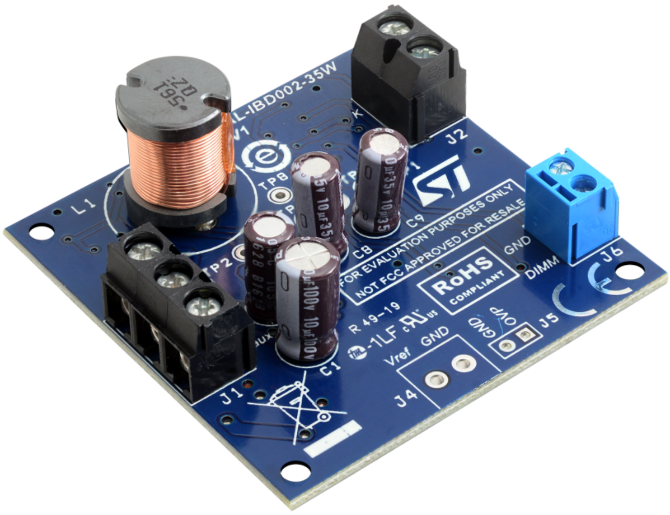
UM2683

User manual

Inverse buck 35W with LED current controlled by HVLED002 with Analog/PWM dimming regulation

Introduction



This document describes the EVAL-IBD002-35W demonstration board behavior, designed to manage a dimmable 35 W LED load with a single inverse buck stage.

The HVLED002 controller manages the inverse buck circuit mainly composed by D1, L1 and Q1 components. This circuit provides around 700 mA as maximum LED load current. The board operates in peak current mode with FOT (Fixed Off Time) and it has been designed to operate with wide input (48 V - 60 V) and wide output (24 V - 48 V) voltages. The on-time changes according to the operating condition to keep output current regulated and the switching frequency is consequently adapted.

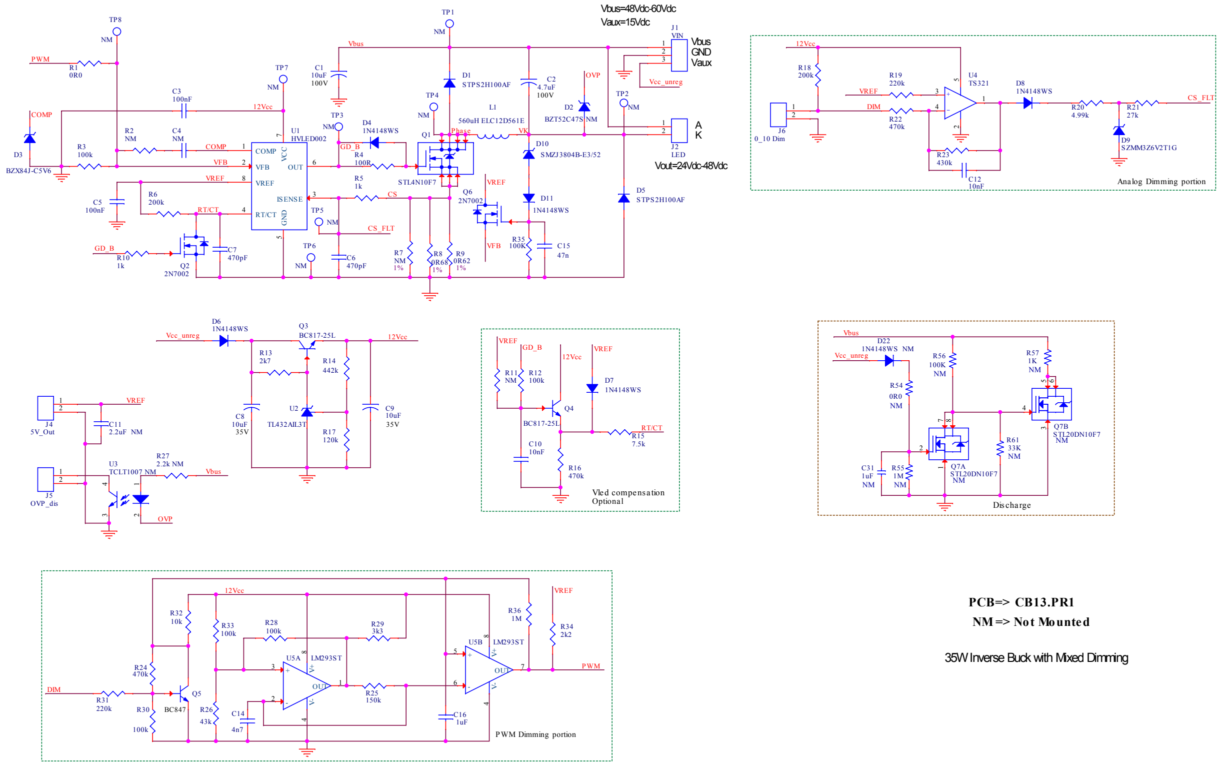
In steady-state condition the pin COMP works at its maximum value because the FB signal is zero, providing the maximum average current.. In this condition, decreasing VDimm input below 10 V, the Analog dimming circuit injects an ever higher offset signal on HVLED002 current sense, so decreasing the output average current. When VDimm input voltage decreases under 2 V, the PWM Dimming circuit starts to generate a PWM output voltage with 5 V - 0 V amplitude. When PWM state is 0 V the FB signal is zero providing the maximum average current and when the PWM state is 5 V the pin FB is pulled up to VREF and the switching activity of HVLED002 is stopped providing zero output current. In this way, when the Vdimm is under 2 V, the output average current increases/decreases depending on the PWM state condition. . Decreasing VDimm voltage level, the PWM high level percentage increases, further decreasing the output average current too. So, the external 0 -10 V dimming signal is dedicated to managing a dimmed output LED current between 1%-100% of its maximum value with both Analog control 100%÷10% (10 V÷2 V) and PWM control 10%÷1% (2 V÷0 V).

An external 15 Vdc of auxiliary voltage is needed to power up the HVLED002 controller while the D6, Q3 and U2 components regulate a precise 12 V to the Vcc of HVLED002 and manage a constant pull-up voltage used for both dimming circuits.

The short-circuit protection is guaranteed by Zener diode D10 which detects a sudden fast slope rise of LED load Cathode Voltage activating Q6 MOSFET and bringing the pin FB high and stopping the switching activity. On the PCB there are also available (not mounted) the Discharge and OVP circuit positions, usable and useful with a primary stage connection (converter): the first needed to discharge the C2 output capacitance after power turn-off and the second to stop the primary activity when an Overvoltage occurs on the Output LED load.

