UM10377

STARplug Universal SO14 and DIP8 demo boards

Rev. 2 — 20 July 2011 **User manual**

Document information

Info	Content
Keywords	STARplug, SMPS, flyback converter
Abstract	The NXP Semiconductors STARplug Universal demo board comes in two versions: one with an SMD SO14 STARplug IC mounted and one with a through-hole DIP8. The flyback converter demo board is highly flexible and can be configured for isolated and non-isolated operation. Multiple output configurations and feedback schemes can be achieved on the PCB. The default board comes as an isolated SMPS which provides two DC output voltages: 12 V and 5 V. The nominal power that can be drawn from the board is 8 W. This manual describes the SO14 and the DIP8 variants of the STARplug Universal demo board version 1.11. Refer to the TEA152x and TEA162x data sheets for details on the STARplug device and the STARplug application note AN00055 for general application information.

Revision history

Rev	Date	Description
v.2	20110720	second issue
v.1	20100407	first issue

Contact information

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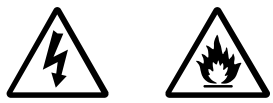
1. Introduction

WARNING

Lethal voltage and fire ignition hazard



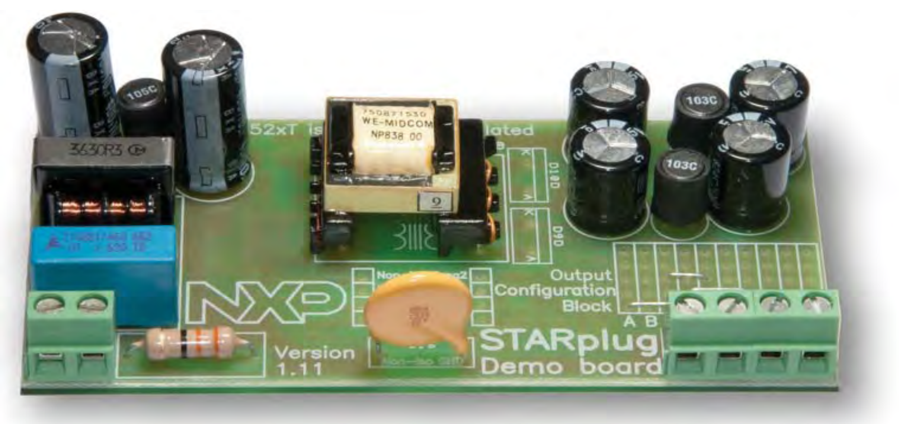
The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

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 Universal Switched Mode Power Supply (SMPS) demo board described in this user manual, provides two DC output voltage levels: 12 V and 5 V. Fundamentally, the two output voltages are galvanically isolated enabling the 12 V and 5 V outputs to be combined in an arbitrary way (see Section 2). In the default configuration, the 12 V and 5 V outputs are galvanically connected using a common GND (0 V). The board has a universal mains input and the total nominal output power is rated at 8 W. Non-continuous/peak output power levels of up to 12 W are also supported in the default configuration.

The flyback circuit is built around the TEA1522 STARplug IC. On the STARplug Universal demo board there are several provisions to enable reconfiguration such as input filtering, snubber circuit, output voltage configuration, regulation feedback scheme and more. The STARplug Universal demo board can be used both in isolated and non-isolated mode. In addition, with the DIP8 version of the STARplug Universal, you can easily swap the STARplug IC, as the IC is mounted in an IC socket.

Small changes in the output voltage (up to ±20 %) are also supported but the ratio between the first and the second output voltage remains unaltered. If an alternative transformer is considered, the Printed-Circuit Board (PCB) can be used to generate any output voltage and output voltage combination. These features make the STARplug Universal demo board highly versatile. This versatility requires some PCB space. Therefore this board is not intended as a showcase for minimal PCB space consumption and it is by no means an end solution. It is, however, very useful for exploring all the board features and the features of the STARplug family of ICs during development of a final solution for an isolated or non-isolated low power SMPS application.



