AN11126

Reference design for a remote controlled non-isolated 11 W LED driver using SSL21082, TEA1721 and JN5148

Rev. 1 — 23 February 2012 Application note

Document information

Info	Content
Keywords	SSL, SSL2108XT, TEA1721XT, JN5148, remote control, lighting, buck driver, LED, 2.4 GHz antenna.
Abstract	This application note provides basic information on the operation and performance of NXP Semiconductors SSL2108X_DR1166 reference design. It contains complete remote controller 11 W SSL driver. However, not included are a casing with heat sink, LEDs and the 2.4 GHz antenna. Using the RF remote control, brightness and on/off switch are controlled. The design is based on buck topology.

Revision history

Rev	Date	Description
v.1	20120223	first issue

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1. Introduction

This application note provides basic information on the operation and performance of NXP Semiconductors SSL2108X_DR1166 reference design. It contains complete remote controller 11 W SSL Driver. However, the casing with heat sink, LEDs and 2.4 GHz antenna are not included in the shipment.

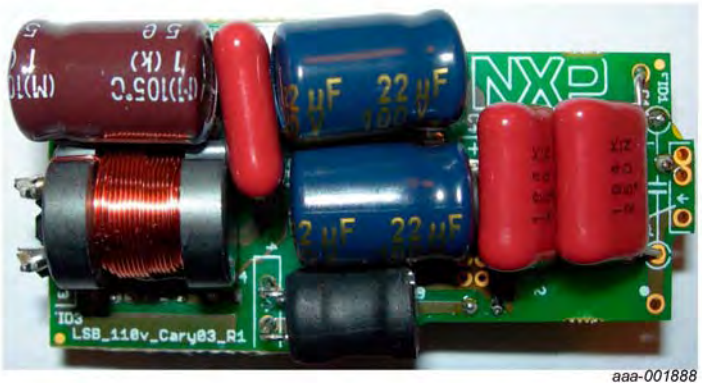
The design is based on buck topology which does not provide galvanic isolation. Using the RF remote control, brightness and on/off switch are controlled.

Remark: Unless otherwise stated all voltages are AC.

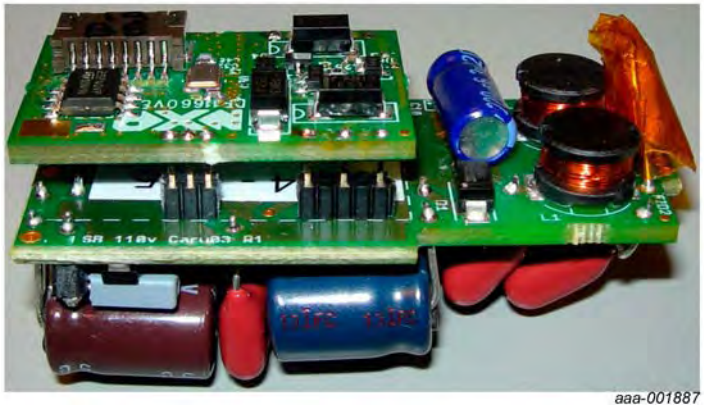
The design contains:

- Large signal board (SSL2108X)
  - EMI filter
  - Mains rectifier
  - Valley fill circuit
  - Buck inductor for supply unit
  - SSL driver (SSL21082)
- Small signal board (DR1166) buck supply (TEA1721)
  - Generates VCC = 2.7 V for JN5148 microcontroller/RF
  - Generates VDD = 13.5 V for SSL2108 driver IC
- RF/microcontroller (JN5148)
  - Contains microcontroller with flash memory
  - Contains 2.4 GHz transceiver
  - Contains connector for programming the flash memory

DR1166 is connected to SSL2108X (120 V version) using four connector headers as shown in Figure 1.



a. Top view.



b. Bottom view.

Fig 1. The 120 V SSL2108X and DR1166 demo boards

2. Safety warning

WARNING

Lethal voltage and fire ignition hazard

The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

This evaluation board is connected to a high AC voltage. Avoid touching the reference board during operation. An isolated housing is mandatory when used in uncontrolled, non-laboratory environments. Galvanic isolation of the mains phase using a fixed or variable transformer (variac) is always recommended. The symbols shown in Figure 2 indicate these devices.

a. Isolated

b. Not isolated

Fig 2. Variac isolation symbols

3. Overview of the SSL2108X/DR1166T

3.1 Electrical specification

Table 1. Overview of electrical specifications

Parameter	Min	Typ	Max	Units	Comment
AC input voltage[1]	108	120[2]	132	V	
output voltage	15	36	45	V	
output current		300		mA	fixed output current[3]
output power		10.8		W	
Power Factor		0.81			
output current ripple		5		%	depends on LED type and output capacitor
efficiency		90		%	
standby power		140[4]		mW	
PWM dimming frequency		300		Hz	
conducted EMI	meets CISPR22B				
safety	non-isolated				short circuit protection of string; thermal protection; optional open-string protection
ambient temperature	−25		+75	°C	Industrial product is available for −25 °C to +100 °C

[1] Triac dimmer tolerance feature is available with optional circuitry described in Section 3.4.6

[2] Modification for 230 V application is described in Section 3.4.7

[3] Value can be changed through source resistor described in Section 3.4.2. The maximum output current of this system is 350 mA.

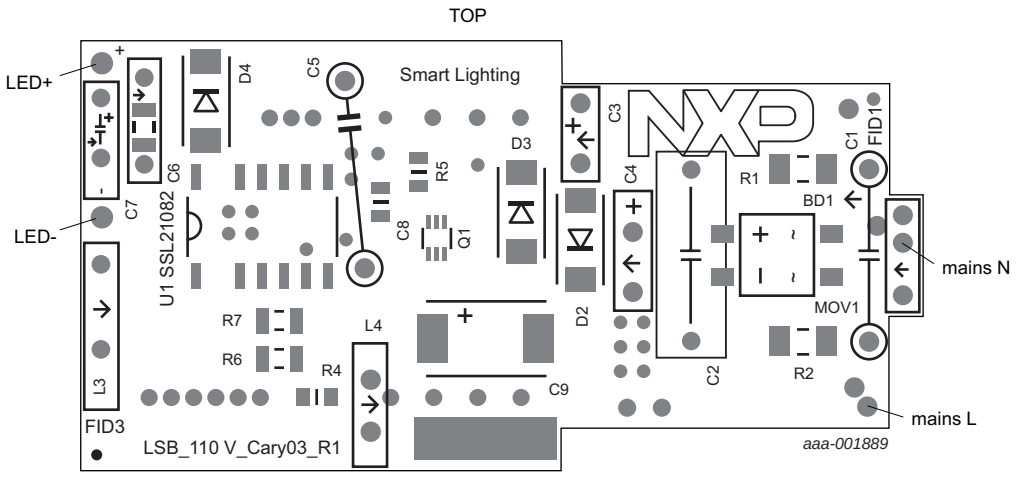
[4] 140 mW with using JenNet-IP software stack. Option to reduce to 50 mW with JenNet-LP.

[5] Short-circuit of string and thermal condition are detected through IC. More details are available in *SSL2108 data sheet*. Optional open-string protection circuitry is shown in Section 3.4.3

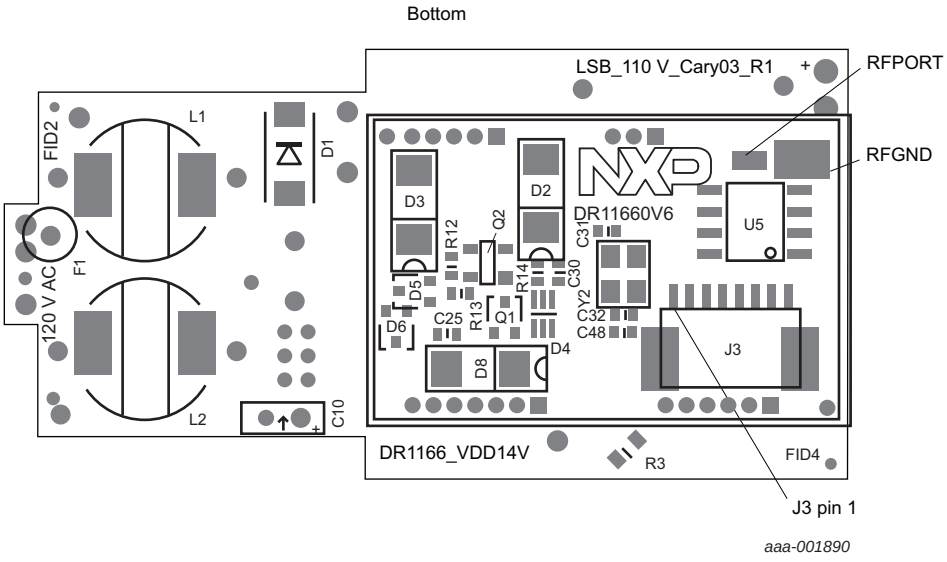
3.2 Pinning

The connections are shown in Figure 3.