1 EVAL-IBD002-35W schematic diagrams

Figure 1. EVAL-IBD002-35W circuit schematic



2 EVAL-IBD002-35W demonstration board layout

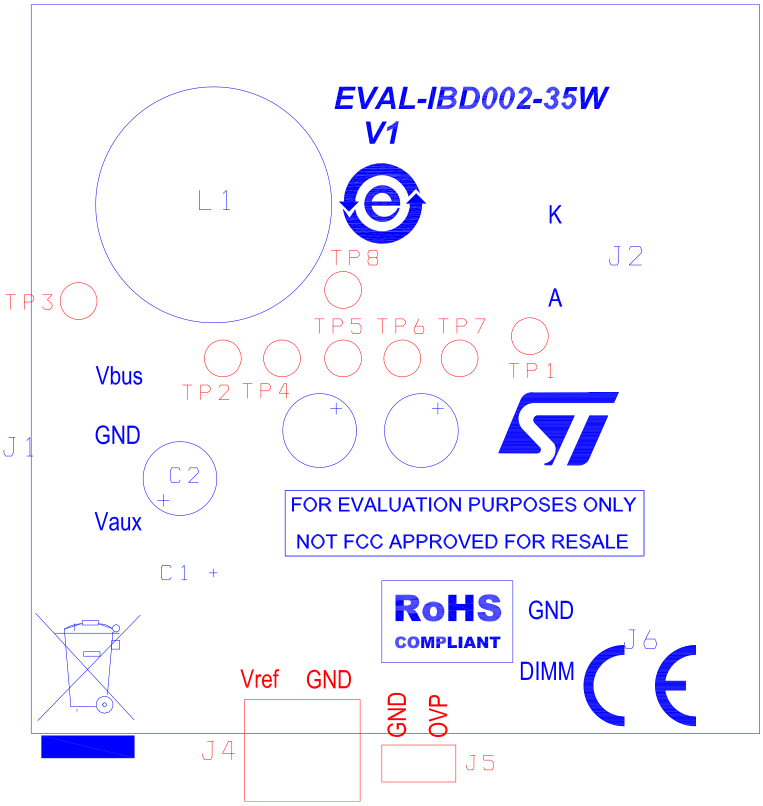
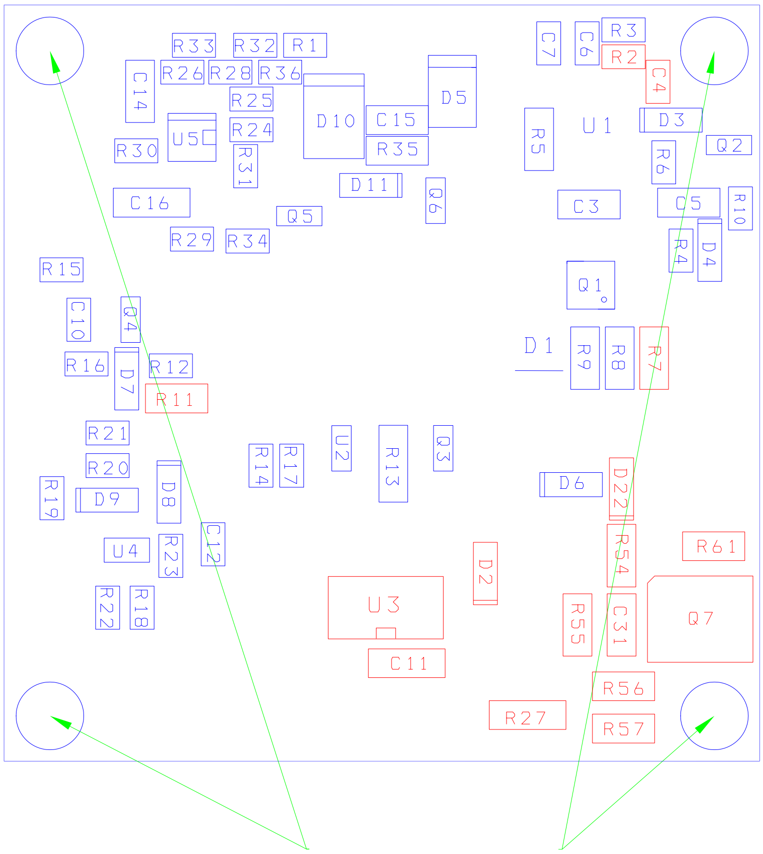


Figure 2. EVAL-IBD002-35W component side

Figure 3. EVAL-IBD002-35W solder side



3 EVAL-IBD002-35W demonstration board overview

The main specifications of the EVAL-IBD002-35W power board can be seen below.

Table 1. EVAL-IBD002-35W specification

Parameter	Specs
Vin at J1 Connector (Vbus)	48Vdc ÷ 60Vdc
Vout at J6 Connector (Vout A-K)	24Vdc ÷ 48Vdc
Vaux at J1 Connector (Vaux)	15Vdc
Iout Led max. (J2)	700mA
Dimming range	1% ÷ 100%
No load consumption	50mW
Pout max.	35W
Efficiency	Full Load: 97% Load Over 20% (analog dimming): > 95%
Output ripple current max.	<80mA@worst case 50Vindc-48Voutdc
Short-circuit protection	OK
RoHS compliant	OK

Table 2 shows a Legend of all connector and Test Point available on the EVAL-IBD002-35W demonstration board

Table 2. EVAL-IBD002-35W Connectors and Test Point description

Reference	Type	Specs
J1	PCB terminal	Vbus - GND
J1	PCB terminal	Vaux - GND
J2	PCB terminal	Output A/K LED load
J4	PCB terminal	5v_Out – VREF - Not mounted
J5	PCB terminal	OVP_dis - Not mounted
J6	PCB terminal	VDIMM - GND
TP1	Test Point	Vbus - Not mounted
TP2	Test Point	VKathode - Not mounted
TP3	Test Point	VGS - Not mounted
TP4	Test Point	VDS - Not mounted
TP5	Test Point	VCS - Not mounted
TP6	Test Point	GND - Not mounted
TP7	Test Point	VCC - Not mounted
TP8	Test Point	VFB - Not mounted

4 EVAL-IBD002-35W measurement

Figure 4 shows the efficiency measured covering the whole dimming range (1%-100%), supplying the demonstration board with 60 Vdc (15 Vdc as Auxiliary Voltage) with three different LED loads of 48 V(16LED), 45 V(15LED) and 24 V (8LED), while Figure 5 shows the efficiency measurement with a different input voltage of 48 Vdc and 50 Vdc. In both cases the Efficiency is 97% in Full Load conditions of 35 W (48 Vout-16LED) and higher than the 95% for Load over the 20% of its maximum Load.

