

UM10402

STARplug Triple Output demo board

Rev. 1 — 1 September 2011

User manual

Document information

Info	Content
Keywords	STARplug, SMPS, flyback, converter
Abstract	<p>The NXP Semiconductors STARplug Triple Output demo board comes in two versions: 12 W and 18 W. By default the boards are configured as an isolated SMPS with DC output voltages at 12 V, 5 V and 3.3 V. Multiple configurable options are available on these boards; for example: snubber type, regulation and feedback strategy and more. The boards use the TEA1523P SMPS IC in a DIP8 package.</p> <p>This manual describes the STARplug Triple Output demo board version 1.10.</p> <p>Refer to the TEA152x data sheet for details on the STARplug device and the STARplug application note AN00055 for general application information.</p>



Revision history

Rev	Date	Description
v.1	20110901	first issue

Contact information

For more information, please visit: <http://www.nxp.com>

For sales office addresses, please send an email to: salesaddresses@nxp.com

1. Introduction

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.

The STARplug Triple Output SMPS demo board described in this user manual produces DC output voltage levels at 12 V, 5 V and 3.3 V. The 5 V and 3.3 V outputs are generated by separate flyback transformer taps of the 12 V secondary winding. The board has a universal mains input and the total nominal output power is rated at either 12 W or 18 W depending on the version.

The flyback circuit is built around the NXP Semiconductors TEA1523P STARplug IC. On the STARplug Triple Output demo board several provisions are available enabling modification of the input filtering, snubber circuit, regulation feedback scheme and output filtering. Small changes in output voltage (up to $\pm 20\%$) are also supported but the ratio between the three output voltages remains unaltered. If an alternative transformer is considered, the PCB can be used to generate virtually any output voltage and output voltage combination.

These features make the STARplug Triple Output demo board very versatile but this versatility requires some Printed-Circuit Board (PCB) space. Therefore, this board is not intended as a showcase for minimal PCB space utilization. The demo board is intended for exploring the features/possibilities of the STARplug family of ICs. It is ideal for use in both the design and development phases of a final solution for multi-output low power Switched Mode Power Supply (SMPS).

1.1 Features

- Universal mains input
- DC output voltages: 12 V, 5 V and 3.3 V
- Stable regulated voltage
- Highly flexible and easily tuned to meet user requirements
- Used with the TEA1523P
- 12 W or 18 W nominal output power; board version dependent
- Highly efficient: > 80 %
- Low standby (no-load) power: < 80 mW
- OverPower Protection (OPP)
- OverTemperature Protection (OTP)
- Built-in ElectroMagnetic Interference (EMI) filter

2. Technical specification

Table 1. Input specification

Parameter	Condition	Value	Remark
Input voltage (V _i)	-	90 V (AC) to 276 V (AC)	universal mains
Input frequency (f)	-	47 Hz to 63 Hz	-

Table 2. Output specification

Output supply	Condition	Value	Remark
Output voltage 1	-	12 V	default configuration: regulated output
Output voltage 1 tolerance	at 75 % load	± 2 %	-
Output voltage 1 stability	-	± 2 %	Over full power range
Output voltage 2	-	5 V	default configuration: non-regulated
Output voltage 2 tolerance	-	-	dependent on the load on output 1
Output voltage 2 stability	-	-	dependent on the load on output 1
Output voltage 3	-	3.3 V	default configuration: non-regulated
Output voltage 3 tolerance	-	-	dependent on the load on output 1
Output voltage 3 stability	-	-	dependent on the load on output 1

Remark: Output voltages 2 and 3 can vary considerably when no-load is connected because this output voltage is not regulated in the default configuration.

3. Performance data

3.1 Output voltage and no-load power consumption

[Table 3](#) shows the no-load power consumption figures for the STARplug Triple Output demo board's default configuration.

Table 3. No-load output voltage and power consumption

Condition	Energy start 2.0 requirement	Output voltage 1	Power consumption
12 W version			
115 V/60 Hz	≤ 300 mW	11.9 V	75 mW
230 V/50 Hz	≤ 300 mW	11.9 V	75 mW
18 W version			
115 V/60 Hz	≤ 300 mW	11.9 V	77 mW
230 V/50 Hz	≤ 300 mW	11.9 V	77 mW

Remark: Output voltages 2 and 3 can vary considerably when no-load is connected because this output voltage is not regulated in the default configuration.

3.2 Efficiency performance data

Table 4 shows the efficiency figures for the default configuration of the STARplug Triple Output demo board.

Table 4. Efficiency of the 12 W version

Power supply	Energy star requirement	Efficiency (η)				
		average	25 % load	50 % load	75 % load	100 % load
12 W version						
115 V/ 60 Hz	77.8 %	80.7 %	81.3 %	81.3 %	80.8 %	79.2 %
230 V/ 50 Hz	77.8 %	80.9 %	79.4 %	81.4 %	81.8 %	81.0 %
18 W version						
115 V/ 60 Hz	80.3 %	81.9 %	82.9 %	83.4 %	81.1 %	80.1 %
230 V/ 50 Hz	80.3 %	82.0 %	81.2 %	82.4 %	82.3 %	82.2 %

Remark: The load is on the 12 V output only.

Remark: The warm-up time is 15 minutes and the settle time, after load change, is 90 s.