The pins RFPORT and RFGND are solder islands that are intended for soldering the antenna connection.



a. Top view.



b. Bottom view.

Fig 3. The pinning outline

Table 2. Pin list for normal operation

Pin name	Type	Function	Electrical
mains L	supply	mains connection	120 V (AC)
mains N	supply	mains connection	120 V (AC)
LED+	output	LED out positive	maximum 45 V; 350 mA
LED–	output	LED out negative	-
RFPORT	output	50 Ω RF output	2.4 GHz
RFGND	ground	RF ground for coax shield	-

Table 3. Pin list of programming connector (bottom side of DR1166; see Figure 3b)

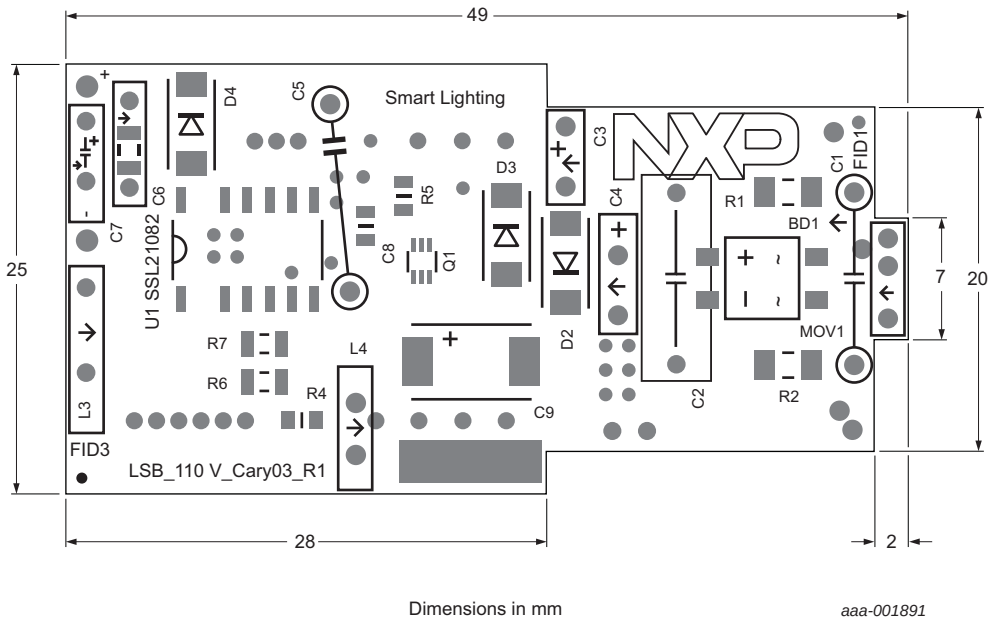
Connector	Pin	Pin name	Type	Function	Electrical
J3	1	n.c.	-		
	2	n.c.	-		
	3	SPIMISO	-		0 V to 3.6 V[1]
	4	DIO7	digital I/O	UART	0 V to 3.6 V
	5	DIO6	digital I/O	UART	0 V to 3.6 V
	6	RESETN	digital I/O	Reset_not signal for microcontroller	0 V to 3.6 V
	7	RFGND	ground		
	8	VCCRF[2]	supply		0 V to 5 V[2]

[1] Maximum voltage on SPIMISO, DIO7, DIO6 and RESETN is the lower of V_{DD2} + 2 V and 5.5 V. See the JN5148 data sheet for details. V_{DD2} is connected to VCCRF of DR1166.

[2] There is a 68 Ω resistor and a 3.3 V Zener for protection on VCCRF connection. The actual voltage shown on VCCRF is equal to or less than 3.6 V when programming. See DR1166 schematic for details in Section 4.4.

3.3 Mechanical characteristics

As the components are not grouped symmetrically on the top and bottom board. The position of the SSL2108X is typically not centered in the casing but is offset. As a result, the diameter of the casing must be between 1 mm and 3 mm larger than the width of the SSL2108X board.



PCB thickness: 1.6 mm, 2-layers.

Fig 4. Dimensions of the SSL2108X

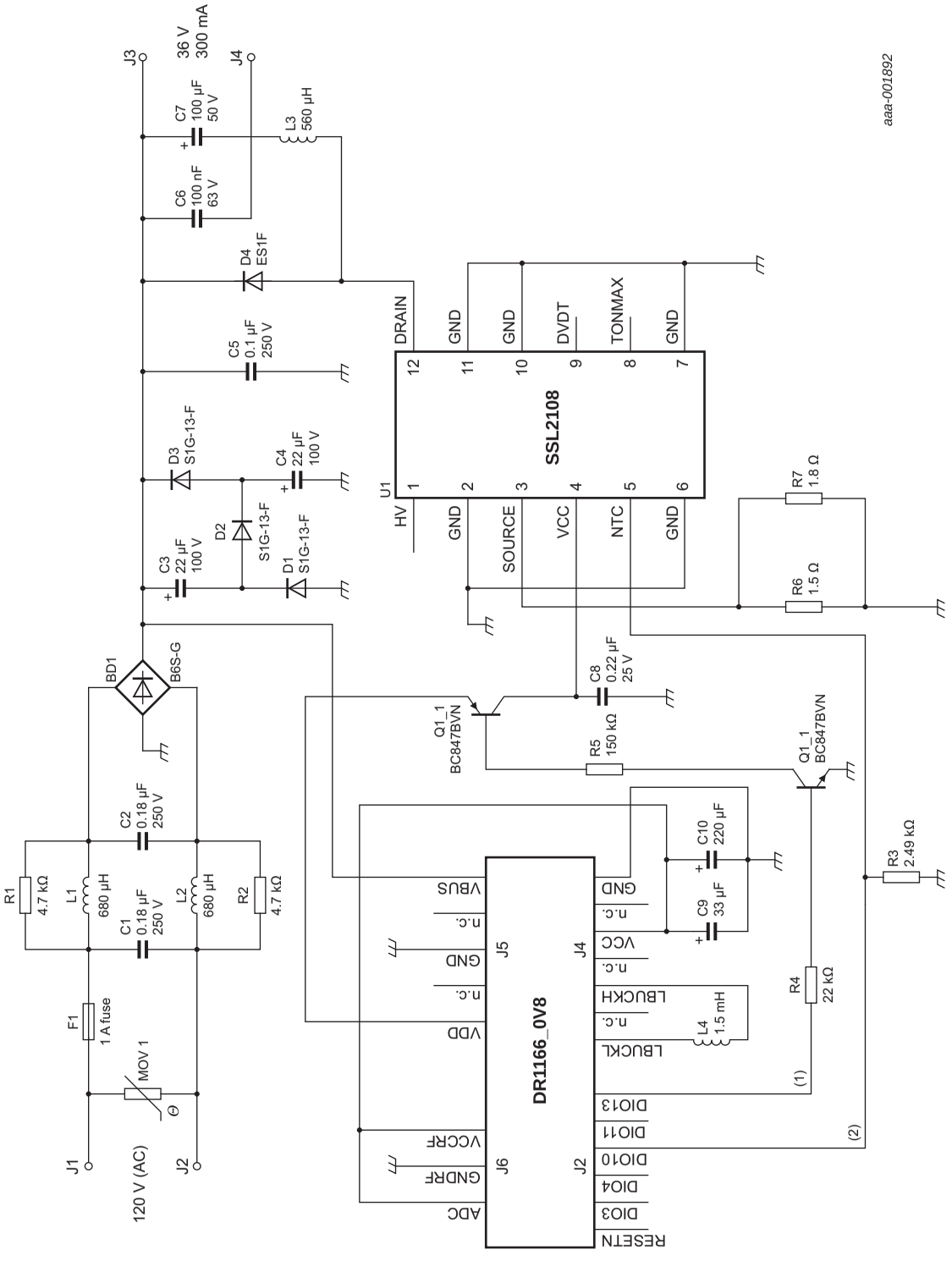
3.3.1 Recommendations

Remark: Ensure that the PCB is electrically isolated when it is used with a metal case and/or heat sink. For example, a piece of heat-resistant isolation foil.