Figure 4. EVAL-IBD002-35W Efficiency vs. dimming@60Vindc

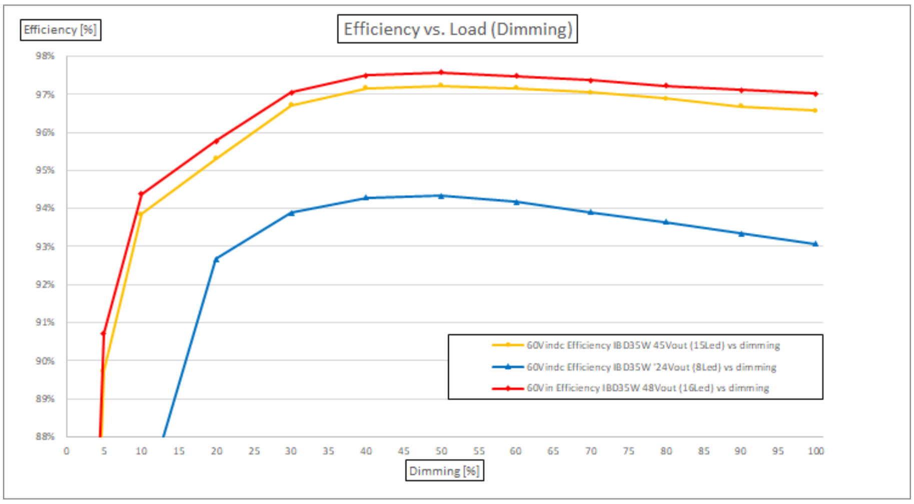
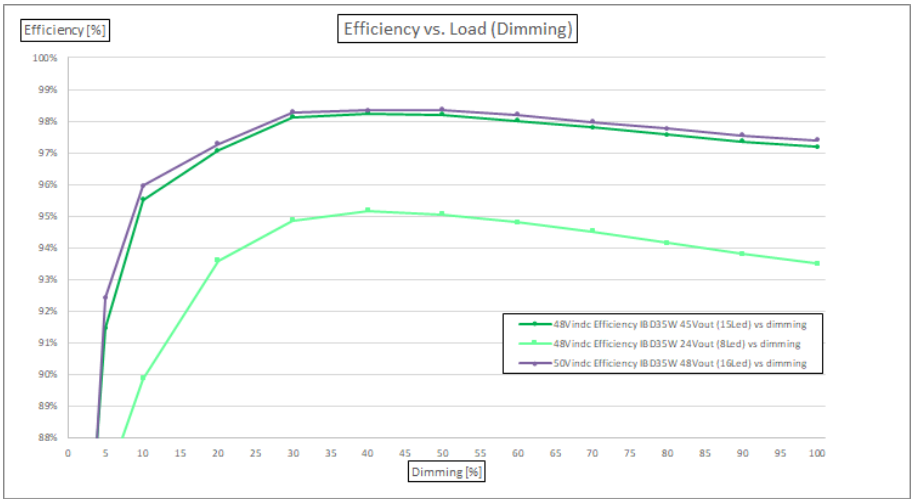


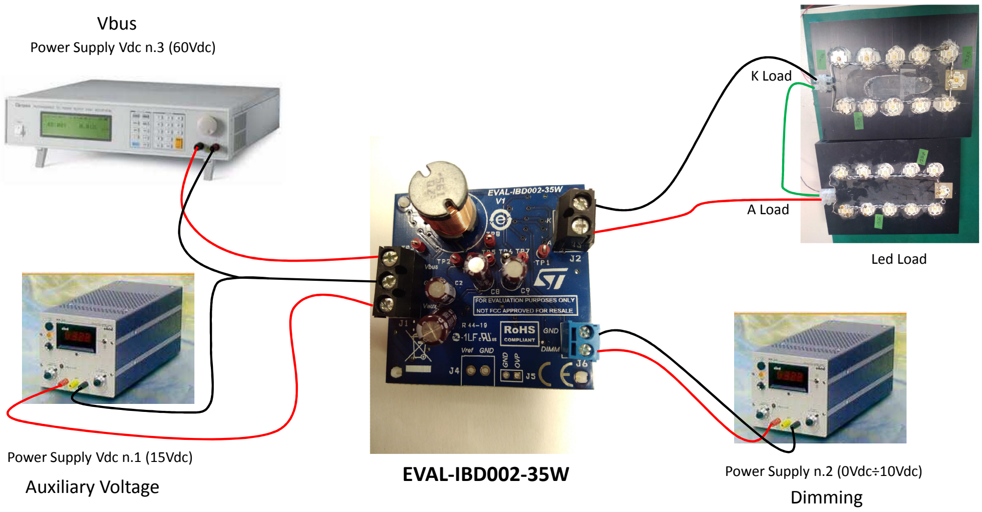
Figure 5. EVAL-IBD002-35W Efficiency vs. dimming@48/50Vindc



5 EVAL-IBD002-35W set-up

Figure 6 here below shows a typical set-up, an example of the equipment needed to turn on the EVAL-IBD002-35W and how/where to connect each one of them.

Figure 6. EVAL-IBD002-35W demonstration board



Here below a brief guide list to switch on the EVAL-IBD002-35W demonstration board:

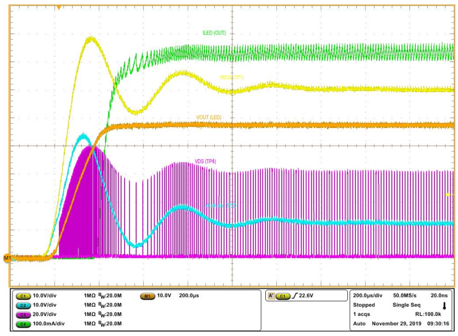
- Set the voltage of the Power Supply n.1 to 15 Vdc and from OFF conditions connect it to J1 with (+) to Vaux and (-) to GND;
- Set the voltage of the Power Supply n.2 to 10 Vdc and from OFF conditions connect it to J6 with (+) to DIMM and (-) to GND;
- Set the voltage of the Power Supply n.3 to 60 Vdc and from OFF conditions connect it to J1 with (+) to Vbus and (-) to GND;
- Connect the LED load to the J2 connector with the A output connected to the LED's anodes and with the K output connected to the LED's cathodes. In order to have 24 V or 48 V output voltage, it must be selected several LED appropriate depending on the total LED drop voltage desired. The measurements shown in this document have been executed between 8LED (24 V) and 16LED (48 V) taking into account that single LED drop voltage is around 3 V. Alternatively an Electronic Load settled as an LED voltage can be used.
- Turn on the Power Supply n.1, Power Supply n.2 and then Power Supply n.3 and the Output Current LED, independently by the Voltage Load Settled, it will be the maximum and thus around 700 mA.
- In order to decrease the output current, it is possible to act on Power Supply n.2. and more precisely decreasing its own voltage value:
  – between 10 V to 2 V and so injecting an analog offset on pin CS, lowering the output average current.
  – between 2 V to 0 V, it manages an output PWM signal which acts on FB pin stopping the switching activity and so further decreasing the average LED current to 1% of its maximum value available.
- Once the system is turned on it is possible to modify Input Voltage, Output Voltage and Output Current respecting the limits listed in parameter specifications of Table1 and taking also into account that the Input Voltage must be always at least 2 V higher than Output Voltage. Furthermore, the LEDs have to be selected also to be capable to support at least 1A of peak current.