3.3 ElectroMagnetic Compatibility (EMC) performance data

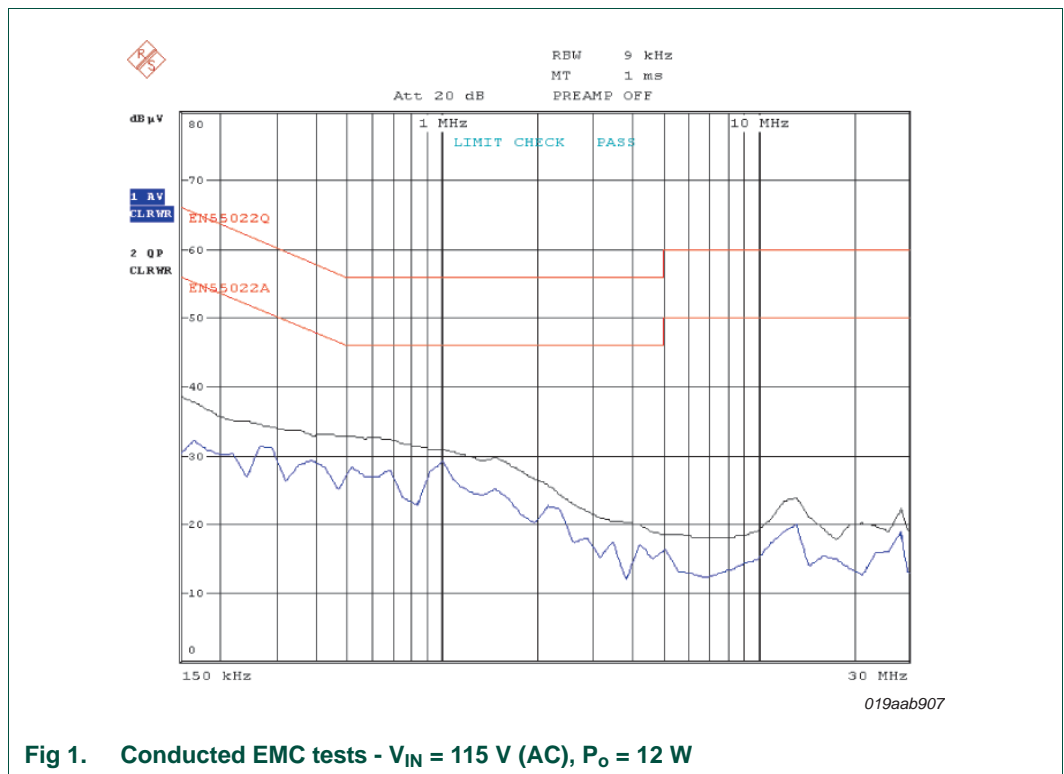
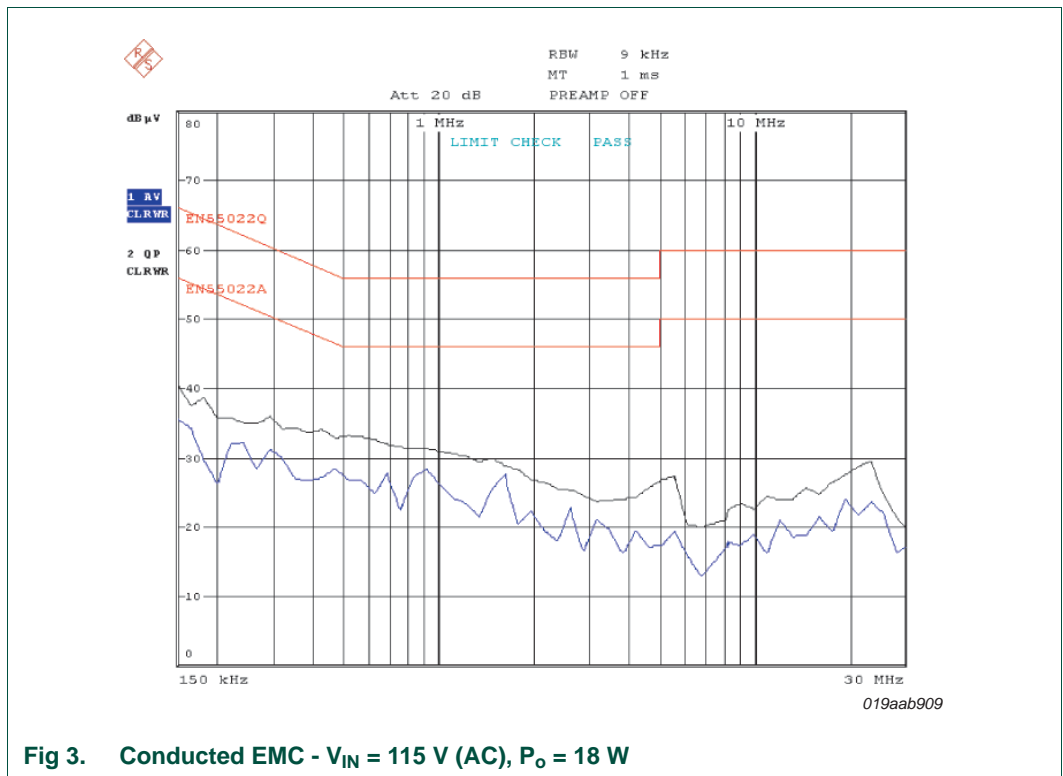
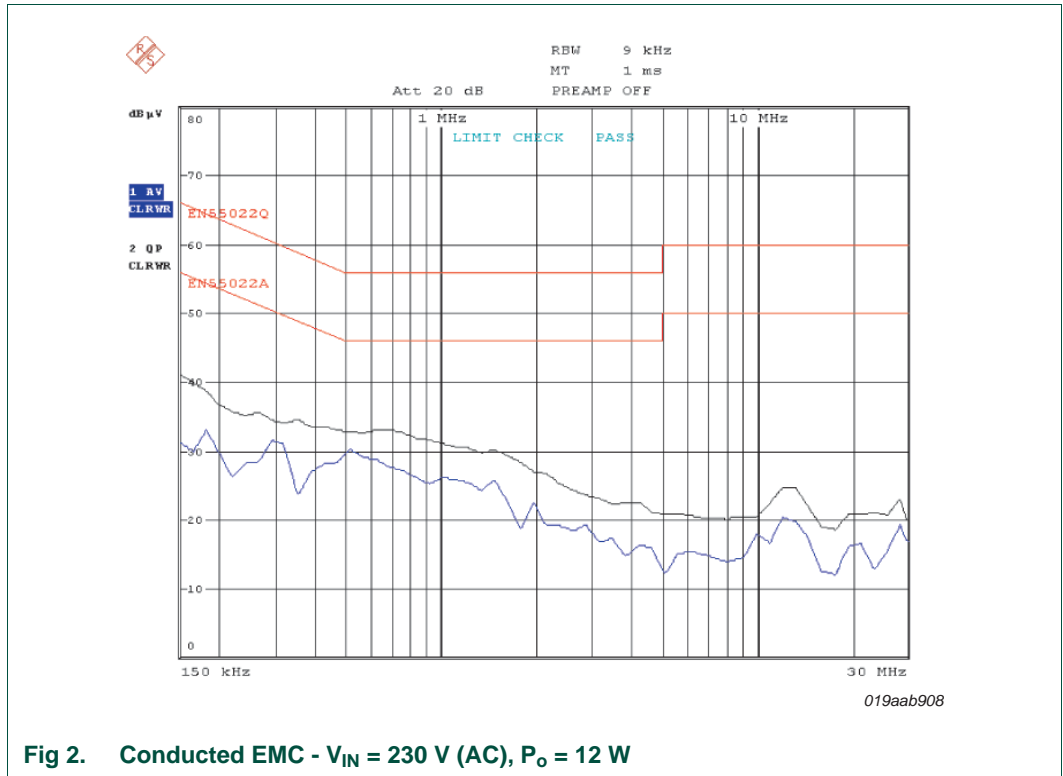


Fig 1. Conducted EMC tests - $V_{IN} = 115 \text{ V (AC)}$, $P_o = 12 \text{ W}$



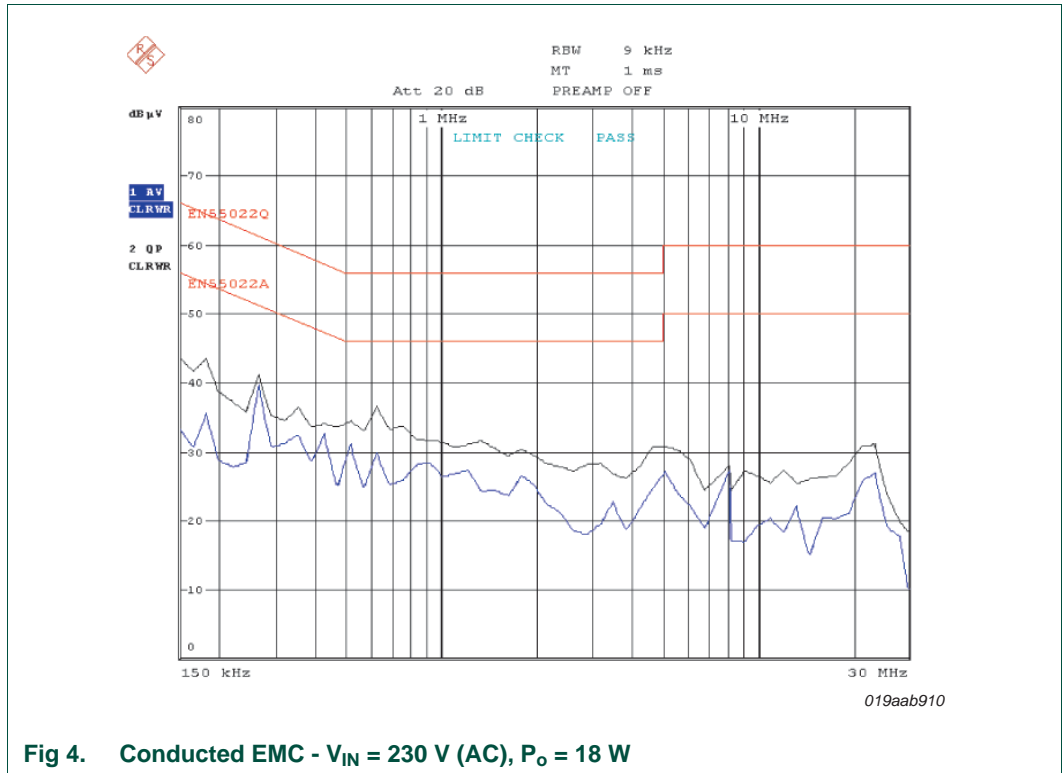


Fig 4. Conducted EMC - $V_{IN} = 230\text{ V (AC)}$, $P_o = 18\text{ W}$

Remark: Average and quasi-peak EMC performance of the STARplug Triple Output demo board complies with the standard EN55022.