The wide-side of the boards must face the LED plate. The narrow-side must face the lamp socket.

The efficiency of the driver is around 90 % for 300 mA 36 V LED string. The board dissipation is limited and potting is not normally required.

3.4 SSL2108X schematic diagram



(1) On/off signal.
(2) PWM signal.

Fig 5. Schematic diagram

The application shown in Figure 5 is a buck converter working in Boundary Condition Mode (BCM) using the SSL21082. The mains voltage is 120 V (AC).

The design is optimized for direct wall AC connection, without the use of a dimmer. The LED brightness is controlled using the RF controller. The PWM signal is 300 Hz. A PWM HIGH-level signal switches on the SSL driver. A PWM LOW-level signal switches it off.

When the LED supply is switched off and it goes into standby mode, the driver IC VDD supply is switched off to achieve low standby power.

3.4.1 EMI filter

To pass the production level safety requirements, use X2 capacitors in the EMI filter. Do not use film capacitors used in the reference design. Alternatively, replace the bridge rectifier with a fast recovery type. Mounting the EMI filter after the bridge enables the use of film capacitors. See Figure 6.

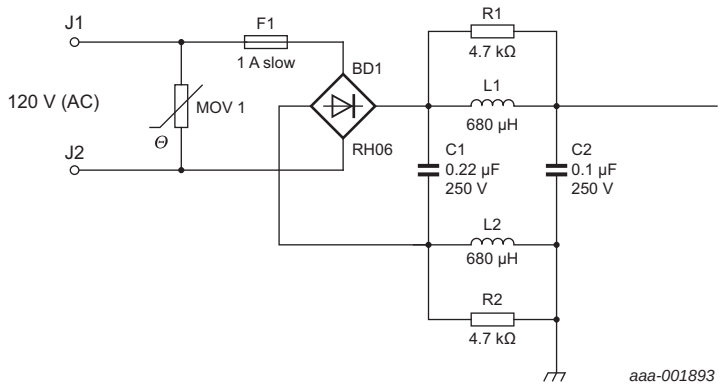


Fig 6. EMI filter option

3.4.2 LED current adjustment

The default configuration supplies a 305 mA current to the LEDs. Modifying R6 (default 1.5 Ω) and R7 (default 1.8 Ω) enables the LED current to be adapted according to:

$$I_{LED} = \frac{I_{pk}}{2} = \frac{V_{SOURCE}}{2(R6//R7)} \quad (1)$$

The V_{SOURCE} value is 0.5 V (typical).

The saturation current of L3 determines the upper limit of I_{pk}. Using the default inductor, keep the LED current below 350 mA. Dissipation of the MOSFET switch in the IC limits the maximum output current. The size of R6 and R7 is 0805. See Figure 7 for their positions and Table 5 “Bill of materials”.

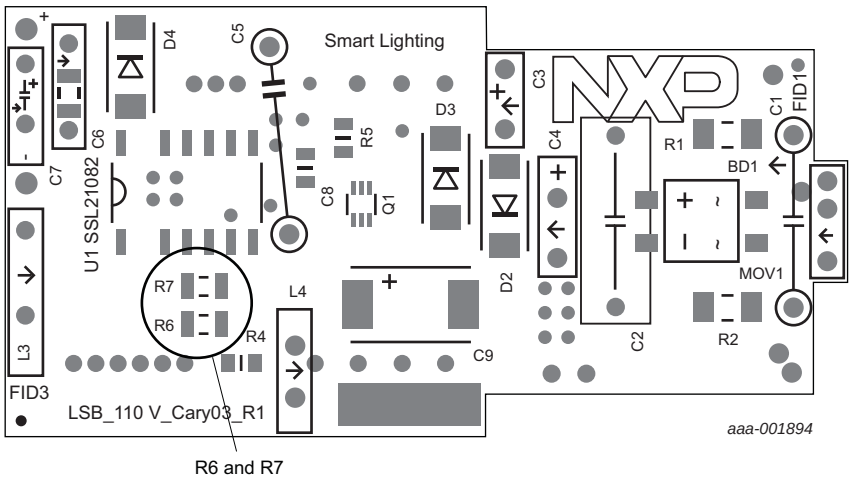


Fig 7. The position of R6 and R7

3.4.3 Protective features (open/short circuit)

The IC can detect a short-circuit string condition. When a short-circuit string condition is detected, the IC triggers the internal latched protection.

An open string condition causes the output capacitor to reach overvoltage in the reference design. Use a high-voltage rated output capacitor which can handle the mains V_{pk}. Alternatively, add a simple SCR/Zener circuit across the output to trigger protection. See circuit in Figure 8.

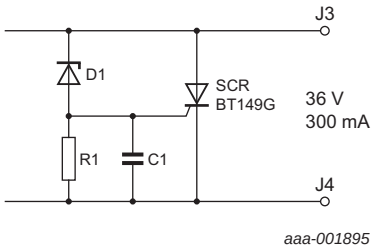


Fig 8. Circuit option for overvoltage protection

3.4.4 Low ESR capacitor (C9)

Connect a low ESR capacitor to VCC of RF IC device to avoid potential disturbance. In the reference design, a Panasonic low ESR capacitor is used. Alternatively, connect low-cost ceramic capacitors in parallel.

3.4.5 Power inductors (L3 and L4)

The unshielded power inductor generates a magnetic flux which affects the surrounding signals. In the PCB design layout, keep the important and low voltage signals far away from the magnetic flux area.

For example, to maintain a good output current accuracy, keep the source resistors R6 and R7 and their traces away from the magnetic flux area.

Remark: Magnetic flux interference (L3) has been noticed in the demoboard layout. To minimize the effect, place the power inductor away from the board and have the inductors assembled with the same polarity over boards.

3.4.6 Optional bleeder circuit for application with dimmers

The schematic shown in Figure 10 is optimized for a dimmer tolerance, which means the design can be used in combination with a phase-cut wall-dimmer.

The LED brightness is controlled only using RF remote control and cannot be controlled with the wall-dimmer. However, the LED can be switched on/off using the wall-dimmer.

Remark: The bleeder circuit, inrush current resistor, V_{bus} detection and blocking diode are added specifically for applications with dimmers.

3.4.7 230 V application schematic

Figure 9 shows the schematic of the 230 V application. In 230 V applications, the valley fill circuit is replaced with an electrolytic capacitor (C2). The Inrush current resistor R1 is added to meet the harmonic requirement (IEC61000-3-2). The components voltage ratings are shown in Figure 9. Performance is similar to the 120 V reference design with an efficiency of approximately 88.5 %.