In the next chapter the main waveforms behavior is represented.

6 EVAL-IBD002-35W waveforms

Here below in Figure 7 and Figure 8 are shown the signal behavior during startup and steady-state conditions when 60 Vindc and Full Load (16LED) has been settled. As can be seen, no LED Iout and Vout overshoot have been highlighted during startup and that a 60mA output ripple current is managed during steady-state operations.

Figure 7. EVAL-IBD002-35W startup 60Vindc (16LED)

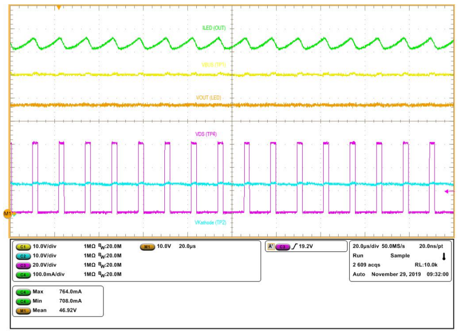


Ch.1: Vbus (TP1) - Ch.2: VKathode (TP2)

Ch.3: VDS (TP4) - Ch.4: LED Output Current

Ch.Math1: Vout LED (Vbus-VKathode/TP1-TP2)

Figure 8. EVAL-IBD002-35W steady-state 60Vindc (16LED)



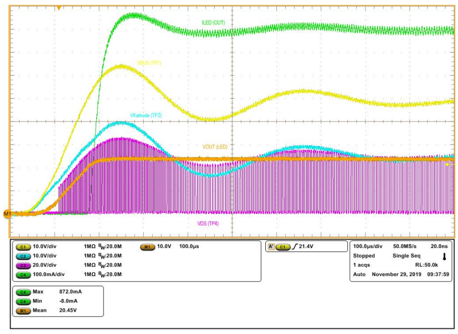
Ch.1: Vbus (TP1) - Ch.2: VKathode (TP2)

Ch.3: VDS (TP4) - Ch.4: LED Output Current

Ch.Math1: Vout LED (Vbus-VKathode/TP1-TP2)

Figure 9 and Figure 10 show the same operative conditions as seen before but setting an input voltage of 48 V with a minimum voltage LED load of 24 V (8LED). In this case a slight current overshoot (around 880 mA) has been noted during start-up operations and also a different 70 mA output ripple current.

Figure 9. EVAL-IBD002-35W startup 48Vindc (8LED)

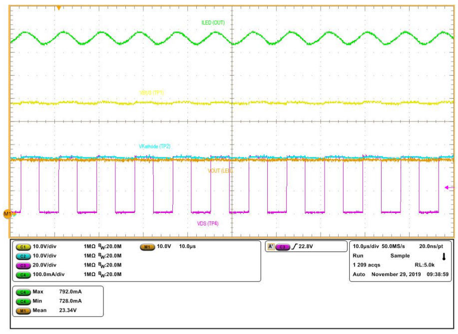


Ch.1: Vbus (TP1) - Ch.2: VKathode (TP2)

Ch.3: VDS (TP4) - Ch.4: LED Output Current

Ch.Math1: Vout Led (Vbus-VKathode/TP1-TP2)

Figure 10. EVAL-IBD002-35W steady-state 48Vindc (8LED)



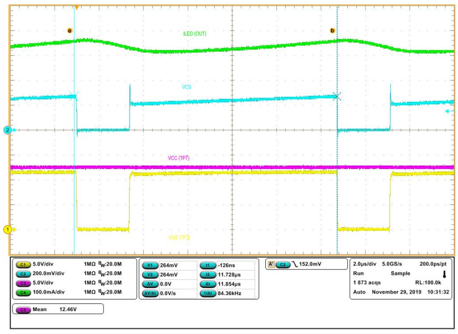
Ch.1: Vbus (TP1) - Ch.2: VKathode (TP2)

Ch.3: VDS (TP4) - Ch.4: LED Output Current

Ch.Math1: Vout Led (Vbus-VKathode/TP1-TP2)

Figure 11 and Figure 12 show ,during steady-state conditions, other signal behavior. It is possible to monitor the Vcc stabilized at around 12 V, the VGate and VCurrent sense behavior in steady-state conditions for different Vin and Vout settings.

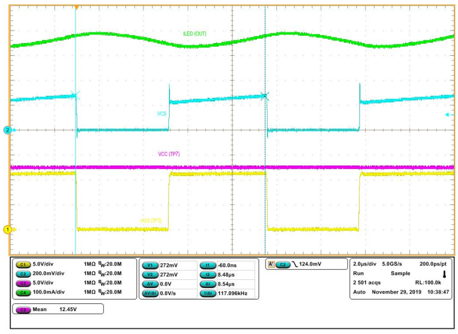
Figure 11. EVAL-IBD002-35W main waveforms 60Vindc (16LED)



Ch.1: VGS (TP3) - Ch.2: VCS

Ch.3: VCC (TP7) - Ch.4: LED Output Current

Figure 12. EVAL-IB002-35W main waveforms 48Vindc (8LED)

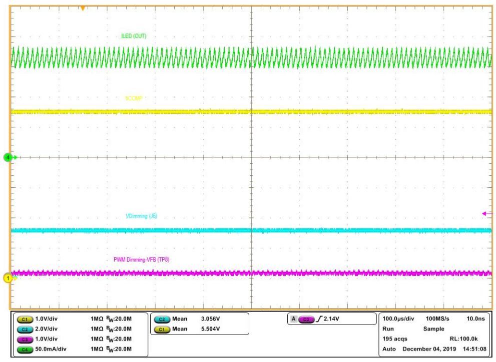


Ch.1: VGS (TP3) - Ch.2: VCS

Ch.3: VCC (TP7) - Ch.4: LED Output Current

Figure 13 and Figure 14 show a different managing of Analog and PWM dimming status regarding the main signals (focused on ILed current). The demo is working at 60 Vin Full Load (16LED) and two different dimming levels have been settled. Figure13, with 3 V of dimming input voltage, shows a level of Analog dimming current (ILED is around 155 mA) while in Figure14 with 1 V of dimming input voltage as highlighted, a PWM dimming with a hiccup current (ILED average is around 35 mA).