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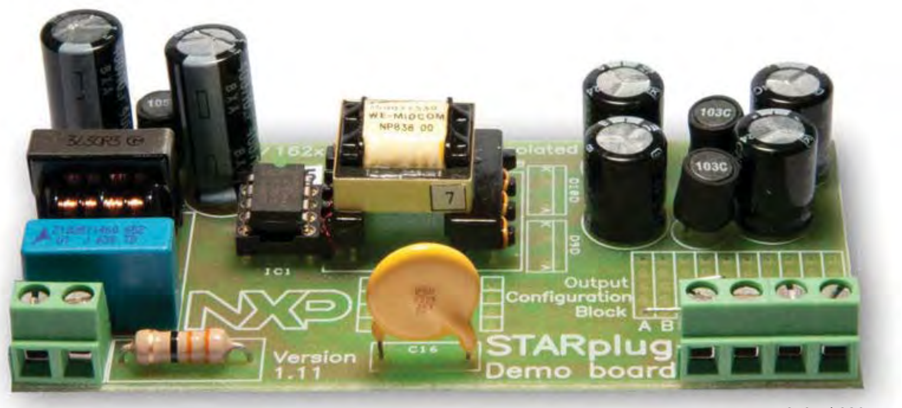
a. SO14 demo board



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b. DIP8 demo board

Fig 1. STARplug Universal demo boards

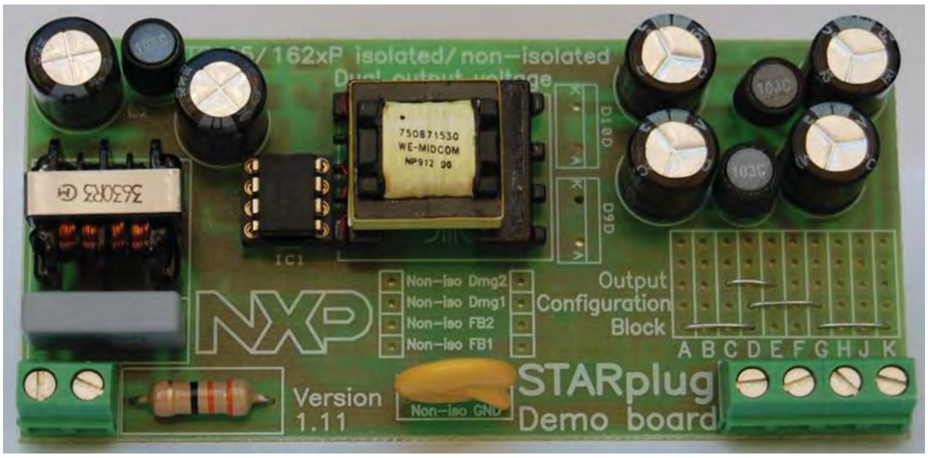

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Fig 2. STARplug Universal demo board

1.1 Features

- Universal mains input
- Operates in isolated and non-isolated mode
- Two default DC output voltages: 12 V and 5 V
- Very stable regulated voltage
- User selectable output voltage configuration
- Highly flexible and easily tunable to user requirements
- Supports the TEA152x and TEA162x family of ICs (except the TEA1623PH)
- 8 W nominal output power, 12 W peak/maximum
- High-efficiency: > 80 %
- Low standby (no-load) power: < 80 mW
- Overload protection
- OverTemperature Protection (OTP)
- Built-in ElectroMagnetic Interference (EMI) filter

2. Safety warning

This reference board is connected to a high AC voltage (up to 276 V). Touching the demo board during operation must be avoided at all times. An isolated housing is obligatory when used in uncontrolled, non laboratory environments. Galvanic isolation of the mains phase using a fixed or variable transformer (Variac) is always recommended. These devices can be recognized by the symbols shown in Figure 3

a. Isolated

b. Not isolated

Fig 3. Variac isolation symbols

3. Technical specification

Table 1. Input specification

Parameter	Condition	Value	Remark
Input voltage	-	90 V (AC) to 276 V (AC)	universal mains
Input frequency	-	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 output 1 load
Output voltage 2 stability	-	-	

4. Performance data

4.1 Output voltage and no-load power consumption

Table 3 shows the no-load power consumption figures for the default configuration of the STARplug Universal demo board.