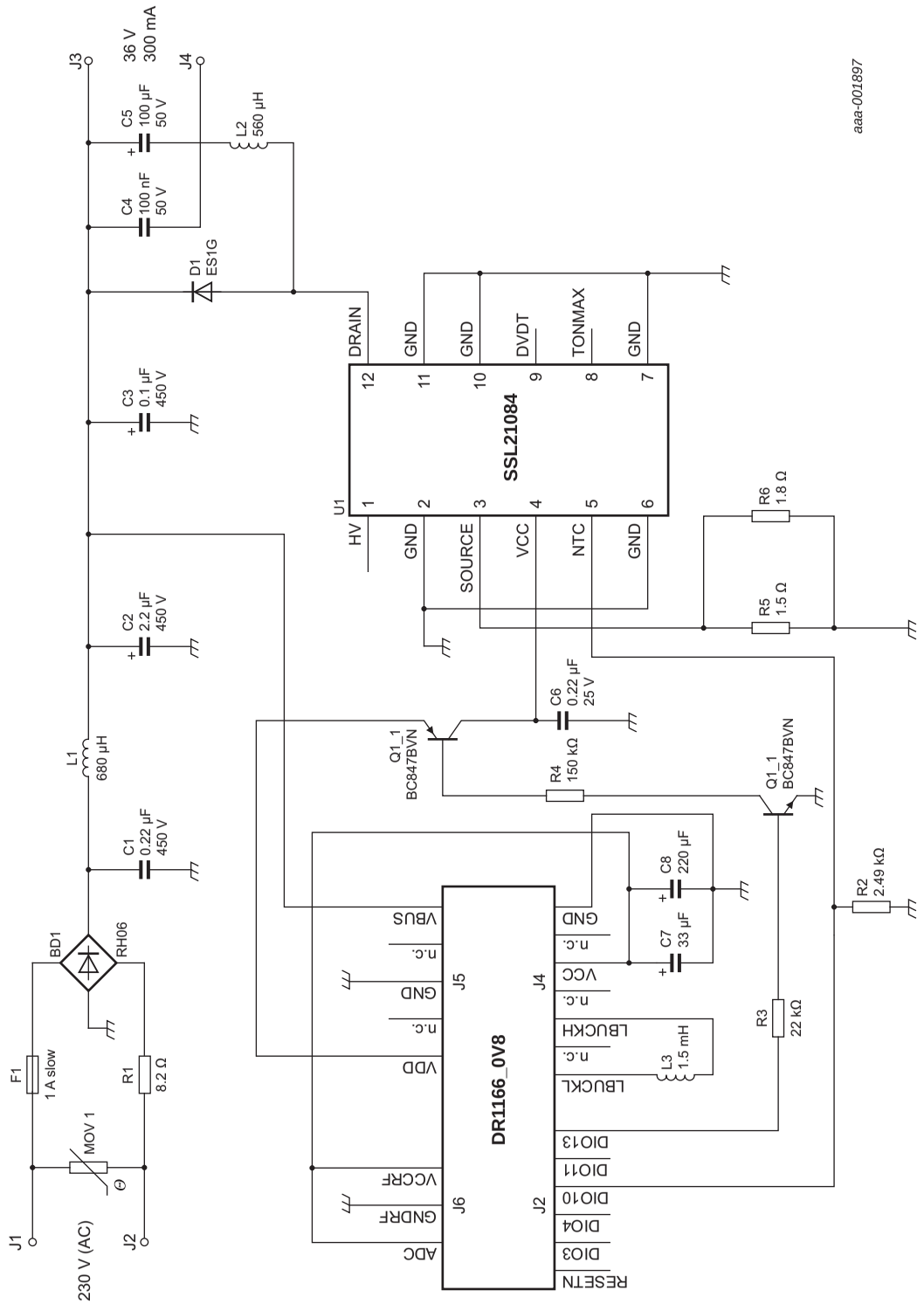


Fig 9. 230 V application schematic

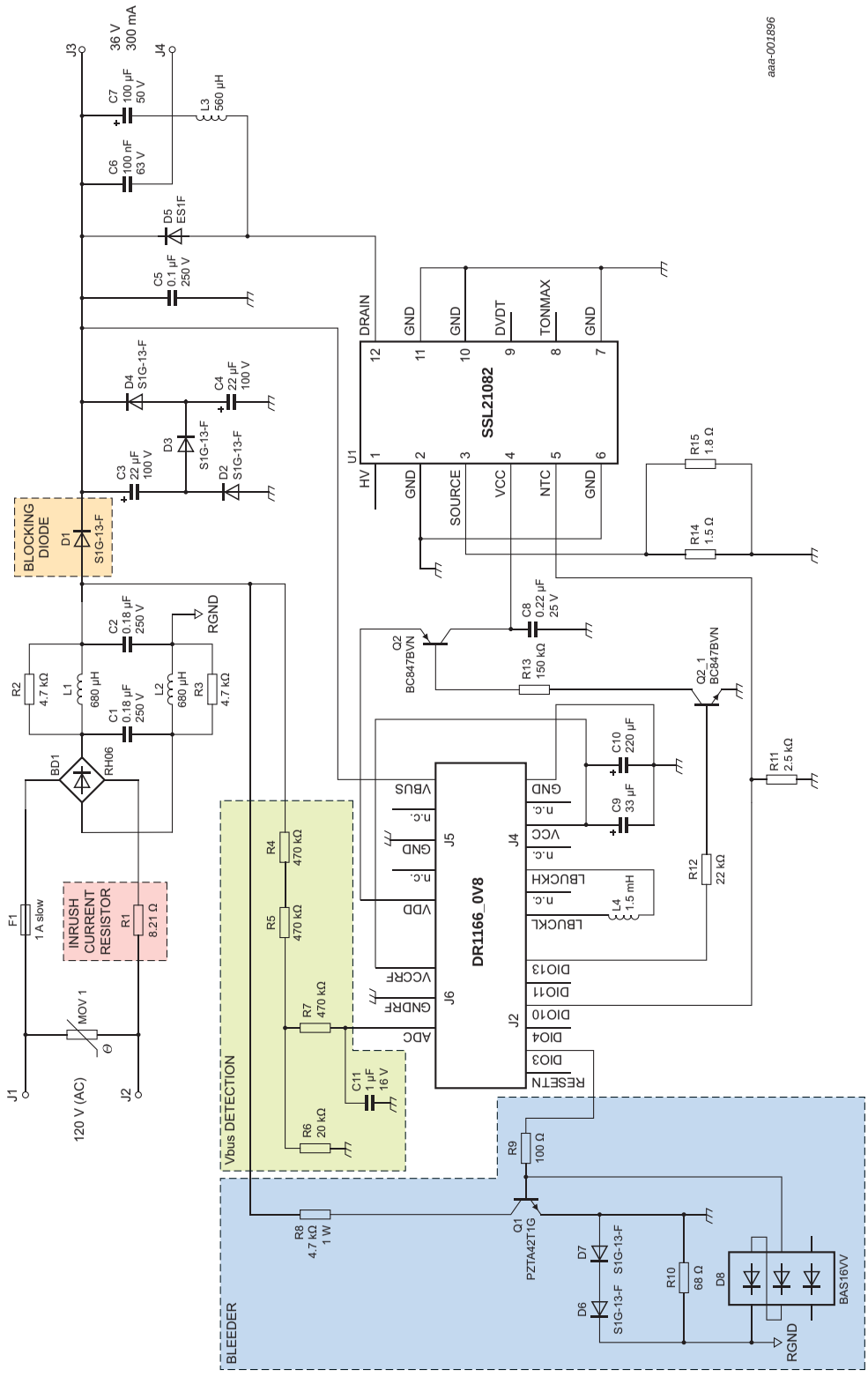


Fig 10. SL2108X schematic with wall dimmer circuit option

4. DR1166 overview

The Small Signal Board DR1166 consists of two separate parts.

- the buck supply (TEA1721)
- the RF/microcontroller (JN5148)

The ground of both parts is connected through Large Signal Board (SSL2108X).

Remark: The programming connector and the antenna are directly connected to the mains. Offline operation or isolation is required for safety purposes.

4.1 DR1166 Electrical specifications

Table 4. DR1166 electrical specifications

Parameter	Explanation	Condition	Min	Typ	Max	Unit
V_{bus}			40	-	400	V
VCC_oper	V_{CC}[1] during normal operation	I_{load} = 0 mA to 30 mA	2.6	-	3	V
VCC_program	V_{CC}[1] during programming	supply via programming connector	3	-	3.6	V
VDD		0 mA to 3 mA	-	13.5	-	V
L_{buck}	inductor value for buck supply		-	1.5	-	mH
I_{sat}	saturation current for L_{buck}	10 % change of inductance	125	-	-	mA
C_{buck}	capacitor value for buck supply		-	33 + 150		µF
ESR_Cbuck	maximum ESR series resistance of C_{buck}		-	-	0.07	Ω
F_PWM	default PWM frequency[2]		-	-	300	Hz
F_PWM_alt	alternative PWM frequency[2]		-	-	2000	Hz
Impedance			-	50	-	Ω
Frequency Range			2.4	-	2.485	GHz
Transmit Power			0.5	2.5	-	dBm

[1] VCC on JN5148.