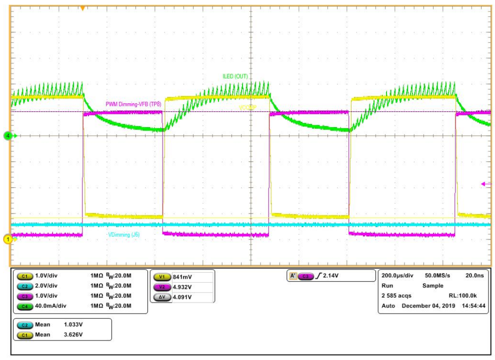
Figure 13. EVAL-IBD002-35W VDIMM = 3 V 60Vindc (16LED)



Ch.1: VCOMP - Ch.2: VCS

Ch.3: VCC (TP7) - Ch.4: LED Output Current

Figure 14. EVAL-IBD002-35W VDIMM = 1 V 60Vindc (16LED)

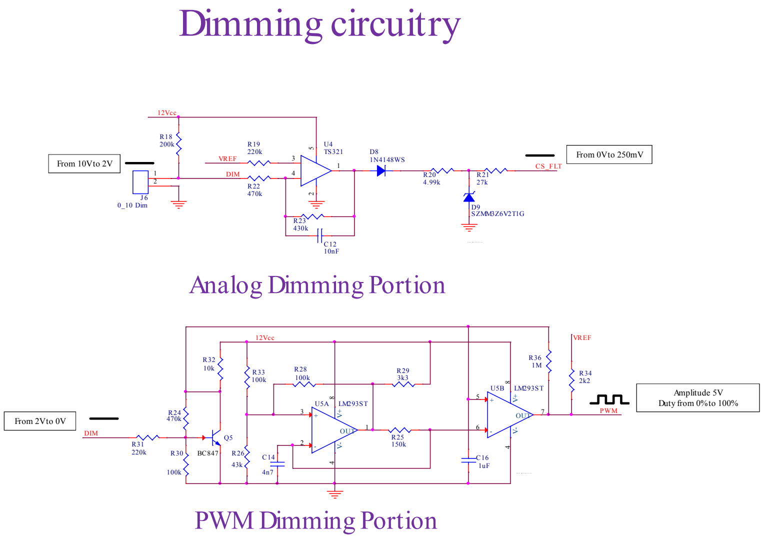


Ch.1: COMP (TP3) - Ch.2: VCS

Ch.3: VCC (TP7) - Ch.4: LED Output Current

Figure 15 shows Analog and PWM schematic with dimming's portion both managed via J6 connector. For Input Voltage between 10 V to 2 V the Analog dimming circuit injects an ever higher offset signal on HVLED002 current sense, so decreasing the output current. When VDimm input voltage decreases under 2 V, the PWM dimming circuit starts to generate a PWM output voltage with 5 V - 0 V amplitude, the FB pin is pulled up to VREF and the switching activity of HVLED002 is stopped as much as FB=VREF, further decreasing the output average current.

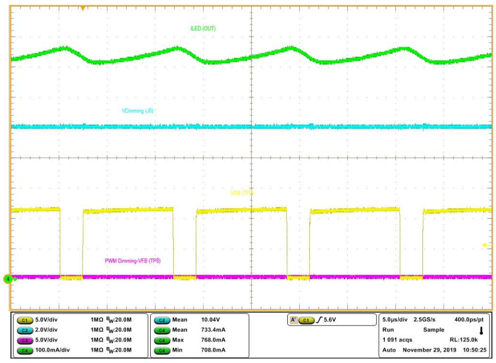
Figure 15. EVAL-IBD002-35W Analog and PWM dimming schematic



Images showing several dimming states are shown in the following pages.

From Figure 16 to Figure 19 we see 4 different levels of dimming input voltage that manage both Analog and PWM dimming control for 60 Vin at Full Load (16Led 48 V).

Figure 16. EVAL-IBD002-35W VDIMM = 10 V



Ch.1: VGS (TP3) - Ch.2: VDimming (J6)

Ch.3: PWM dim/FB(TP8) - Ch.4: Led Output Current

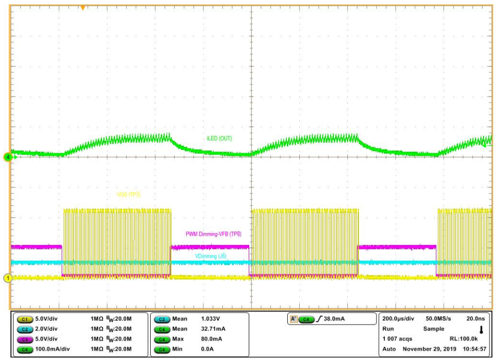
Figure 17. EVAL-IBD002-35W VDIMM = 2 V

Ch.1: VGS (TP3) - Ch.2: VDimming (J6)

Ch.3: PWM dim/FB(TP8) - Ch.4: Led Output Current

Note: *Figure16 (Vdimm=10 V) → Iled = 733 mA*
Figure17 (Vdimm= 2 V) → Iled = 76 mA
Figure18 (Vdimm= 1 V) → Iled = 32 mA
Figure19 (Vdimm= 0.2 V) → Iled = 5 mA

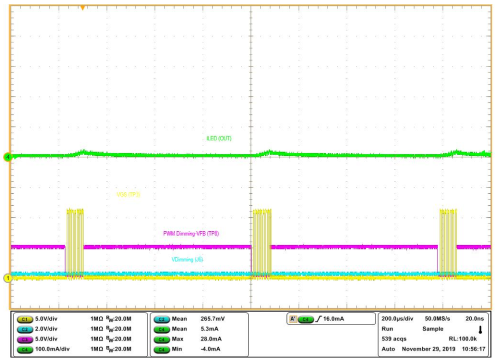
Figure 18. **EVAL-IBD002-35W VDIMM = 1 V**



Ch.1: VGS (TP3) - Ch.2: VDimming (J6)

CCh.3: PWM dim/FB(TP8) - Ch.4: LED Output Current

Figure 19. **EVAL-IBD002-35W ILed average = 1%**

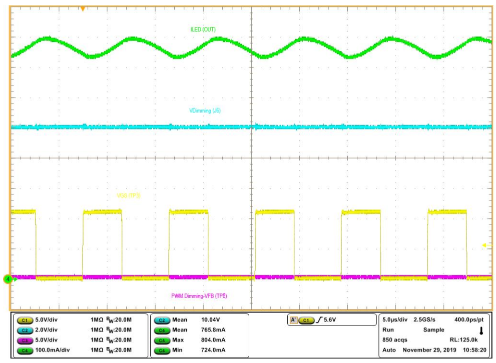


Ch.1: VGS (TP3) - Ch.2: VDimming (J6)

Ch.3: PWM dim/FB(TP8) - Ch.4: LED Output Current

From Figure 20 to Figure 23 we see 4 different levels of dimming input voltage that manage both Analog and PWM dimming control for 48 Vin at Low Load (8LED 24 V).

