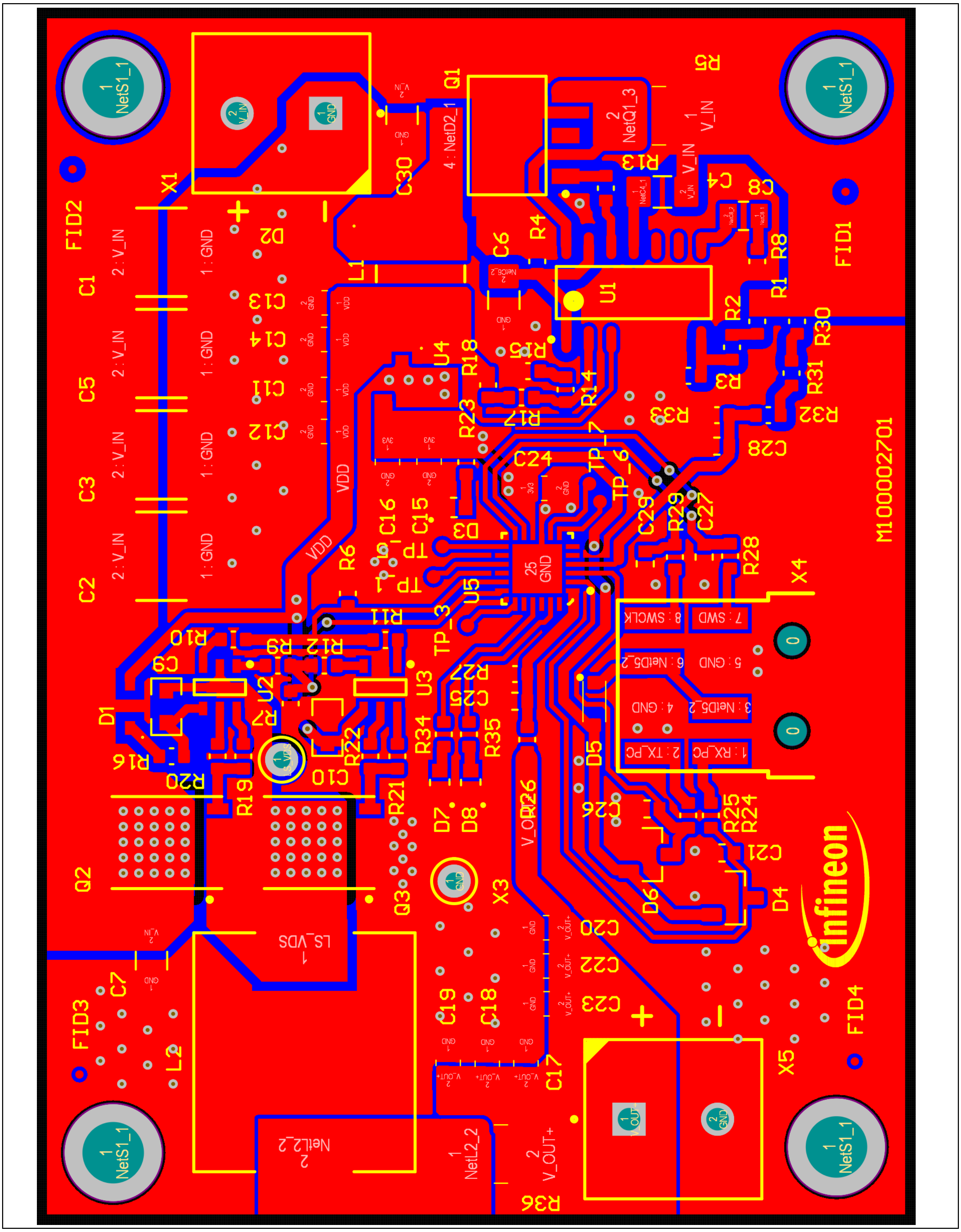


Figure 13 PCB layout

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 µH	SMT shielded tiny power inductor WE-TPC, size 4828, 100 µH, 0.51 A	WE-TPC_4828	Digi-Key	732-1111-1-ND
1	L2	47 µH	WE-LHMI SMD power inductor	INDM135125X650N	Farnell	2434080
1	Q1	BSP321P	P-channel SIPMOS small-signal-transistor, -100 V V_{DS}, -0.98 A ID, -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	IFX80471SK V	Step-down DC-DC controller, 2300 mA Iq, -40 to 125°C, PG-DSO-14-1, reel, green	INF-PG-DSO-14-1_N		
1	U4	IFX20002MB 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	XMC1100-Q024F0064AA	32-bit XMC1000 industrial microcontrollers ARM® Cortex®-M0/PG-VQFN-24-19	QFN50P400X400X90-25N	Infineon	
2	C9, C10	1 µF	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

2	D4, D6	Bat54-04	Schottky diode	SOT23R	Infineon	BAT54-04
2	Q2, Q3	BSC093N15NS5	OptiMOS™ 5 power transistor, 80 V	INF-PG-TDSON-8-FL	Infineon	BSC093N15NS5
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	1EDN7550B	EiceDRIVER™, single-channel LS gate driver IC for MOSFETs and IGBTs, 4.2 V UVLO	SOT95P280X145-6N-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

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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