[2] Fixed in software

4.2 Pinning

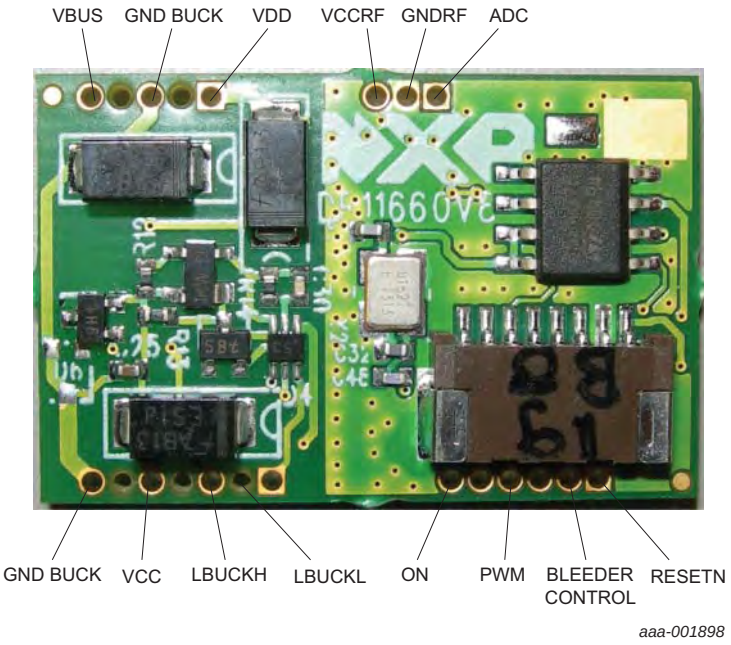
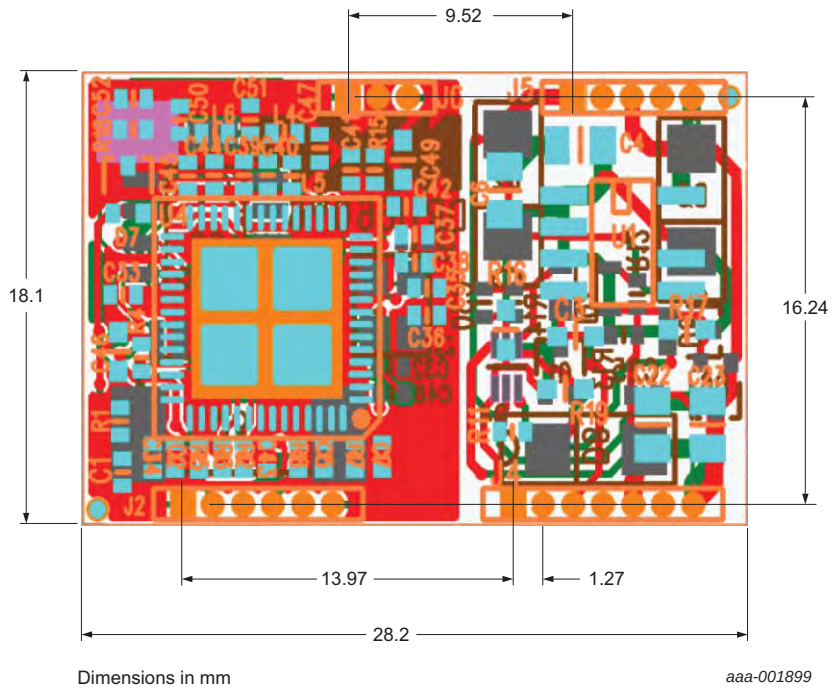


Fig 11. DR1166 pinning outline (bottom view)

4.3 DR1166 dimensions



The thickness of the PCB module: 1.6 mm.

The height above the top layer of the PCB module: 1.5 mm.

Connector drill hole size: 1.1 mm

The height below the top layer of the PCB module: 4 mm.