Table 3. No-load output voltage and power consumption

Supply	Energy star 2.0 requirement	Output voltage 1	Power consumption (P_o)
115 V/60 Hz	≤ 300 mW	11.9 V	75 mW
230 V/50 Hz	≤ 300 mW	11.9 V	75 mW

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

4.2 Efficiency performance data

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

Table 4. Efficiency

Power supply	Energy star requirement	Efficiency (η)				
		average	25 % load	50 % load	75 % load	100 % load
115 V/60 Hz	75.2 %	81.1 %	81.4 %	81.5 %	81.1 %	80.2 %
230 V/50 Hz	75.2 %	81.2 %	79.3 %	81.6 %	82.1 %	82.0 %

The following conditions apply:

- The rated nominal output power at both 115 V (AC) and 230 V (AC) is 8 W
- The load is on the 12 V output only
- Warm-up time of 15 minutes, settle time after load change is 90 s

4.3 ElectroMagnetic Compatibility (EMC) performance data

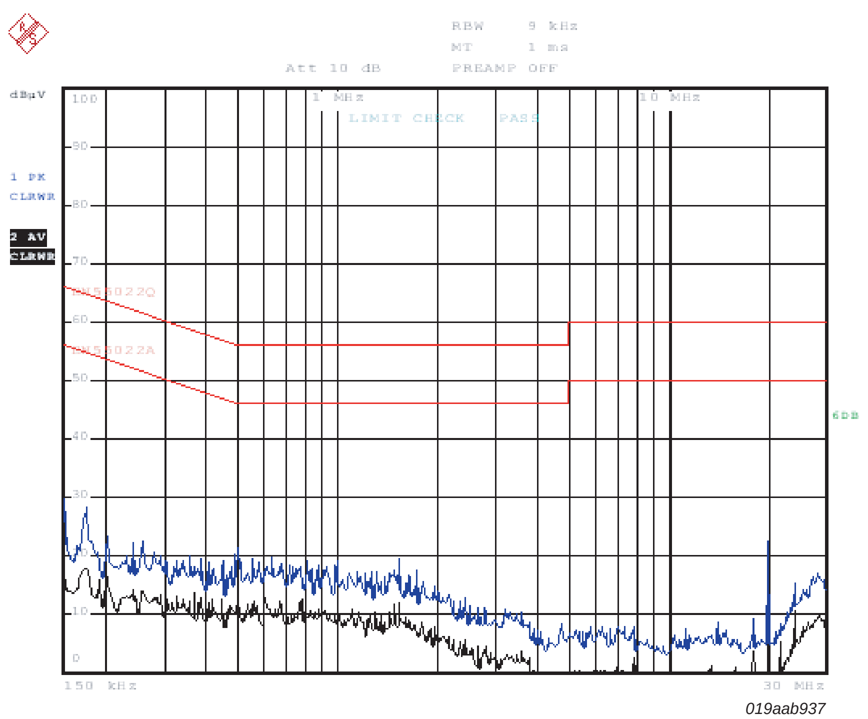

Fig 4. Conducted EMC test: $-V_{IN}$ = 115 V (AC), P_o = 6 W

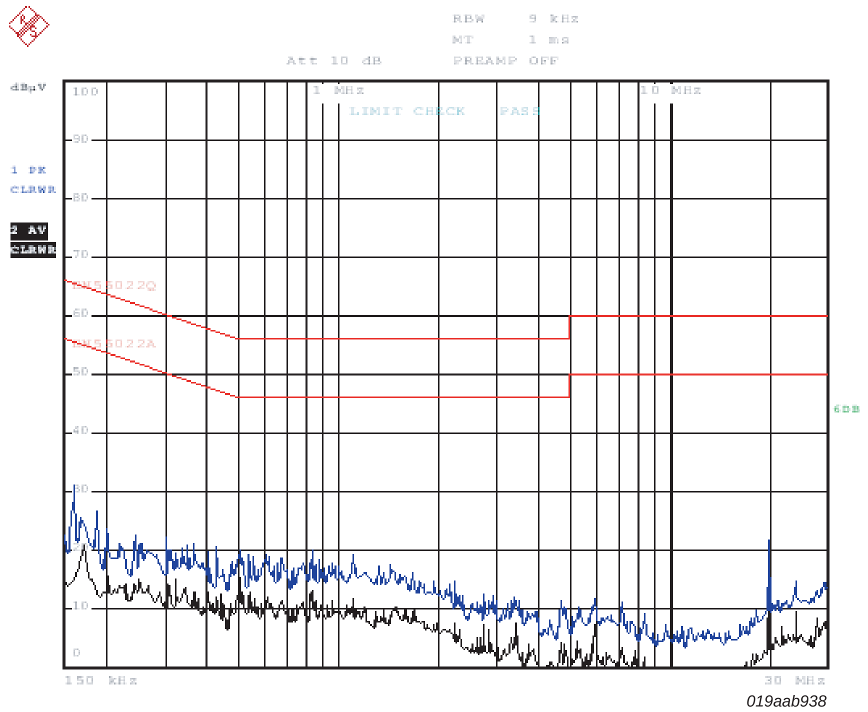

Fig 5. Conducted EMC test: $-V_{IN}$ = 230 V (AC), P_o = 6 W

Remark: Both the average and quasi-peak EMC performance of the STARplug Universal demo board meet EN55022.