4. Connections of the demo board

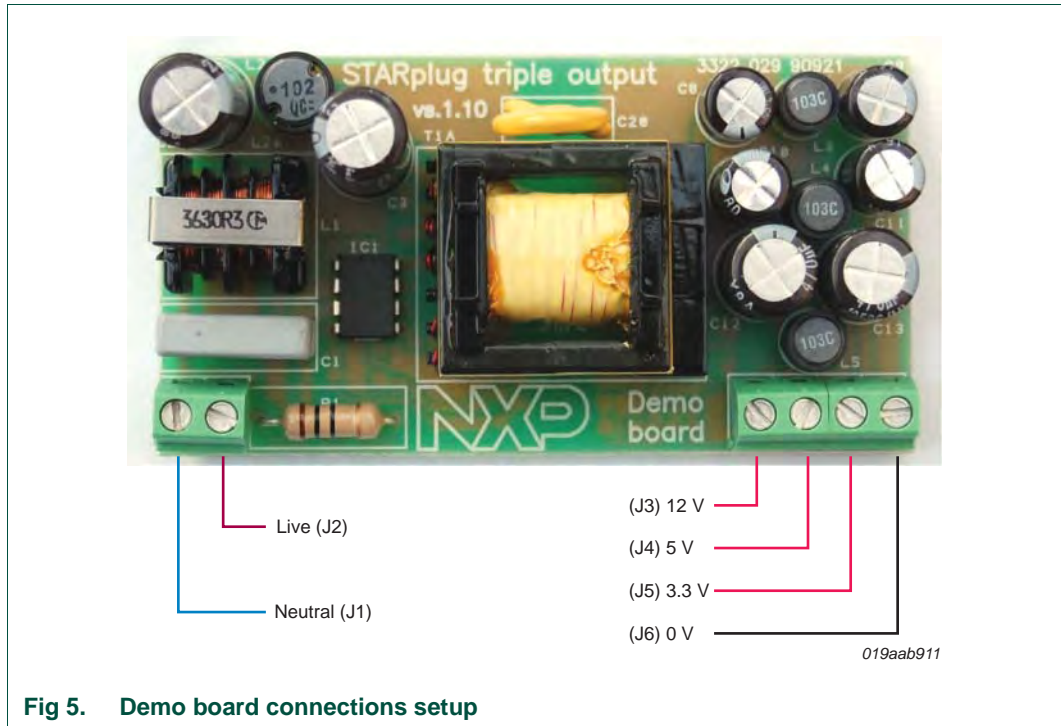


Fig 5. Demo board connections setup

Remark: Reversing the live (J2) and neutral (J1) connections has no influence on the operation of the STARplug Triple Output demo board. Terminal J3 produces 12 V, J4 produces 5 V and J5 produces 3.3 V. Terminal J6 is the reference (GND, 0 V) secondary side reference terminal.

5. Circuit description

The default STARplug Triple Output SMPS demo board consists of a single-phase full wave rectifier circuit, a filtering section, a switching section, an output section and a feedback section. The full circuit diagram of the default configuration of the STARplug Triple Output demo board PCB is shown in [Figure 6](#). Secondary side feedback and regulation are implemented on the 12 V output only.

5.1 Rectification section

The single-phase full wave rectifier is built around a standard Graetz bridge rectifier component (BR1). Capacitors C3 and C4 function as reservoir capacitors for the rectified input voltage. Resistor R1 limits the inrush current. Resistor R1 must be a carbon resistor, not a metal film resistor. A metal film resistor could work as a fuse instead of an inrush current limiter.

Terminals J1 and J2 connect the input to the electricity utility network. J1 is referred to as neutral and J2 as live for convenience. Swapping these two wires does have no effect on the actual operation of the STARplug Triple Output converter.

5.2 Filtering section

The filtering section consists of the common mode choke L1/C1 on the AC-side of the diode bridge and C3, L2, C4 in Π -configuration on the DC-side. The whole filtering configuration effectively reduces the noise and harmonic content that is otherwise injected from the TEA1523 switching electronics into the electricity utility network. The circuitry helps to achieve the EMC performance required by the standard EN55022.

5.3 Switching section

The switching section uses the NXP Semiconductors STARplug TEA1523 IC in a DIP8 package. The operating frequency is set using the combination of R2 and C4. The parallel circuit of resistors R3/R3A, limit the peak current that can occur in the STARplug internal MOSFET switch and consequently in the Transformer T1 primary winding. Current limitation prevents the internal MOSFET switch from being overstressed (the maximum switch current is given in [Equation 1](#)). In addition, it acts as an overload protection for the SMSP output.

$$I_{DS(max)} = \frac{0.5}{R3//R3A} \quad (1)$$

The auxiliary winding on transformer T1 generates the supply voltage for the TEA1523 IC. The voltage from the auxiliary winding is (half-wave) rectified by diode D2 and capacitor C5 is charged. Resistor R9 limits the current. The voltage on C5 is the supply voltage for the TEA1523 VCC pin.

The IC's AUX pin receives voltage information regarding the magnetization status of transformer T1 through resistor R5.

A snubber circuit manages the voltage spikes and associated energy (due to the leakage inductance of the primary winding of transformer T1). It is implemented using a diode-Zener snubber (D3 and D4). This type of snubber conserves energy and is EMI friendly but it is a more expensive option when compared to RCD snubbers (see [Section 6.1](#)).

5.4 Output section

The output section of the STARplug Triple Output application produces 3 DC voltages: 12 V, 5 V and 3.3 V.

The 12 V section consists of diode D5, capacitors C12, C13, C16, and inductor L5. Spikes on the output above 13 V are clamped by Zener diode D10. Similar configurations are implemented for the 5 V and 3.3 V output sections. The output sections provide a good level of ripple filtering and noise suppression by using Π -configurations in all output sections.

All output voltages are generated using the potential at J6 (GND; 0 V) as reference. J3 produces 12 V, J4 produces 5 V and J3 produces 3.3 V.

5.5 Feedback section

The feedback signal is taken from the 12 V supply through resistor R20. The user can change that to one of the other output voltages or a weighed combination thereof (see [Section 6.4](#)). In the default configuration, the feedback network on the secondary side consists of R13, R14, R20, C18, C19 and voltage reference IC3 (a TL431A). Resistors R20 and R14 form a voltage divider and determine the output voltage of the (12 V) supply. The programmed output voltage (of the 12 V output - terminal J3) is calculated using [Equation 2](#)

$$V_{out_12V} = V_{REG} \cdot \frac{R14 + R20}{R14} \quad (2)$$

The factor V_{REG} is the reference voltage of IC3 and for a normal TL431 this voltage is 2.5 V. R19 and C17 provide the supply power for the feedback network. R12 functions as a current limiter for the LED in optocoupler IC2. The feedback signal is transferred across the isolation barrier through optocoupler IC2. On the primary side, the signal is fed to the TEA1523 REG pin through the current limiting resistor R4. The REG pin is pulled down when the optocoupler is in the off-state by resistor R7. The noise is filtered and a pole is added with capacitor C6. Diode-Zener D1 forms a protection if the optocoupler fails (for example, due to aging). In this case, the diode-Zener D1 limits output voltage so that it does not rise in an uncontrolled manner.

Refer to the STARplug TEA152x data sheets and STARplug application note AN00055 for more detailed information on the operation of the STARplug TEA152x ICs and the dimensioning of STARplug circuits.

6. Alternative circuit options

6.1 Alternative snubber circuit

Although the D3/D4 diode-Zener snubber is a good solution for snubbing the leakage energy of the transformer's primary winding, a cheaper RCD solution is sometimes preferred. The STARplug Triple Output demo board has a provision allowing mounting of an RCD snubber circuit (D3, C7, R10, R11) instead of a Zener diode snubber. The "R" part of the RCD is split in two. The power dissipation and voltage drop is equally divided over these standard (1206 sized) SMD resistors.

The circuit diagram shown in [Figure 7](#) and the component changes described in [Table 8](#) show the STARplug Triple Output application with an RCD snubber.

6.2 Primary feedback

The STARplug Triple Output demo board enables the implementation of various primary feedback schemes in an isolated SMPS application. This feature is intended for use in low output power applications. The consequence of this primary feedback option implemented on this board is that the voltage regulation is (much) less accurate. However, the cost saving for primary feedback is significant.

It is vital that the magnetic coupling between the transformer's secondary and auxiliary windings is very good to ensure reasonably good voltage regulation. This requirement can add considerable cost because of the transformer construction.

The circuit diagram ([Figure 8](#)) and component changes in [Table 9](#) show that the circuit diagram is simplified and the parts list is reduced.

6.3 Alternative secondary side feedback

In the default configuration, only the 12 V rail of the STARplug Triple Output demo board is regulated. Depending on the application, regulation of the 5 V or 3.3 V output or a weighed combination of the 12 V, 5 V and 3.3 V output can be required. This regulation is done by installing the relevant value resistors for R14, R16, R18 and R20 (see [Figure 9](#)).