Fig 12. DR1166 dimensions

4.4 DR1166 and JN5148 schematic

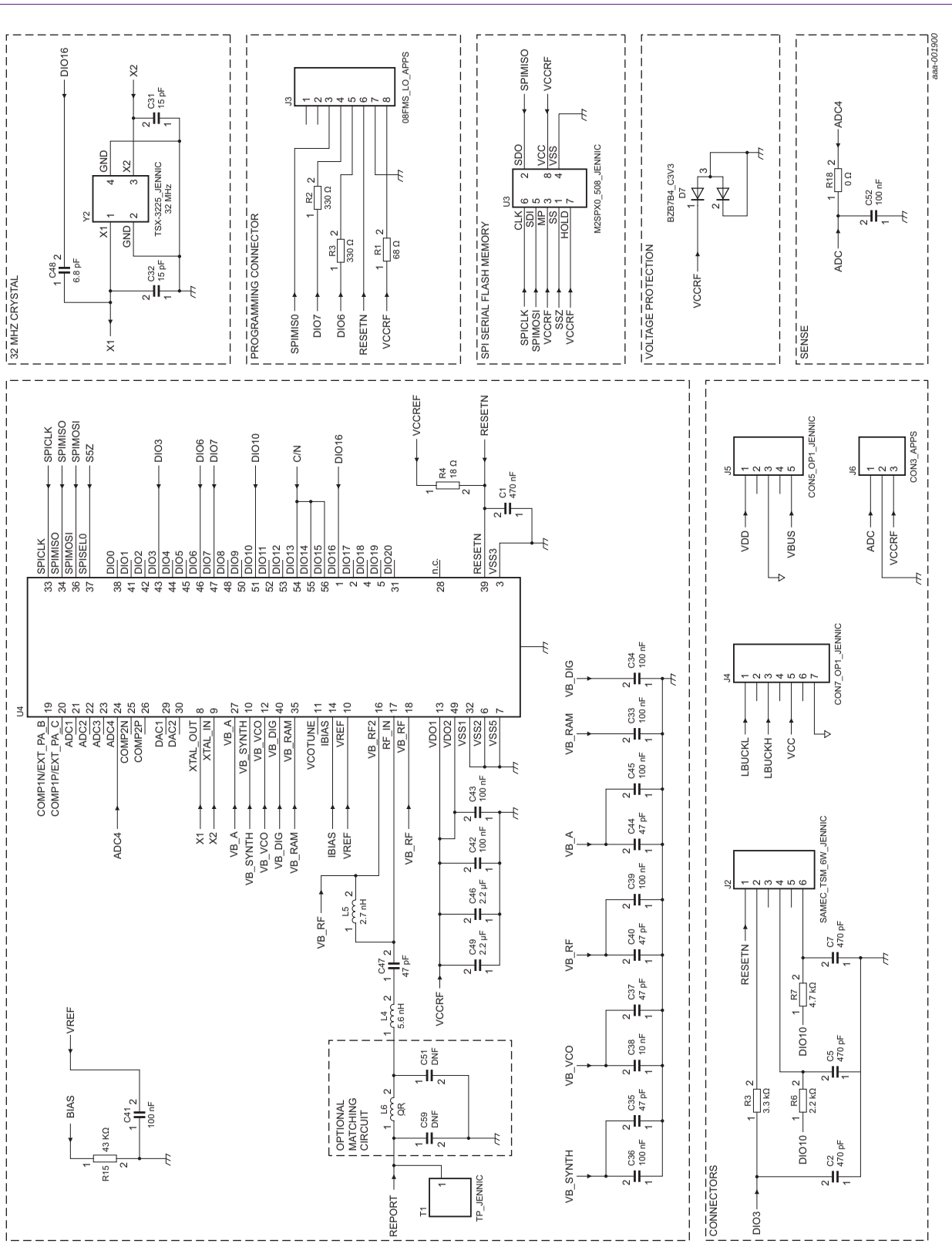


Fig 13. DR1166 and JN5148 RF/microcontroller schematic

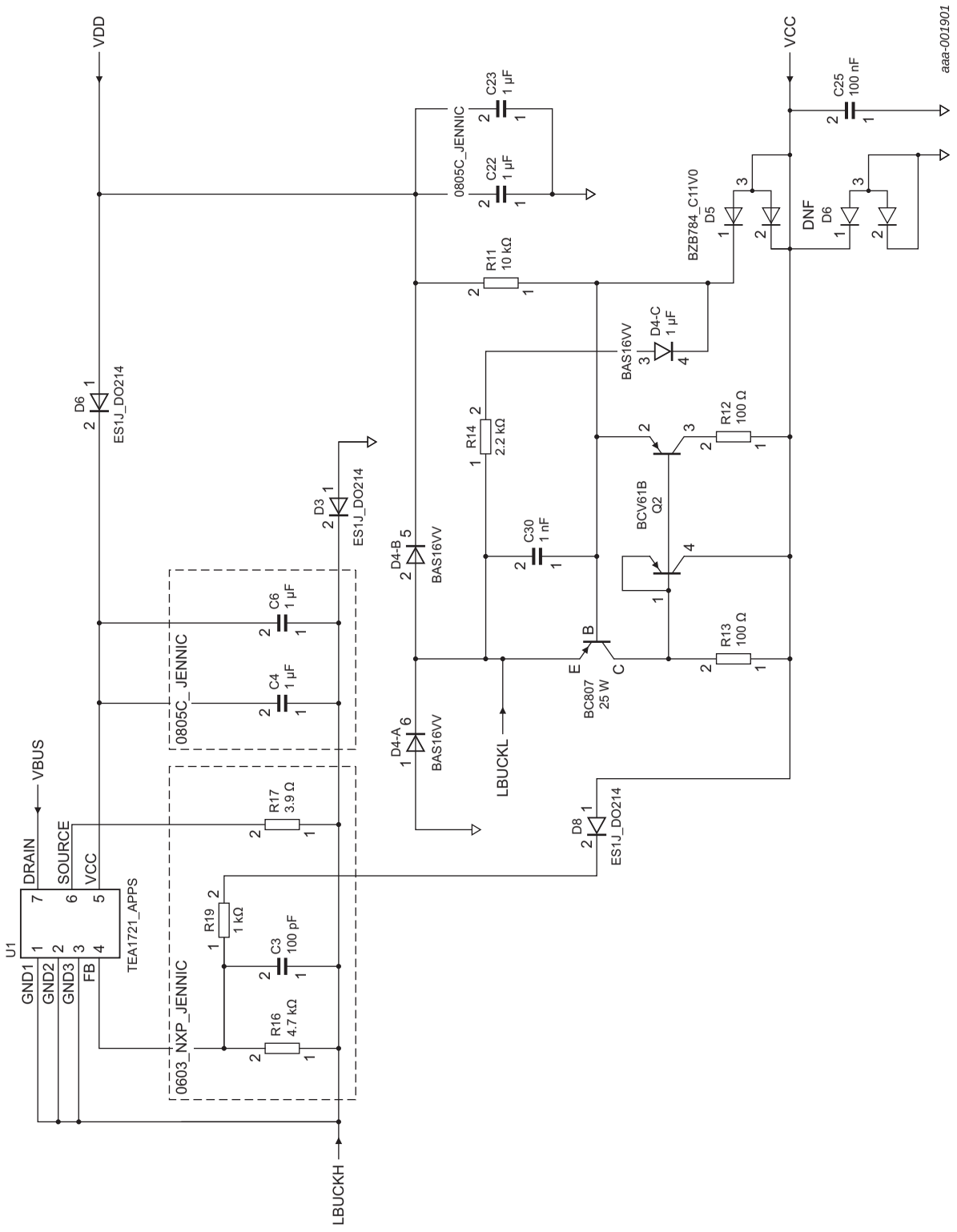


Fig 14. DR1166 and TEA1721 buck supply schematic

4.5 Spacing to mother board

The minimum spacing between the top-side of the module (measured from the top layer of PCB) and highest component on mother board is 3 mm.

The bottom side of the module must face away from SSL2108X allowing room to insert a programming connector. In addition, the 32 MHz crystal also faces away from SSL2108X to avoid the high-voltage switching interference.

4.6 Programming the DR1166

The programming method described here is suitable for prototyping. It is recommended to either program the flash before assembly for mass production or after assembly using needles rather than a programming connector. The DR1166 is programmed with a binary file provided from NXP Semiconductors using a standard PC and a USB TTL serial cable.

Disconnect the DR1166 from the mains supply before attempting to program it. The DR1166 board is supplied by the USB TTL serial interface during programming and it contains a voltage regulator to derive VCCRF from the USB interface.

A serial UART interface with 3.3 V signaling and 5 V supply is available from FTDI. Type: TTL-232R-3V3 Website: http://www.ftdichip.com/Products/Cables/USBTTLSerial.htm.

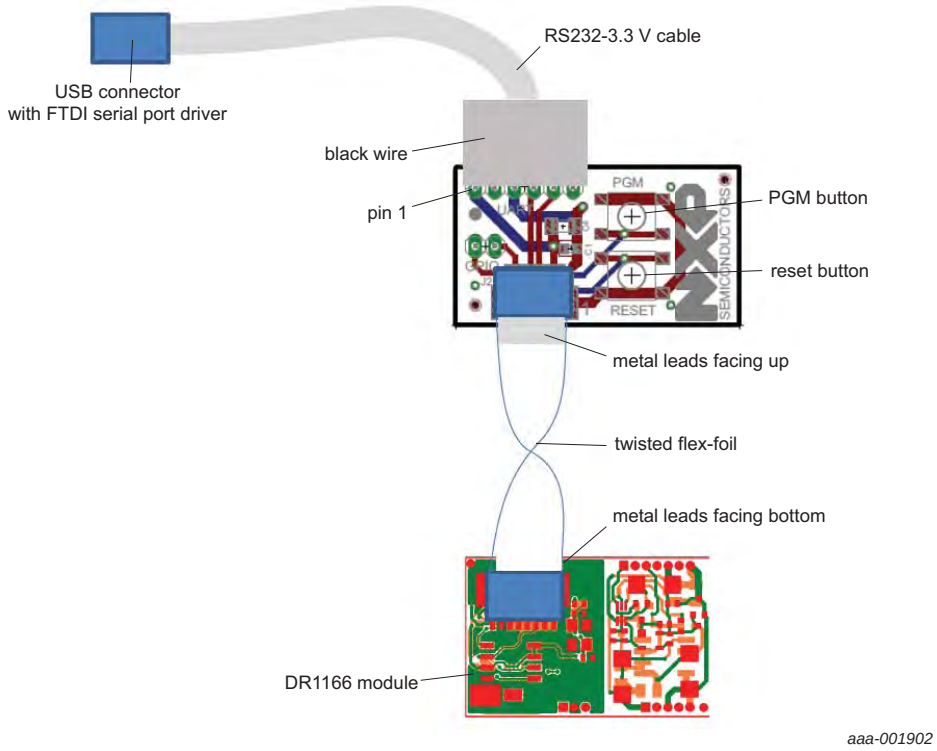


Fig 15. Programming cable connection

The driver software for the USB serial interface and programming software JN-SW-4007 Flash Programmer can be downloaded from the website: http://www.jennic.com/support/software/jn-sw- 4007_flash_programmer.

5. Antenna configuration

Remark: The antenna is directly connected to the mains supply. Make sure that the antenna cannot be reached on the outside of the housing. For example, by making plastic cover over the antenna.

In most SSL designs, the antenna is located beyond the outer edge of the SSL socket. This counters the shielding effect of the metal enclosing the socket which prevents effective RF radiation.

Ideally, the antenna signal is guided through a 50 Ω coaxial cable from the SSB solder pads to an external antenna. Keep the solder connections to the coaxial cable as short as possible. Each mm of wire adds 1 nH of inductance which is already significant in the 2.4 GHz band.

A few alternatives exist for the external antenna.

The best option is a compromise between best RF radiation and minimum visibility of optical shadow.

The first option is a small PCB that contains either an SMD chip antenna or strip line antenna. Refer to Figure 16. Choose an antenna with a good tolerance to surrounding metal and recommended clearance. Consult the antenna data sheet, typically the clearance is 8 mm to 10 mm. Keep the coaxial cable 'tails' as short as possible to maintain the 50 Ω impedance of the system.

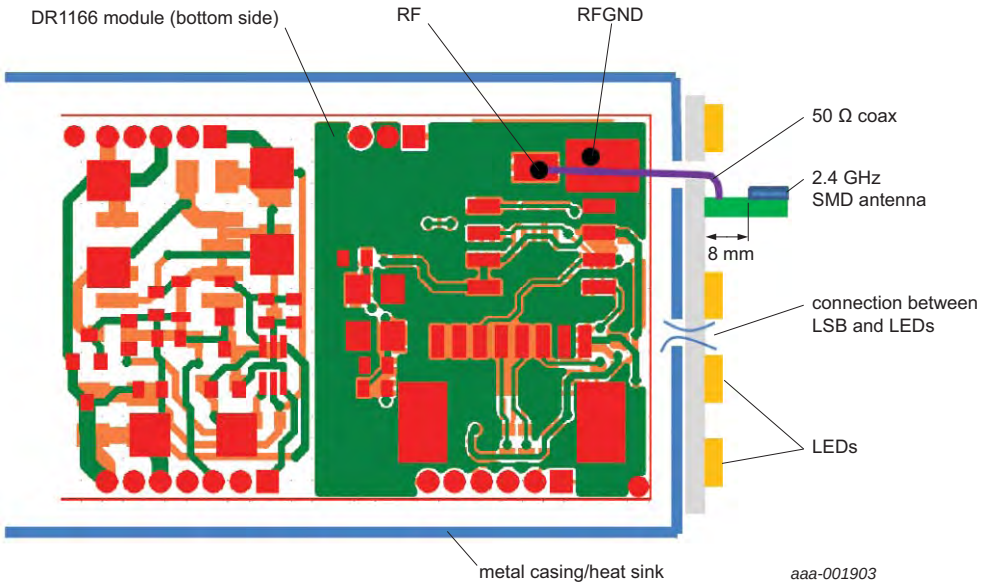


Fig 16. PCB or SMD antenna

The second option is the wire loop antenna as shown in Figure 17. This configuration exhibits good RF performance but causes severe shadow effects if the LEDs cover the complete metal front plate.