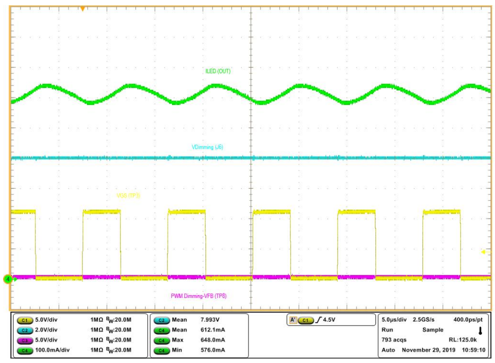
Figure 20. **EVAL-IBD002-35W VDIMM = 10 V**



Ch.1: VGS (TP3) - Ch.2: VDimming (J6)

Ch.3: PWM dim/FB(TP8) - Ch.4: LED Output Current

Figure 21. **EVAL-IBD002-35W VDIMM = 8 V**

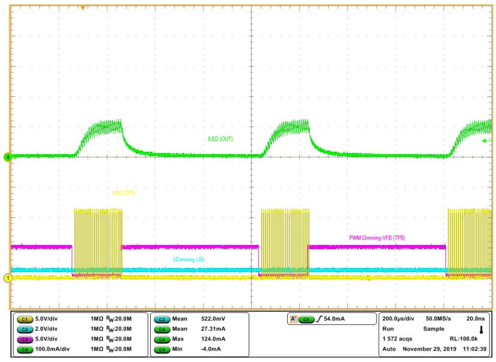


Ch.1: VGS (TP3) - Ch.2: VDimming (J6)

Ch.3: PWM dim/FB(TP8) - Ch.4: LED Output Current

Note: *Figure20 (Vdimm=10 V) → Iled = 765 mA*
Figure21 (Vdimm= 8 V) → Iled = 612 mA
Figure22 (Vdimm=0.5 V) → Iled = 27 mA
Figure23 (Vdimm= 0 V) → Iled = 0 mA

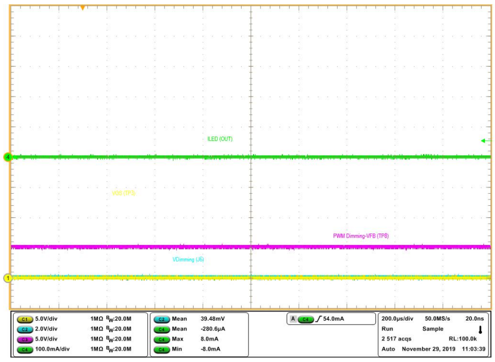
Figure 22. **EVAL-IBD002-35W VDIMM = 0.5 V**



Ch.1: VGS (TP3) - Ch.2: VDimming (J6)

Ch.3: PWM dim/FB(TP8) - Ch.4: LED Output Current

Figure 23. **EVAL-IBD002-35W VDIMM = 0 V**



Ch.1: VGS (TP3) - Ch.2: VDimming (J6)

Ch.3: PWM dim/FB(TP8) - Ch.4: LED Output Current

Figure 24 shows the ILed trend vs. VDimming input voltage from 10 V to 0 V (100%÷0%) and even the Analog dimming area and PWM dimming area have been highlighted. Both 60 Vin-48 Vout and 48 Vin-24 Vout measurements are shown.

Figure 24. **Dimming 0V÷10V (No Load ÷ Full Load) vs. ILed output current**

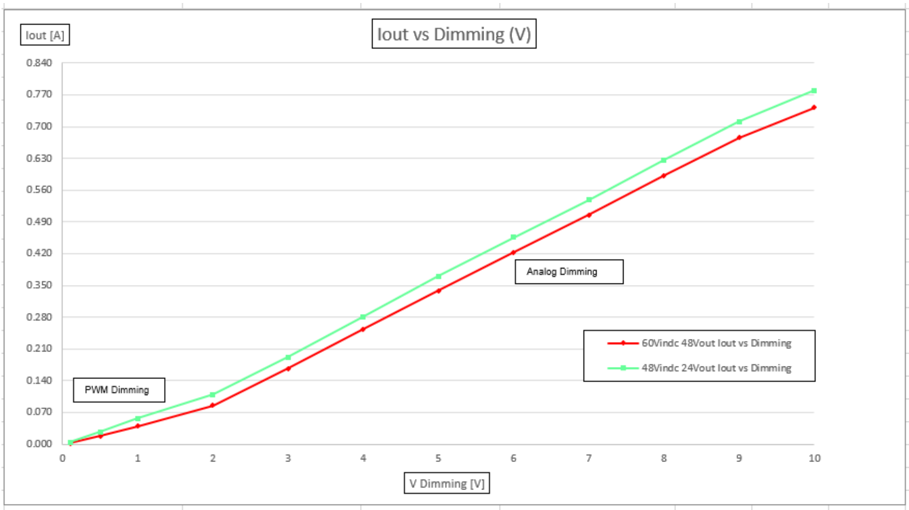
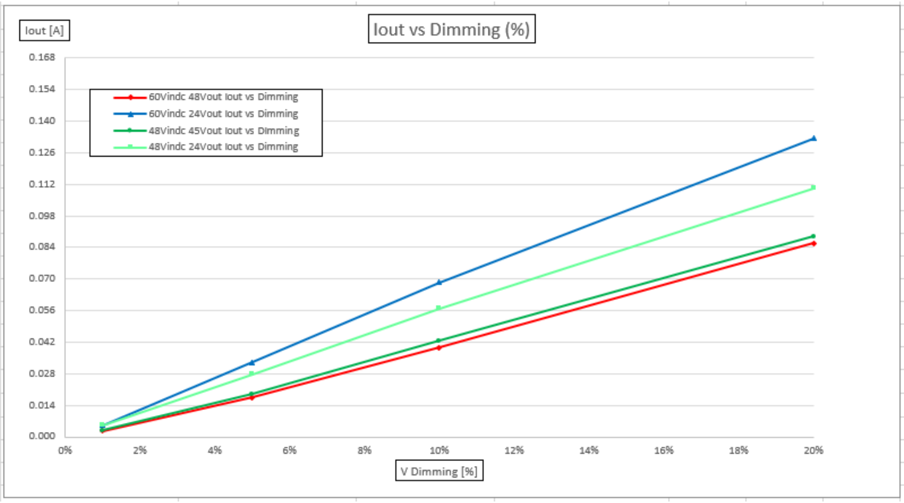