When regulation of the 5 V output voltage is wanted, remove R20 from the PCB (set to $\infty\Omega$), install R18 and do not mount R16. To regulate the 3.3 V output voltage, remove R20, install resistor R16 and do not mount R18. The values for the R14, R16, R18 and R20 resistors for the various options can be found in [Table 5](#) and [Table 6](#).

When a weighed combination of 12 V, 5 V and 3.3 V output is regulated, the ratio between the 12 V, 5 V and 3.3 V outputs are fixed. This ratio is 12 : 5 : 3.3. The only way to change this ration is by modifying the turns ratio on the secondary side of the T1 transformer. Resistors R16, R18 and R20 play in a role in this case and their values must be adapted.

The mathematical expression for weighed regulation of the three output voltages is more complex than the expression that applies to single output voltage regulation (see [Equation 2](#)).

The expression for weighed regulation is given in [Equation 3](#), [Equation 4](#) and [Equation 5](#).

$$V_{out_12V} = V_{REG} \cdot \frac{R14 \cdot R16 \cdot R18 + R14 \cdot R16 \cdot R20 + R14 \cdot R18 \cdot R20 + R16 \cdot R18 \cdot R20}{R14 \cdot (R16 \cdot R18 + \alpha \cdot R16 \cdot R20 + \beta \cdot R18 \cdot R20)} \quad (3)$$

$$V_{out_5V} = \alpha \cdot V_{out_12V} \quad (4)$$

$$V_{out_3.3V} = \beta \cdot V_{out_12V} \quad (5)$$

In the STARplug Triple Output demo board default configuration:

- $V_{REG} = 2.5 \text{ V}$ (IC2 TL431 reference voltage)
- $\alpha = 5 / 12 = 0.4167$ (the turns ratio between the 12 V and 5 V output on the secondary winding of transformer T1)
- $\beta = 3.3 / 12 = 0.275$ (the turns ratio between the 12 V and 3.3 V output on the secondary winding of transformer T1)

[Equation 3](#), [Equation 4](#) and [Equation 5](#) transform into [Equation 2](#) when R18 and R16 are removed (that is, $R18 = R16 = \infty\Omega$).

When a 12 V + 5 V + 3.3 V Triple Output SMPS is created, the balance between the R16, R18 and R20 values determines the weighting each output voltage has on the regulation. [Equation 6](#), [Equation 7](#) and [Equation 8](#) show the weighting of the feedback regulation contribution of either voltage rails.

$$Weight_{V_{out_12V}} = \frac{R14}{R20} \cdot \frac{V_{out_12V} - V_{REG}}{V_{REG}} \cdot 100 \% \quad (6)$$

$$Weight_{V_{out_5V}} = \frac{R14}{R18} \cdot \frac{V_{out_5V} - V_{REG}}{V_{REG}} \cdot 100 \% \quad (7)$$

$$Weight_{V_{out_3.3V}} = \frac{R14}{R16} \cdot \frac{V_{out_3.3V} - V_{REG}}{V_{REG}} \cdot 100 \% \tag{8}$$

Table 5 gives an overview of the R16, R18 and R20 resistor combinations and weighting factors. However, R14 remains at its 2.4 kΩ default value.

Table 5. R14, R16, R18 and R20 exact component values for weighed regulation

Output weighting (%)			Resistor value			
3.3 V	5.0 V	12.0 V	R14	R16	R18	R20
0 %	0 %	100 %	2.4 kΩ	∞Ω	∞Ω	9.12 kΩ
0 %	25 %	75 %	2.4 kΩ	∞Ω	9.6 kΩ	12.16 kΩ
0 %	75 %	25 %	2.4 kΩ	∞Ω	3.2 kΩ	36.48 kΩ
0 %	100 %	0 %	2.4 kΩ	∞Ω	2.4 kΩ	∞Ω
25 %	0 %	75 %	2.4 kΩ	3.072 kΩ	∞Ω	12.16 kΩ
25 %	25 %	50 %	2.4 kΩ	3.072 kΩ	9.6 kΩ	18.24 kΩ
25 %	50 %	25 %	2.4 kΩ	3.072 kΩ	4.8 kΩ	36.48 kΩ
25 %	75 %	0 %	2.4 kΩ	3.072 kΩ	3.2 kΩ	∞Ω
50 %	25 %	25 %	2.4 kΩ	1.536 kΩ	9.6 kΩ	36.48 kΩ
75 %	0 %	25 %	2.4 kΩ	1.024 kΩ	∞Ω	36.48 kΩ
75 %	25 %	0 %	2.4 kΩ	1.024 kΩ	9.6 kΩ	∞Ω
100 %	0 %	0 %	2.4 kΩ	768 Ω	∞Ω	∞Ω

Table 5 lists some impractical R16, R18 and R20 resistance values. Table 6 list more practical vales because defining the regulation balance so accurately is not necessary.

The practical values given in Table 6 for R14, R16, R18, R20 combinations retain the idea of weighed regulation. The resistance values come from the E24 range. Small deviations (± 1 %) in the output voltages are allowable.

Table 6. Some practical R17, R18 and R20 value combination for weighed regulation

Resistance values				Weighted output (%)			Weighted output (V)		
R14	R16	R18	R20	3.3 V	5.0 V	12.0 V	3.3 V _o	5 V _o	12 V _o
2.4 kΩ	∞Ω	∞Ω	9.1 kΩ	0 %	0 %	100 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	∞Ω	10 kΩ	12 kΩ	0 %	24 %	76 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	∞Ω	3.3 kΩ	33 kΩ	0 %	72 %	28 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	∞Ω	2.4 kΩ	∞Ω	0 %	100 %	0 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	3.3 kΩ	∞Ω	12 kΩ	24 %	0 %	76 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	3 kΩ	10 kΩ	18 kΩ	25 %	24 %	51 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	3 kΩ	4.7kΩ	39 kΩ	26 %	51 %	23 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	3.9 kΩ	3 kΩ	∞Ω	20 %	80 %	0 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	1.5 kΩ	10 kΩ	36 kΩ	51 %	24 %	26 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	1 kΩ	∞Ω	39 kΩ	77 %	0 %	23 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	1 kΩ	10 kΩ	∞Ω	76 %	24 %	0 %	3.3 V	5.0 V	12.0 V
2.4 kΩ	820 Ω	∞Ω	150 kΩ	94 %	0 %	6 %	3.3 V	5.0 V	12.0 V

In the default configuration, the supply for the optocoupler's LED is derived from the 12 V output via resistor R19. The supply could also be derived from the 5 V output via resistor R17. In which case, remove R19 and install R17.

If you want to derive the supply from the 3.3 V, only install resistor R15. However, in this case, replace IC3 by a 1.25 V voltage reference device. In addition, recalculate the R14, R16, R18 and R20 feedback resistor values using [Equation 3](#), [Equation 4](#), [Equation 5](#), [Equation 6](#), [Equation 7](#) and [Equation 8](#) with V_{REG} equal to 1.25 V.

The circuit that corresponds to the alternative (weighed) secondary feedback implementations is shown in [Figure 9](#). See [Table 6](#) for the component changes involved.

6.4 Self-supplied TEA152x

The option exists to have the TEA152x SMPS IC generate its own power supply using the built-in JFET. The advantage is that the auxiliary winding on the transformer T1 is not required, reducing cost. The disadvantage is that generating the supply voltage using the built-in JFET causes additional power losses. The high efficiency figures and low standby figures as shown in [Table 3](#) and [Table 4](#) no-longer apply.

Apart from supplying the V_{CC} power for the IC, the transformer's auxiliary winding also informs the IC's AUX pin of the transformer's magnetization. When the auxiliary winding is no longer present, an alternative method is needed to inform the AUX pin about the transformer's magnetization status. This alternative method is capacitive coupling.

As the hot connections of the respective transformer T1 windings are in phase during operation, the voltage (or information) appearing on the primary winding's hot side can be used to indicate if the transformer is demagnetized. Creating a capacitive coupling between the "hot" side of the primary winding and the STARplug IC AUX pin enables easy transfer of the information. Due to the relatively high impedance of the AUX pin, only a small capacitive coupling is enough. Pull the AUX pin to ground using a high value resistor (around 500 k Ω). This action guarantees the voltage on the pin is below 100 mV during start-up.