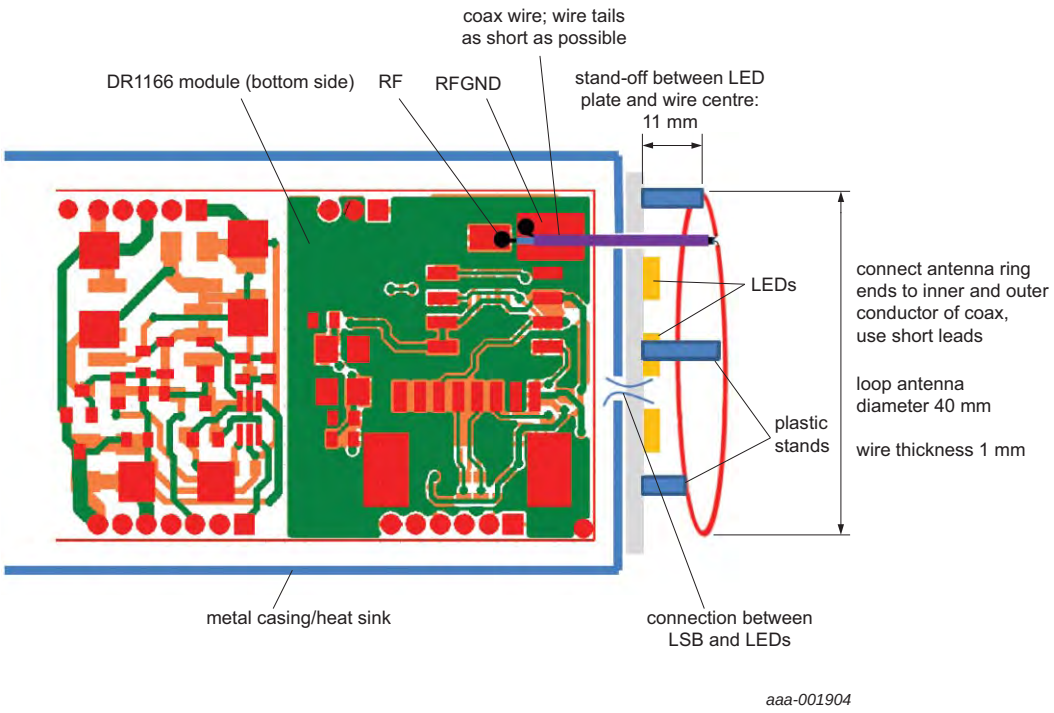
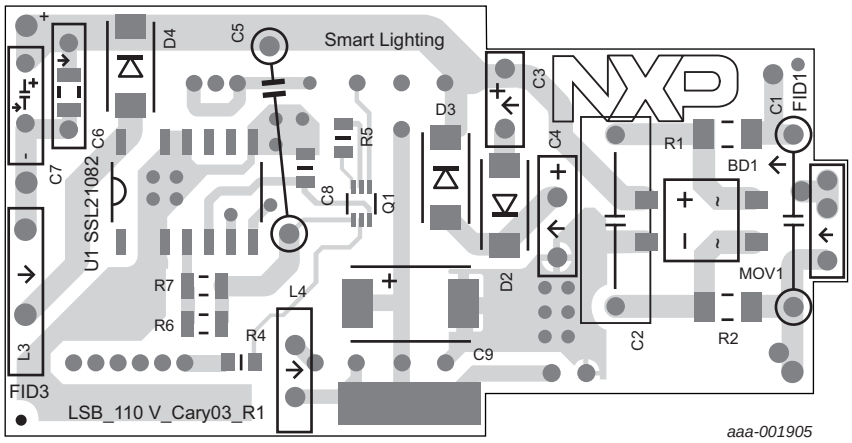


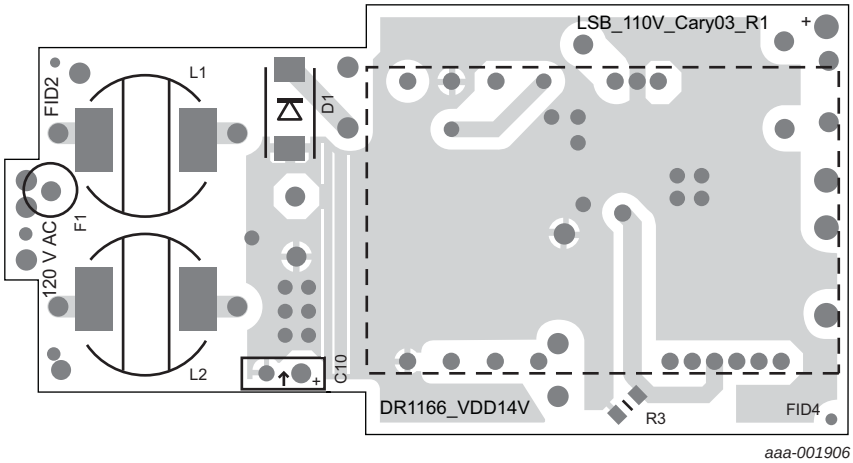
Fig 17. Loop antenna

6. PCB layouts

6.1 SSL2108X



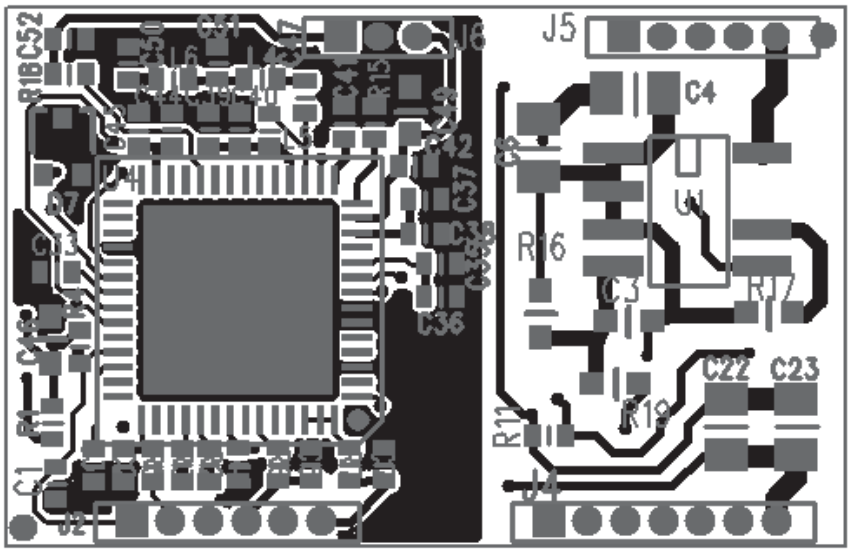
a. Top view.



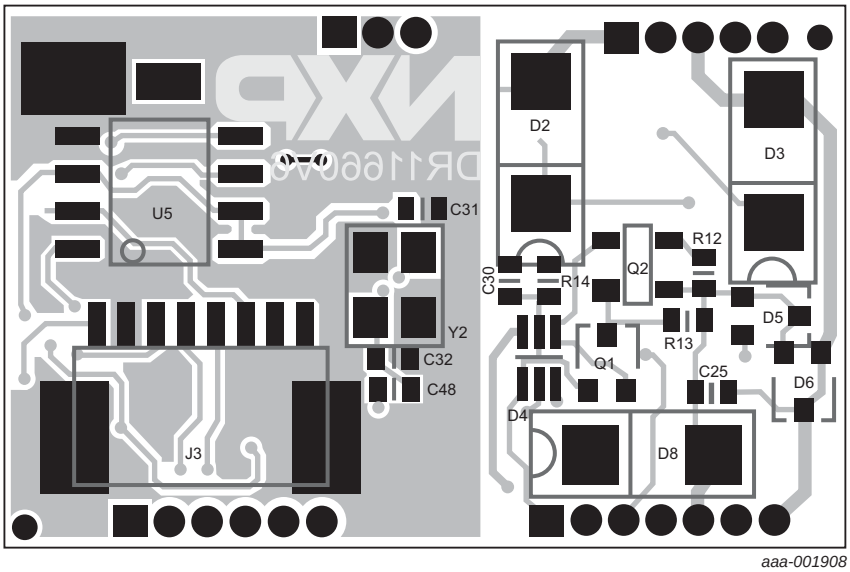
b. Bottom view.