5. Demo board connections

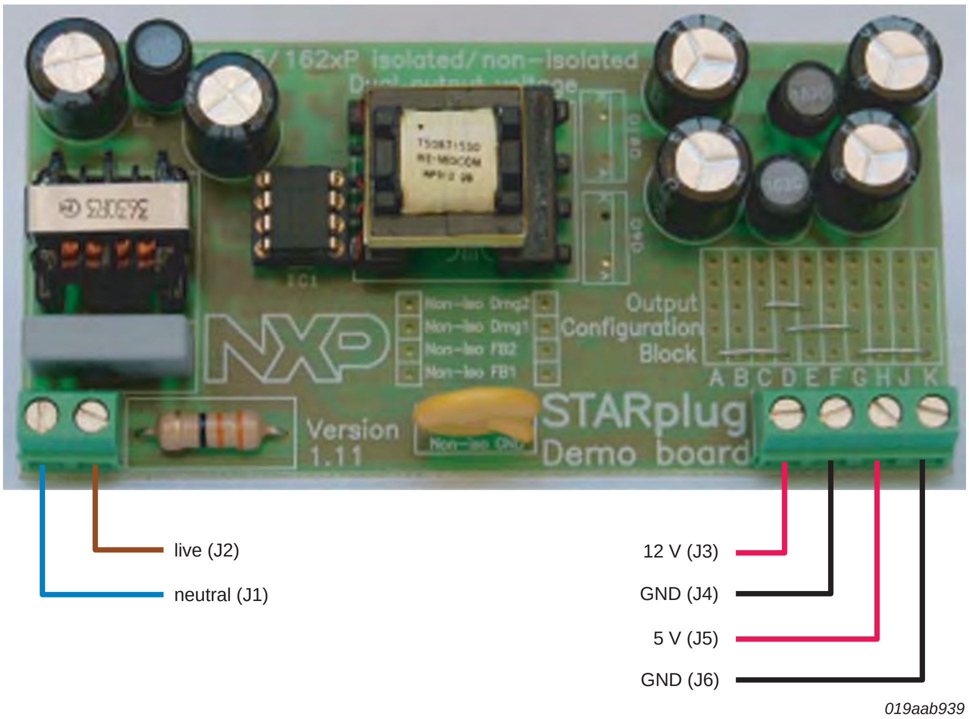

Fig 6. Demo board connection set-up

Remark: Reversing the live and neutral connections has no influence on the practical operation of the STARplug Universal demo board.

Terminals J3 and J4 produce 12 V (J3 positive with respect to J4). The combination of J5 and J6 produces 5 V (J5 positive with respect to J6). In the default configuration, J4 is connected to J6 by means of a wire bridge (G to K) on the output configuration block. In alternative configurations, the pairs (J3, J4) and (J5, J6) could be used completely independently or even floating.

6. Circuit description

The default STARplug Universal 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 Universal demo board PCB, including the connections (A to K) on the output configuration block, is shown in Figure 7.

The STARplug Universal demo board comes with wire bridges A to D, C to E, D to G and G to K installed as the default. This results in an SMPS with 12 V and 5 V output that shares a common GND. Regulation in this case is only on the 12 V output. Figure 8 shows the relevant electrical circuit diagram.

6.1 Rectification section

The single-phase full-wave rectifier consists of four individual diodes (D1 to D4) in a Greatz bridge configuration. The reason for using four individual diodes instead of a single diode bridge component is purely practical. If the STARplug Universal demo board is used with half-wave rectification, it is easy to create a PCB populated with just one diode (D1). See Section 7.8 for details.

Capacitor C3 functions as a reservoir capacitor for the rectified input voltage. Inrush current is limited by resistor R1. This resistor must be a carbon resistor and not a metal film resistor because a metal film type 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 has no effect on the operation of the STARplug Universal converter.

6.2 Filtering section