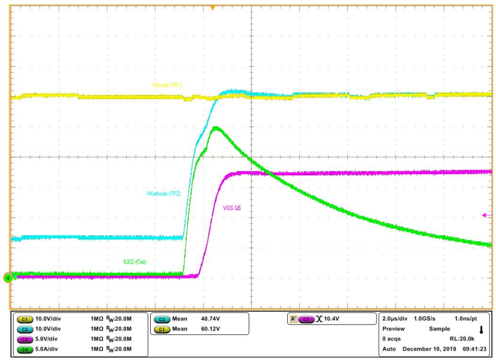
Figure 25 shows the PWM Dimming area detail of several settings (Vin and Vout) to show the linear current shape.

Figure 25. Dimming 1%÷20% vs. ILed Output Current (PWM Dimming area)



7 EVAL-IBD002-35W short-circuit protection

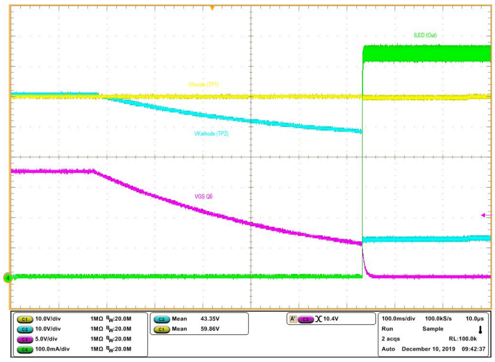
Figure 26. **EVAL-IBD002-35W output short-circuit 60Vindc (16LED)**



Ch.1: VAnode (TP1) - Ch.2: VKathode (TP2)

Ch.3: VGS Q6 - Ch.4: LED Current + Ishort

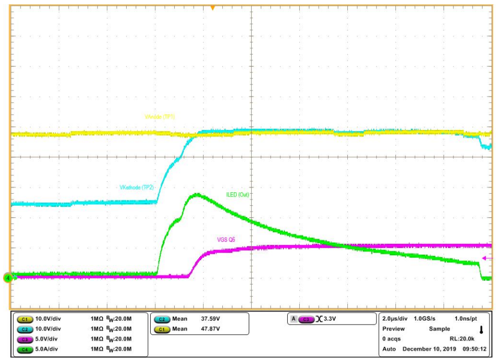
Figure 27. **EVAL-IBD002-35W output short-circuit removal 60Vindc (16LED)**



Ch.1: VAnode (TP1) - Ch.2: VKathode (TP2)

Ch.3: VGS Q6 - Ch.4: LED Current + Ishort

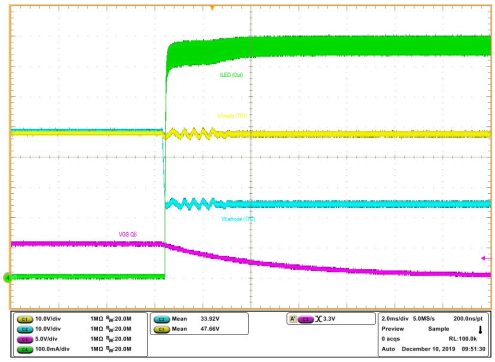
Figure 28. **EVAL-IBD002-35W output short-circuit 48Vind (8LED)**



Ch.1: VAnode (TP1) - Ch.2: VKathode (TP2)

Ch.3: VGS Q6 - Ch.4: LED Current + Ishort

Figure 29. **EVAL-IBD002-35W output short-circuit removal 48Vindc (8LED)**

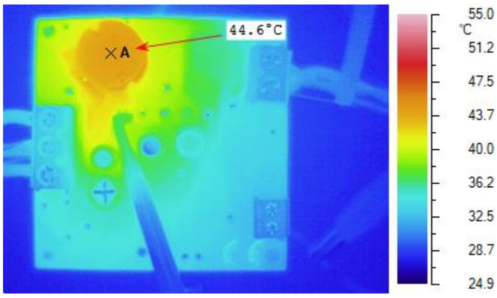


Ch.1: VAnode (TP1) - Ch.2: VKathode (TP2)