The capacitor C14* shown in circuit diagram [Figure 10](#) acts as the capacitive coupler between the transformer's "hot" side and the STARplug IC AUX pin. A typical value for this capacitor is 2 pF. The parasitic capacitance that can be created with the layout of the PCB is generally adequate to give sufficient coupling. There is usually no need to mount the C14* component. To be formally correct, the ~500 k Ω impedance between the IC AUX pin and GND is split in two resistor values: R6 and R10. R6 limits the current that can be injected into the AUX pin through the capacitive coupling (typical value 100 k Ω).

Remark: An overcurrent on the AUX pin can damage the IC!

The combination of R6 and R10 builds the impedance that pulls the AUX pin to ground during start-up (typical value for R10: 390 k Ω).

When the STARplug IC is self-supplied from the built-in JFET, there is no-longer any use for Zener diode D3. This is because the VCC voltage never rises that high. In addition, the protection described in [Section 5.5](#) is no-longer active.

Remark: A defective or strongly degraded optocoupler IC2 results in an uncontrolled rise of the output voltage(s) in the SMPS!

See [Table 11](#) for the component changes involved.

6.5 Alternative output diode

In the default STARplug Triple Output demo board configuration, SMA-sized diodes are used as the secondary output rectifiers. The PCB also accommodates SOD123F sized diodes that are a cost-effective alternative to SMA-sized diodes. When thermal stress and performance requirements do not impose restrictions, replaced one or more of the default diodes D5, D6 and D7 with the smaller sized diodes D5A, D6A and D7A.

The circuit diagram remains the same as shown in [Figure 6](#). [Table 12](#) shows the relevant component changes.

6.6 Combining options and features

Options and features can be combined as described in [Section 6.1](#) to [Section 6.5](#). Check any new combination of options and features so that the specific combination does not cause an electrical conflict. If needed, contact NXP Semiconductors application support for additional application help.