Fig 18. SSL2108X demo board layout

6.2 DR1166



a. Top view.



b. Bottom view

Fig 19. DR1166 demo board layout

7. Bill of materials

7.1 SSL2108X board

Table 5. Bill of materials

Part	Qty	Description/Value	Part number	Manufacturer
C1; C2	2	0.18 μF; 250 V; radial	ECQ-E2184KF	Panasonic - ECG
C3; C4	2	22 μF 100 V; radial	EEU-FC2A220	Panasonic - ECG
C5	1	0.1 μF; 250 V; radial	ECW-F2104JAQ	Panasonic - ECG
C6	1	100 nF; 63 V; radial	BFC237011104	Vishay
C7	1	100 μF; 50 V; radial	EKY-500ELL101MHB5D	United Chemi-Con
C8	1	0.22 μF 25 V; 0603	GRM188R71E224KA88D	Murata
C9	1	33 μF; low ESR; 8 V; SMD	EEF-HL0K330R	Panasonic - ECG
C10	1	220 μF; 6.3 V; radial	ECA-0JM221B	Panasonic - ECG
BD1	1	bridge rectifier; 600 V; 0.8 A; MBS	B6S-G	Comchip Tech
D1; D2; D3	3	400 V; 1 A; DO214AC	S1G-13-F	Diodes Inc
D4	1	fast diode; 300 V; DO214AC	ES1F	Fairchild Semiconductor
L1; L2	2	680 μH; coil; 0.28 A; SMD	SDR0805-681KL	Bourns
L3	1	560 μH; Coil; 0.68 A; radial	ELC10D561E	Panasonic - ECG
L4	1	1.5 mH; Coil; 0.13 A; radial	22R155C	Murata
R1; R2	2	4.7 kΩ; 1206	ERJ-8GEYJ472V	Panasonic - ECG
R3	1	2.49 kΩ; 0603	ERJ-3EKF2491V	Panasonic - ECG
R4	1	22 kΩ; 0603	ERJ-3GEYJ223V	Panasonic - ECG
R5	1	150 kΩ; 0603	ERJ-3GEYJ154V	Panasonic - ECG
R6	1	1.5 Ω; 0805	CRCW08051R50FKEA	Vishay/Dale
R7	1	1.8 Ω; 0805	CRCW08051R80FKTA	Vishay/Dale
MOV1	1	surge absorber; disc; 7 mm	ERZ-V07D241	Panasonic - ECG
Q1	1	dual NPN and PNP transistor; SOT666	BC847BVN,115	NXP Semiconductors
U1	1	SSL21082; SO12	SSL21082	NXP Semiconductors
F1	1	1 A; 250 V; slow; axial	MCPMP 1 A 250 V	Multicomp

7.2 DR1166 board

Table 6. Bill of materials

Part	Qty	Description/Value	Part number	Manufacturer
C1	1	470 nF; 16 V; 0402	C1005X5R1C474K	TDK Corporation
C2; C5; C7	3	470 pF; 0402	C1005X7R1H471K	TDK Corporation
C3	1	100 pF; 0603	GRM1555C1H101JZ01D	Murata
C4; C6; C22; C23	4	1 μF; 25 V; 0805	C2012X7R1E105K	TDK Corporation
C25; C33; C34; C36; C39; C41; C42; C43; C45; C52	10	100 nF; 16 V; 0402	GRM155R71C104KA88D	Murata
C30	1	1 nF; 0402	GRM155R71H102KA01D	Murata
C31; C32	2	15 pF; 0402	GRM1555C1H150JZ01D	Murata
C35; C37; C40; C44; C47	5	47 pF; 0402	GRM1555C1H470JZ01D	Murata
C38	1	10 nF; 16 V; 0402	0402YC103KAT2A	AVX Corporation
C46; C49	2	2.2 μF; 0603	C1608X5R1A225M/0.80	TDK Corporation
C48	1	6.8 pF; 0402	C1005C0G1H6R8D	TDK Corporation
C50; C51	2	not mounted (n.m.); 0402	-	-
D2; D3; D8	3	ES1J; DO214	ES1J	Fairchild Semiconductor
D4	1	BAS16VV; SOT666	BAS16VV,115	NXP Semiconductors
D5	1	BZB784_C11; SOT323	BZB784-C11,115	NXP Semiconductors
D6	1	not mounted (n.m.); SOT323	-	-
D7	1	BZB784_C3V3; SOT323	BZB784-C3V3,115	NXP Semiconductors
L4	1	5.6 nH; 0402	LQG15HS5N6S02D	Murata
L5	1	2.7 nH; 0402	LQG15HS2N7S02D	Murata
L6	1	0 Ω; 0402	ERJ-2GE0R00X	Panasonic - ECG
Q1	1	BC807-25W; SOT323	BC807-25W,115	NXP Semiconductors
Q2	1	BCV61B; SOT143B	BCV61B,215	NXP Semiconductors
R1	1	68 Ω; 0402	ERJ-2RKF68R0X	Panasonic - ECG
R2; R3	2	330 Ω; 0402	ERJ-2RKF3300X	Panasonic - ECG
R4	1	18 kΩ; 0402	ERJ-2RKF1802X	Panasonic - ECG
R5; R6; R7	3	4.7 kΩ; 0402	ERJ-2RKF4701X	Panasonic - ECG
R11	1	10 kΩ; 0402	ERJ-2RKF1002X	Panasonic - ECG
R12; R13	2	100 Ω; 0402	ERJ-2RKF1000X	Panasonic - ECG
R14	1	2.2 kΩ; 0402	ERJ-2RKF2201X	Panasonic - ECG
R15	1	43 kΩ; 0402	ERJ-2RKF4302X	Panasonic - ECG
R16	1	4.7 kΩ; 0603	ERJ-3EKF4701V	Panasonic - ECG
R17	1	3.9 Ω; 0603	ERJ-3RQF3R9V	Panasonic - ECG
R18	1	0 Ω; 0402	ERJ-2GE0R00X	Panasonic - ECG
R19	1	1 kΩ; 0603	ERJ-3EKF1001V	Panasonic - ECG
J2	1	SAMTEC-TMS_6W; 1.27 mm pitch	-	-
J3	1	08FMS-1.0SP	08FMS-1.0SP-TF(LF)(SN)	JST
J4	1	SAMTEC-TMS_7W; 1.27 mm pitch	-	-

Table 6. Bill of materials *...continued*

Part	Qty	Description/Value	Part number	Manufacturer
J5	1	SAMTEC-TMS_5W; 1.27 mm pitch	-	-
J6	1	SAMTEC-TMS_3W; 1.27 mm pitch	-	-
U1	1	TEA1721 N1B; SO-7; SOT96	-	NXP Semiconductors
U4	1	JN5148; QFN56	JN5148/001,531	NXP Semiconductors
U5	1	M25P40VMN6PB; SO8M1	M25P40-VMN6PB	Numonyx
Y2	1	TSX3225; 32.000; 9 pF load; 10 ppm; TSX-3225	TSX-3225, 32MHZ, 10PPM, 9PF	EPSON TOYOCOM

8. Abbreviations

Table 7. Abbreviations

Acronym	Description
CSP	Coil Saturation Protection
EMI	ElectroMagnetic Interference
EMC	ElectroMagnetic Compatibility
ESR	Equivalent Series Resistance
LSB	Large Signal Board
OCP	OverCurrent Protection
OVP	OverVoltage Protection
PF	Power Factor
PFC	Power Factor Correction
PWM	Pulse-Width Modulation
RLC	Resistance, Inductance, Capacitance
SSB	Small Signal Board
SSL	Solid-State Light

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