Ch.3: VGS Q6 - Ch.4: LED Current + Ishort

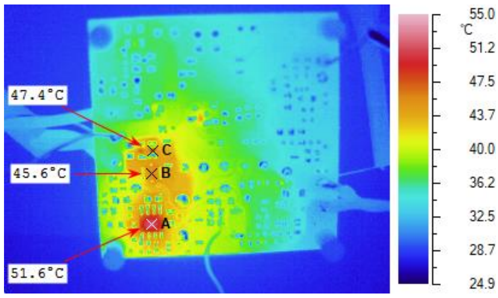
8 EVAL-IBD002-35W thermography

Figure 30. **EVAL-IBD002-35W 60 Vindc (16LED) - Top View**



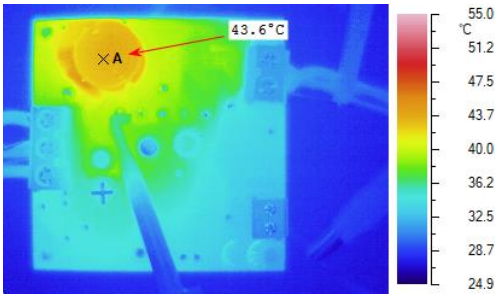
A: L1 (pcb) Hottest Front area

Figure 31. **EVAL-IBD002-35W 60 Vindc (16LED) - Bottom View**



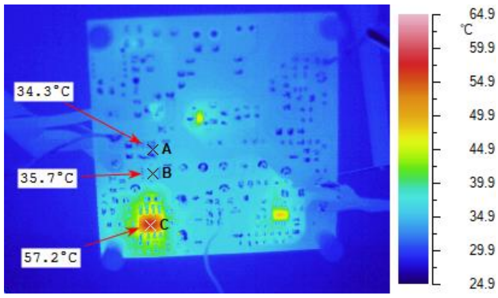
A: U1 - B: Q1 - C: R9

Figure 32. **EVAL-IBD002-35W Short - Top View**



A: L1 (pcb) Hottest Front area

Figure 33. **EVAL-IBD002-35W Short - Bottom View**



A: R9 - B: Q1 - C: U1

9 EVAL-IBD002-35W Bill of Material

Reference	Description	Value	PCB Footprint	Supplier
C1	Elcap	10uF	C6.3\P2.54	Nichicon
C2	Elcap	4.7uF	C5P2	Nichicon
C3	Ceramic Capacitor	100nF	0805	Several
C4	Ceramic Capacitor	NM	0603	Several
C5	Ceramic Capacitor	100nF	0805	Several
C6	Ceramic Capacitor	470pF	0603	Several
C7	Ceramic Capacitor	470pF	0603	Several
C8	Elcap	10uF	C5P2	Nichicon
C9	Elcap	10uF	C5P2	Nichicon
C10	Ceramic Capacitor	10nF	0603	Several
C11	Ceramic Capacitor	2.2uF NM	1206	AVX
C12	Ceramic Capacitor	10nF	0603	Several
C14	Ceramic Capacitor	4n7	0805	Several
C15	Ceramic Capacitor	47n	0805	Vishay
C16	Ceramic Capacitor	1uF	1206	Several
C31	Ceramica Capacitor	1uF NM	0805	Several
D1	Diode	STPS2H100AF	SMA	STMicroelectronics
D2	Diode Zener	BZT52C47S NM	SOD323	Taiwan
D3	Diode Zener	BZX84J-C5V6	SOD323	Nexperia
D4	Diode	1N4148WS	SOD323	Several
D5	Diode	STPS2H100AF	SMA	Several
D6	Diode	1N4148WS	SOD323	Several
D7	Diode	1N4148WS	SOD323	Several
D8	Diode	1N4148WS	SOD323	Several
D9	Diode Zener	SZMM3Z6V2T1G	SOD323	On Semi
D10	Diode Zener	SMZJ3804B-E3/52	SMB	Vishay
D11	Diode	1N4148WS	SOD323	Several
D22	Diode	1N4148WS NM	SOD323	Several
J1	Connector	VIN	Morsetti vite 3posi P.5.08	Weidmuller
J2	Connector	LED	morsetti vite 2pos P.5.08	Weidmuller
J4	Connector	5V_Out NM	morsetti vite 2pos p.3.5	TE Connectivity
J5	Connector	OVP_dis NM	2pins	Molex
J6	Connector	0_10 Dim	morsetti vite 2pos p.3.5	TE Connectivity
L1	Inductor	560uH ELC12D561E	Dia14, h16.5 p7.5	Panasonic
Q1	Power Mosfet	STL4N10F7	PF3.3X3.3	STMicroelectronics

Reference	Description	Value	PCB Footprint	Supplier
Q2	Power Mosfet	2N7002	SOT23	Infineon
Q3	Transistor	BC817-25L	SOT23	On Semi
Q4	Transistor	BC817-25L	SOT23	On Semi
Q5	Transistor	863-BC847BLT1G	SOT23	On Semi
Q6	Power Mosfet	2N7002	SOT23	Infineon
Q7	Power Mosfet	STL20DN10F7 NM	PF5X6_DOUBLE	STMicroelectronics
R1	Resistor	0R0	0603	Several
R2	Resistor	NM	0603	Several
R3	Resistor	100k	0603	Several
R4	Resistor	100R	0603	Several
R5	Resistor	1k	0805	Several
R6	Resistor	200k	0603	Several
R7	Resistor	NM	0805	Several
R8	Resistor	0R68 1%	0805	Several
R9	Resistor	0R62 1%	0805	Several
R10	Resistor	1k	0603	Several
R11	Resistor	NM	0805	Several
R12	Resistor	100k	0603	Several
R13	Resistor	2k7	1206	Several
R14	Resistor	442k 1%	0603	Several
R15	Resistor	7.5k 1%	0603	Several
R16	Resistor	470k	0603	Several
R17	Resistor	120k 1%	0603	Several
R18	Resistor	200k	0603	Several
R19	Resistor	220k	0603	Several
R20	Resistor	4.99k 1%	0603	Several
R21	Resistor	27k 1%	0603	Several
R22	Resistor	470k	0603	Several
R23	Resistor	430k	0603	Several
R24	Resistor	470k	0603	Several
R25	Resistor	150k	0603	Several
R26	Resistor	43k	0603	Several
R27	Resistor	2.2k NM	1206	Several
R28	Resistor	100k	0603	Several
R29	Resistor	3k3	0603	Several
R30	Resistor	100k	0603	Several
R31	Resistor	220k	0603	Several
R32	Resistor	10k	0603	Several
R33	Resistor	100k	0603	Several
R34	Resistor	2k2	0603	Several

Reference	Description	Value	PCB Footprint	Supplier
R35	Resistor	100K	0805	Several
R36	Resistor	1M	0603	Several
R54	Resistor	0R0 NM	0805	Several
R55	Resistor	1M NM	0805	Several
R56	Resistor	100K NM	0805	Several
R57	Resistor	1K NM	0805	Several
R61	Resistor	33K NM	0805	Several
TP1	Test Point Red	TP1 NM	KEYSTONE-5000	KEYSTONE
TP2	Test Point Red	TP2 NM	KEYSTONE-5000	KEYSTONE
TP3	Test Point Red	TP3 NM	KEYSTONE-5000	KEYSTONE
TP4	Test Point Red	TP4 NM	KEYSTONE-5000	KEYSTONE
TP5	Test Point Red	TP5 NM	KEYSTONE-5000	KEYSTONE
TP6	Test Point Black	TP6 NM	KEYSTONE-5000	KEYSTONE
TP7	Test Point Red	TP7 NM	KEYSTONE-5000	KEYSTONE
TP8	Test Point Red	TP8 NM	KEYSTONE-5000	KEYSTONE
U1	Controller	HVLED002	SO8	STMicroelectronics
U2	Voltage Reference	TL432AIL3T	SOT23	STMicroelectronics
U3	Optocoupler	TCLT1007 NM	SO4L	Vishay
U4	OpAmp	TS321	SOT23-5	STMicroelectronics
U5	OpAmp	LM293ST	MiniSO8	STMicroelectronics

10 EVAL-IBD002-35W References

HVLED002 Data Sheet rev 1.0 www.st.com

Revision history

Table 3. **Document revision history**

Date	Version	Changes
11-Aug-2020	1	Initial release.

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