7. Schematics

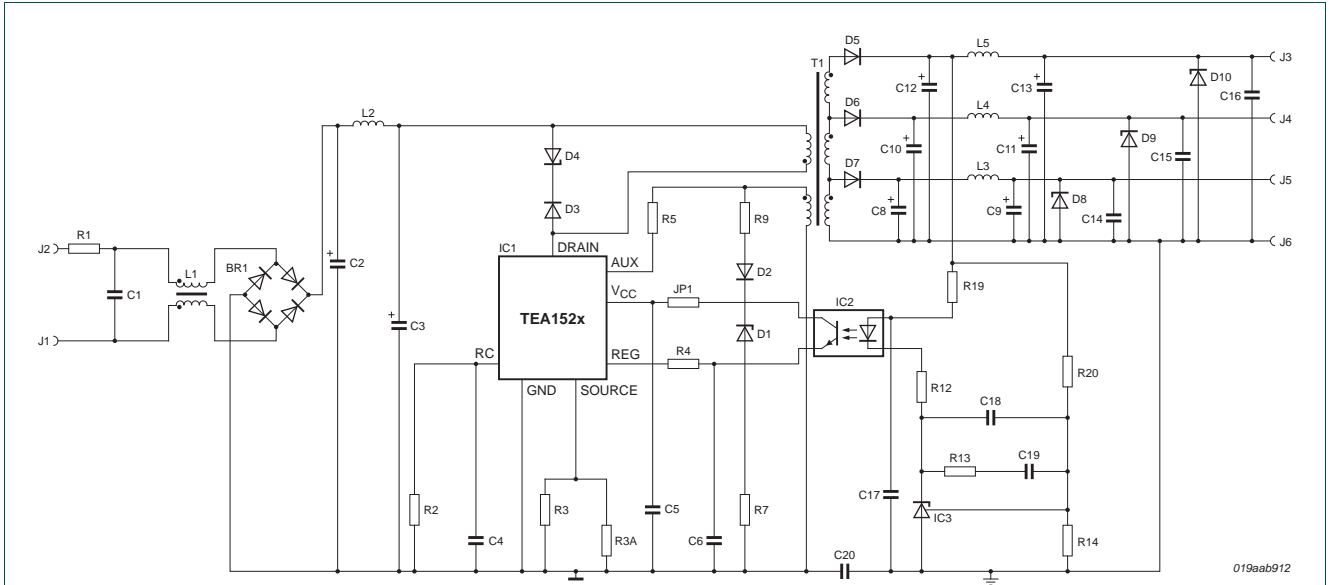


Fig 6. Circuit diagram: STARplug Triple Output - default configuration

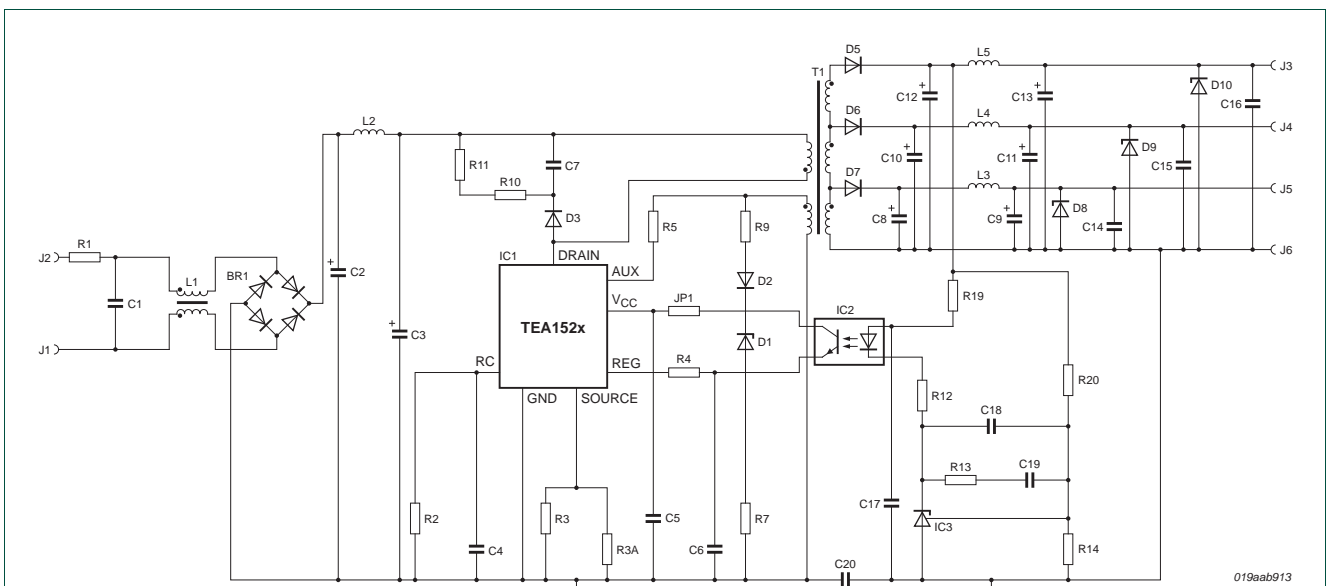


Fig 7. Circuit diagram: STARplug Triple Output - with RCD snubber

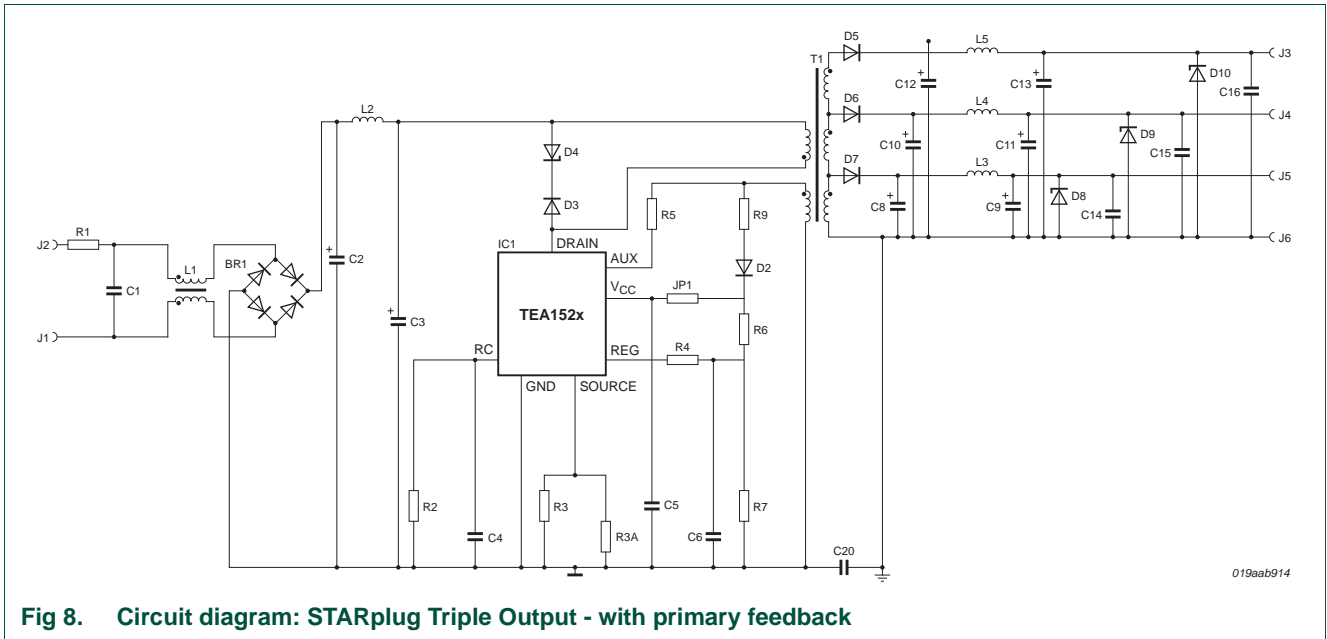


Fig 8. Circuit diagram: STARplug Triple Output - with primary feedback

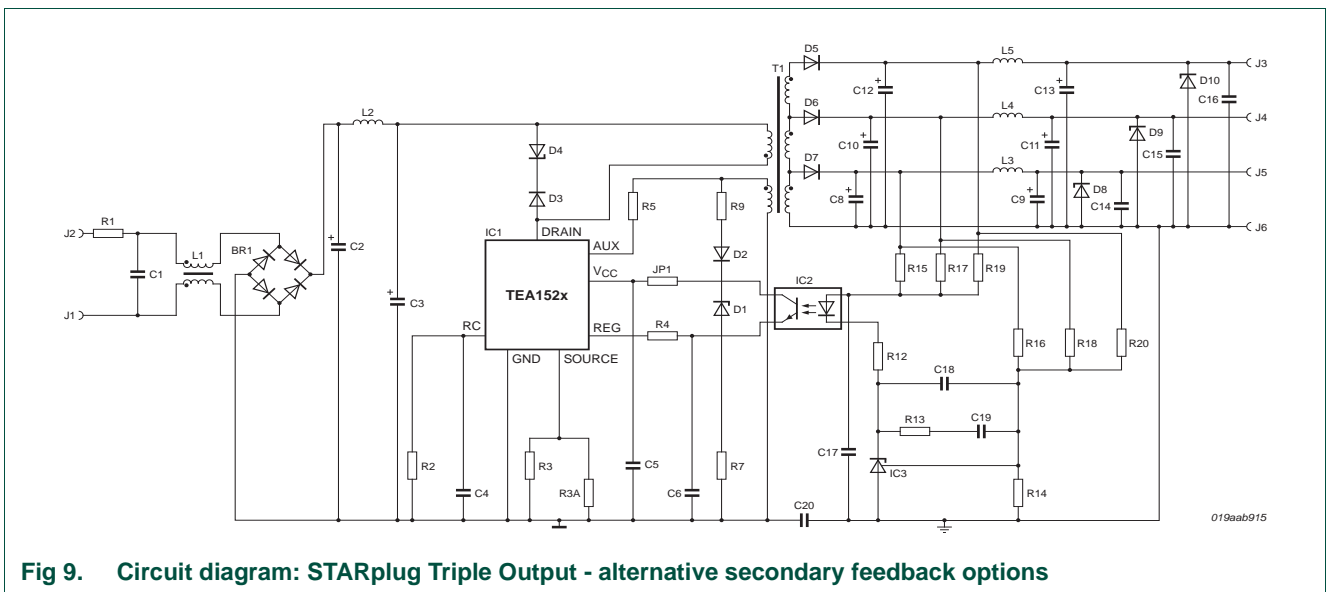
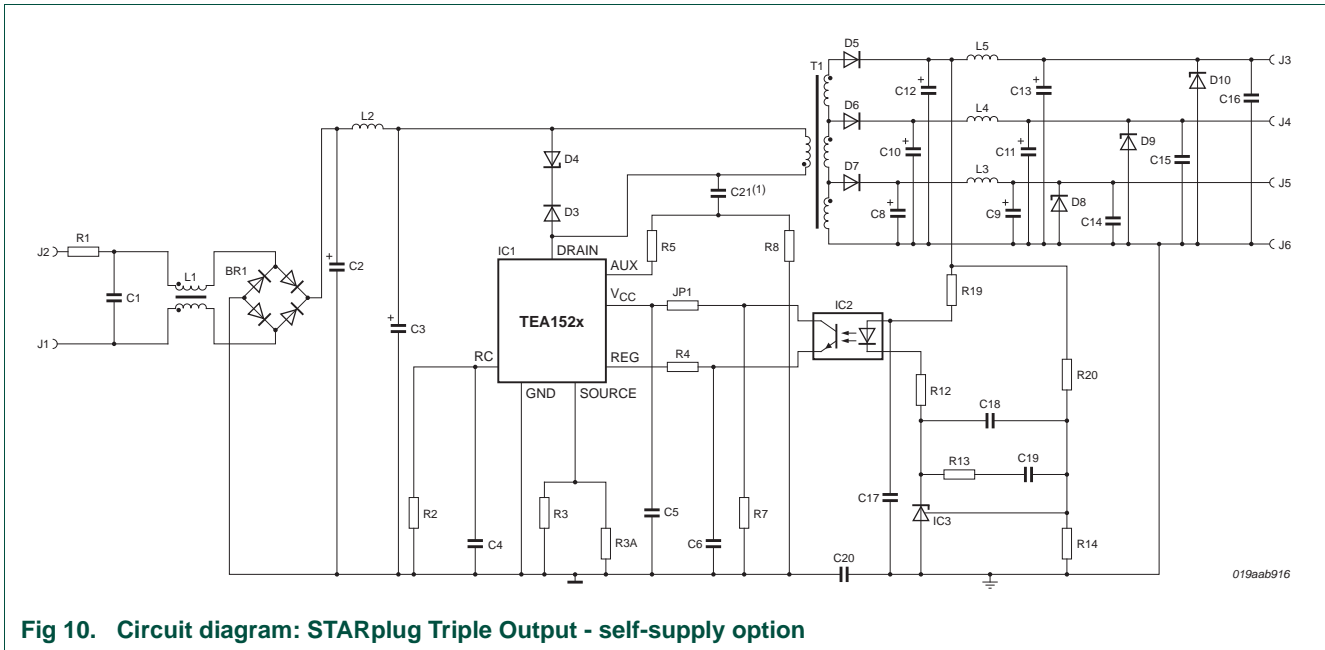


Fig 9. Circuit diagram: STARplug Triple Output - alternative secondary feedback options



8. Component lists

Table 7. Default component list

Part ref.	Description	Package	Remarks
IC1	NXP Semiconductors TEA1523P	DIP8	-
IC2	Vishay SFH6156-4	SMD-4	-
IC3	NXP Semiconductors TL431AMSdT	SOT23	mirrored pinning
BR1	Vishay MB6S	TO-269AA	-
D1	NXP Semiconductors BZX384-C24	SOD323	-
D2	NXP Semiconductors BAS321	SOD323	-
D3	Vishay RS1J	DO214-AC	-
D4	Vishay BZG03C180	DO214-AC	-
D5	Vishay 10MQ100NPbF	DO214-AC	-
D5A	Central Semi CMMSH1-100	SOD123F	not mounted; see Section 6.5
D6	Vishay 10MQ060NPbF	DO214-AC	-
D6A	NXP Semiconductors PMEG6010CEH	SOD123F	not mounted; see Section 6.5
D7	Vishay 10MQ060NPbF	DO214-AC	-
D7A	NXP Semiconductors PMEG6010CEH	SOD123F	not mounted; see Section 6.5
D8	NXP Semiconductors BZX384-C3V6	SOD323	-
D9	NXP Semiconductors BZX384-C5V6	SOD323	-
D10	NXP Semiconductors BZX384-C13	SOD323	-
T1	custom made transformer Würth Elektronik 750871830	-	12 W version only; Würth Elektronik Order no. 750871830
T1A	custom made transformer Würth Elektronik 750871831	-	18 W version only; Würth Elektronik Order no. 750871831
L1	choke PLA10A; 2 × 36 mH	-	PLA10AN3630R3D2B

Table 7. Default component list ...continued

Part ref.	Description	Package	Remarks
L2	inductor ELC09D; 1 mH	2E pitch	-
L3	inductor ELC06D; 10 μ H	1.5E pitch	-
L4	inductor ELC06D; 10 μ H	1.5E pitch	-
L5	inductor ELC06D; 10 μ H	1.5E pitch	-
C1	100 nF; 400 V (AC)	6E pitch	-
C2	electrolytic capacitor; 22 μ F; 400 V	2E pitch	maximum \varnothing 10.5 mm
C3	electrolytic capacitor; 22 μ F; 400 V	2E pitch	maximum \varnothing 10.5 mm
C4	330 pF; 50 V	0805	-
C5	220 nF; 50 V	1206	-
C6	22 nF; 50 V	1206	-
C7	1 nF; 500 V	1206	not mounted; see Section 6.1
C8	electrolytic capacitor; 470 μ F; 6.3 V	1.5E pitch	maximum \varnothing 8 mm
C9	electrolytic capacitor; 470 μ F; 6.3 V	1.5E pitch	maximum \varnothing 8 mm
C10	electrolytic capacitor; 470 μ F; 10 V	1.5E pitch	maximum \varnothing 8 mm
C11	electrolytic capacitor; 470 μ F; 10 V	1.5E pitch	maximum \varnothing 8 mm
C12	electrolytic capacitor; 470 μ F; 16 V	2E pitch	maximum \varnothing 10.5 mm
C13	electrolytic capacitor; 470 μ F; 16 V	2E pitch	maximum \varnothing 10.5 mm
C14	100 nF; 50 V	0805	-
C15	100 nF; 50 V	0805	-
C16	100 nF; 50 V	0805	-
C17	100 nF; 50 V	0805	-
C18	5.6 nF; 25 V	0805	-
C19	22 nF; 25 V	0805	-
C20	Y-capacitor; 2.2 nF; 2 kV	4E pitch	-
C21	2.2 pF; 500 V	parasitic	not mounted; see Section 6.4
R1	10 Ω ; 1 W; carbon	6E pitch	-
R2	7.5 k Ω	0805	-
R3	1.0 R; 0.25 W	1206	-
R3A	1.5 R; 0.25 W	1206	-
R4	2.2 k Ω	0805	-
R5	100 k Ω	0805	-
R6	22 k Ω	0805	not mounted; see Section 6.2
R7	4.3 k Ω	1206	-
R8	390 k Ω	0805	not mounted; see Section 6.4
R9	10 Ω	0805	-
R10	47 k Ω ; 0.5 W	1206	not mounted; see Section 6.1
R11	47 k Ω ; 0.5 W	1206	not mounted; see Section 6.1
R12	1 k Ω	1206	-
R13	24 k Ω	0805	-
R14	2.4 k Ω ; 1 %	0805	-
R15	1 k Ω	1206	not mounted; see Section 6.3

Table 7. Default component list ...continued

Part ref.	Description	Package	Remarks
R16	820 Ω ; 1 %	1206	not mounted; see Section 6.3
R17	1 k Ω	1206	not mounted; see Section 6.3
R18	2.4 k Ω ; 1 %	1206	not mounted; see Section 6.3
R19	5.6 k Ω	1206	-
R20	9.1 k Ω ; 1 %	1206	-
JP0	0 Ω (SMD jumper)	1206	-
J1/J2	2-pole terminal block	2E pitch	Phoenix: 1729128
J3/J4/J5/ J6	4-pole terminal block	2E pitch	Phoenix: 1729144

Table 8. Component list modification for alternative (RCD) snubber

Part ref.	Description	Package	Remarks
D4	Vishay BZG03C180	DO214-AC	not mounted
C7	1 nF; 500 V	1206	-
R10	47 k Ω ; 0.5 W	1206	-
R11	47 k Ω ; 0.5 W	1206	-

Table 9. Component list modification for primary feedback

Part ref.	Description	Package	Remarks
IC2	Vishay SFH6156-4	SMD4	not mounted
IC3	NXP Semiconductors TL431AMSDT	SOT23	not mounted
D1	NXP Semiconductors BZX384-C24	SOD323	not mounted
C17	100 nF; 50 V	0805	not mounted
C18	5.6 nF; 25 V	0805	not mounted
C19	22 nF; 25 V	0805	not mounted
R6	22 k Ω	0805	-
R12	1 k Ω	1206	not mounted
R13	24 k Ω	0805	not mounted
R14	2.4 k Ω ; 1 %	0805	not mounted
R19	5.6 k Ω	1206	not mounted
R20	9.1 k Ω ; 1 %	1206	not mounted

Table 10. Component list alternatives for (weighted) secondary feedback

Part ref.	Description	Package	Remarks
IC3	voltage reference 2.5 V or 1.25 V	SOT23	[1]
R14	see Table 6	0805	[1]
R15*	1 k Ω	1206	-
R16	see Table 6	1206	[1]
R17*	1 k Ω	1206	-
R18	see Table 6	1206	[1]
R19*	5.6 k Ω	1206	-
R20	see Table 6	1206	[1]

[1] Mount only one of the resistors R15, R17, R19; see [Section 6.3](#).

Table 11. Component list modification for self-supplied TEA152x

Part ref.	Description	Package	Remarks
D1	NXP Semiconductors BZX384-C24	SOD323	not mounted
D2	NXP Semiconductors BAS321	SOD323	not mounted
T1/T1A	transformer without auxiliary winding	-	or cut auxiliary winding on original transformer
C21	2.2 pF; 500 V	-	no need to mount; see Section 6.4
R8	390 k Ω	0805	
R9	10 Ω	0805	not mounted

Table 12. Component list modification for alternative secondary output diodes

Part ref.	Description	Package	Remarks
D5	Vishay 10MQ100NPbF	DO214-AC	not mounted
D5A	Central Semi CMMSH1-100	SOD123F	-
D6	Vishay 10MQ060NPbF	DO214-AC	not mounted
D6A	NXP Semiconductors PMEG6010CEH	SOD123F	-
D7	Vishay 10MQ060NPbF	DO214-AC	not mounted
D7A	NXP Semiconductors PMEG6010CEH	SOD123F	-

9. Printed-Circuit Board (PCB)

The STARplug Triple Output demo board PCB is a single-sided board. Dimensions are 86.4 mm × 45.8 mm. The demo boards are produced on 1.6 mm FR4 with single-sided 35 µm copper (1 oz.). FR2 could also be used as the PCB material.

The PCB can accommodate a number of implementations of the NXP Semiconductors STARplug Triple Output SMPS as outlined in chapters [Section 5](#), [Section 6](#), [Section 7](#) and [Section 8](#).

The Gerber File set for the production of the PCBs is available from NXP Semiconductors. Normally, the bottom silk is not used for PCB production. It is only a component position reference.

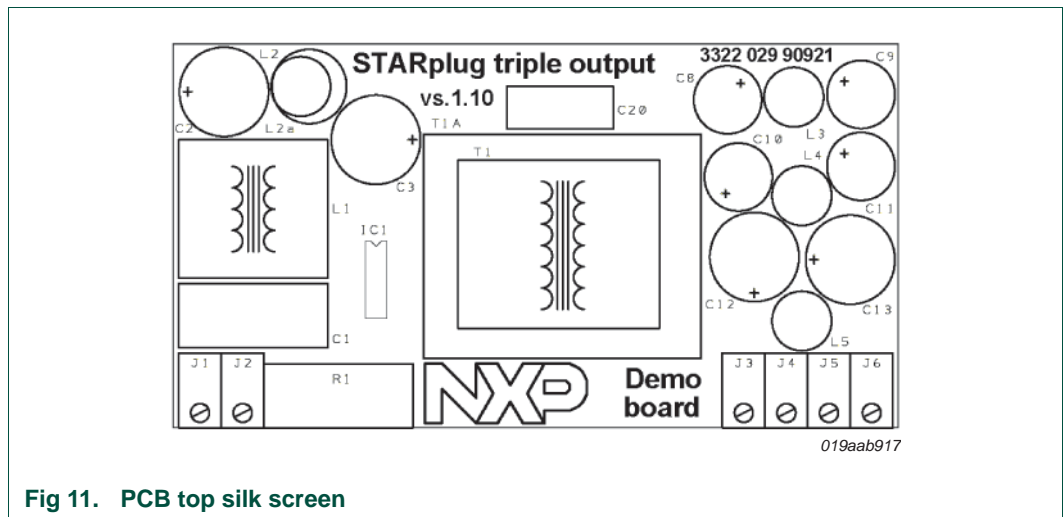
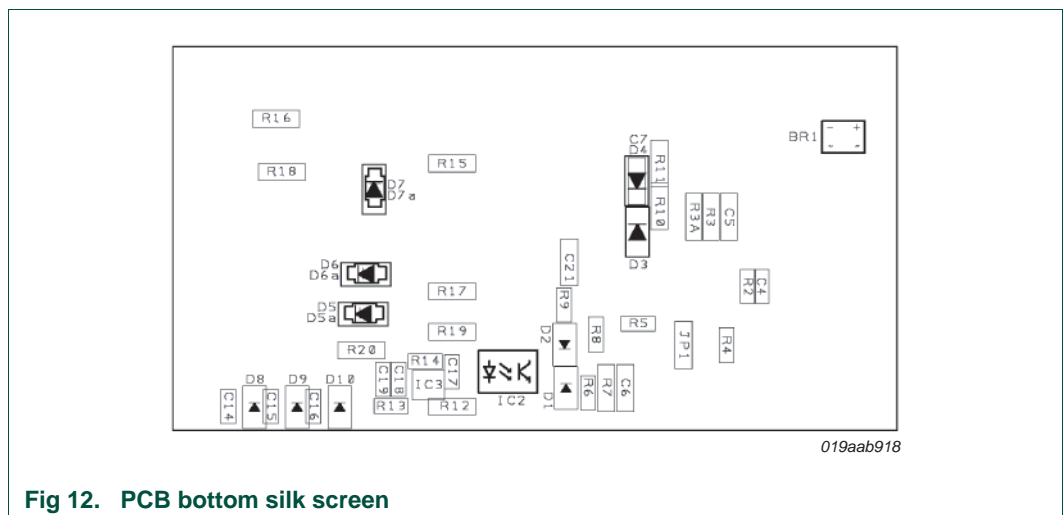
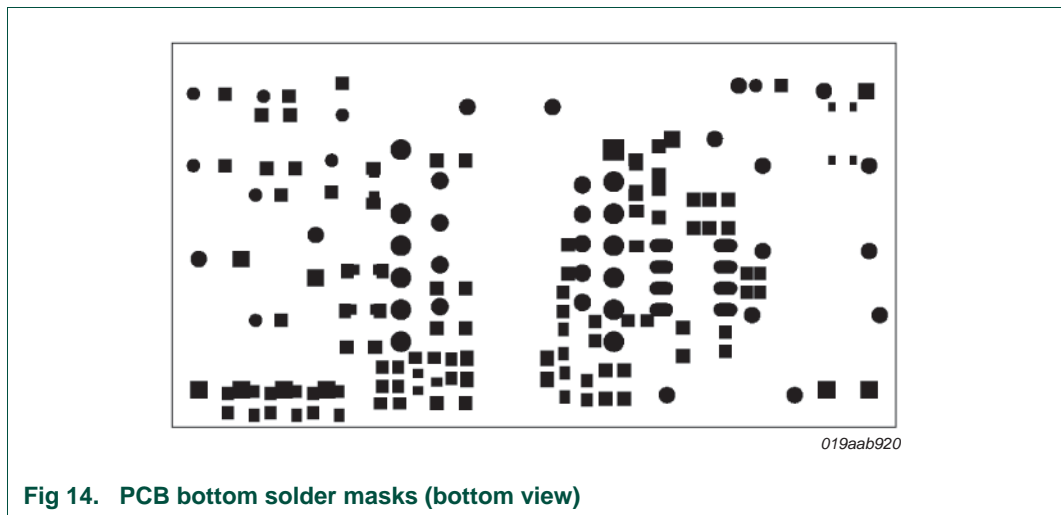
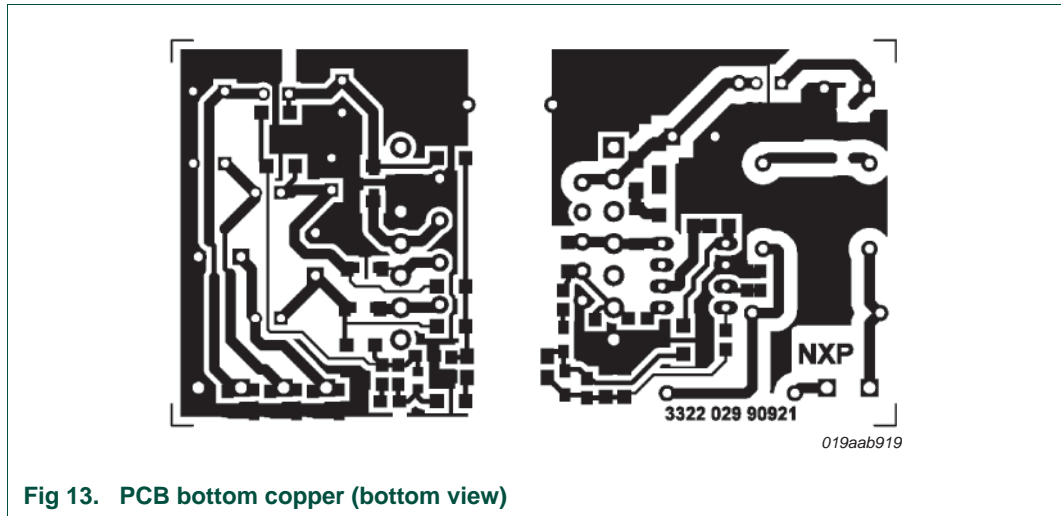


Fig 11. PCB top silk screen





10. Legal information

10.1 Definitions

Draft — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

10.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the *Terms and conditions of commercial sale* of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Suitability for use — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors accepts no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product

design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from national authorities.

Evaluation products — This product is provided on an "as is" and "with all faults" basis for evaluation purposes only. NXP Semiconductors, its affiliates and their suppliers expressly disclaim all warranties, whether express, implied or statutory, including but not limited to the implied warranties of non-infringement, merchantability and fitness for a particular purpose. The entire risk as to the quality, or arising out of the use or performance, of this product remains with customer.

In no event shall NXP Semiconductors, its affiliates or their suppliers be liable to customer for any special, indirect, consequential, punitive or incidental damages (including without limitation damages for loss of business, business interruption, loss of use, loss of data or information, and the like) arising out of the use of or inability to use the product, whether or not based on tort (including negligence), strict liability, breach of contract, breach of warranty or any other theory, even if advised of the possibility of such damages.

Notwithstanding any damages that customer might incur for any reason whatsoever (including without limitation, all damages referenced above and all direct or general damages), the entire liability of NXP Semiconductors, its affiliates and their suppliers and customer's exclusive remedy for all of the foregoing shall be limited to actual damages incurred by customer based on reasonable reliance up to the greater of the amount actually paid by customer for the product or five dollars (US\$5.00). The foregoing limitations, exclusions and disclaimers shall apply to the maximum extent permitted by applicable law, even if any remedy fails of its essential purpose.

10.3 Trademarks

Notice: All referenced brands, product names, service names and trademarks are the property of their respective owners.

STARplug — is a trademark of NXP B.V.

11. Contents

1	Introduction	3
1.1	Features	3
2	Technical specification	4
3	Performance data	4
3.1	Output voltage and no-load power consumption	4
3.2	Efficiency performance data	5
3.3	ElectroMagnetic Compatibility (EMC) performance data	5
4	Connections of the demo board	8
5	Circuit description	8
5.1	Rectification section	8
5.2	Filtering section	9
5.3	Switching section	9
5.4	Output section	9
5.5	Feedback section	10
6	Alternative circuit options	10
6.1	Alternative snubber circuit	10
6.2	Primary feedback	10
6.3	Alternative secondary side feedback	11
6.4	Self-supplied TEA152x	13
6.5	Alternative output diode	14
6.6	Combining options and features	14
7	Schematics	15
8	Component lists	17
9	Printed-Circuit Board (PCB)	21
10	Legal information	23
10.1	Definitions	23
10.2	Disclaimers	23
10.3	Trademarks	23
11	Contents	24

Please be aware that important notices concerning this document and the product(s) described herein, have been included in section 'Legal information'.

© NXP B.V. 2011.

All rights reserved.

For more information, please visit: <http://www.nxp.com>

For sales office addresses, please send an email to: salesaddresses@nxp.com

Date of release: 1 September 2011

Document identifier: UM10402