The filtering section consists of the common-mode choke L1 and C1 on the AC side of the diode bridge and C3, L2 and C4 in Π-configuration on the DC side. If, in exceptional circumstances additional noise suppression is needed, Surface Mounted Device (SMD) capacitors C2 and C5 can be added in parallel to the electrolytic capacitors C3 and C4. The whole filtering configuration effectively reduces the noise and harmonic content that would otherwise be injected from the TEA1522 switching electronics into the electricity utility network. The circuitry helps to achieve the EMC performance required by EN55022.

6.3 Switching section

The switching section uses an NXP Semiconductors STARplug TEA1522 IC in either a SO14 or DIP8 package (depending on the board version). The operating frequency is set using the combination of R2 and C6.

The parallel circuit of resistors R5, R5B and R5C limit the peak current that occurs in the STARplug internal MOSFET switch and as a consequence in the primary winding of transformer T1. The current limitation simultaneously prevents the internal MOSFET switch from being overstressed and it implements an overload protection of the SMSP output. The maximum switch current is shown in Equation 1.

$$I_{DS(max)} = \frac{0.5}{R5//R5B//R5C} \quad (1)$$

The supply voltage for the TEA1522 IC is generated by an auxiliary winding on transformer T1. The voltage from the auxiliary winding (half-wave) is rectified by diode D7. Capacitor C8 is charged via the current limiter resistor R8. The voltage on C8 is the supply voltage for the TEA1522 V_{CC} pin. The AUX pin of the IC receives information regarding the magnetization status of transformer T1 via resistor R6.

A snubber circuit which handles voltage spikes and associated energy caused by the leakage inductance of the primary winding of transformer T1 is implemented using a diode-Zener snubber (D5 and D6). This type of snubber conserves energy and is EMI friendly but it is also a more expensive option compared to an RCD snubber (see Section 7.2).

6.4 Output section

The output section of the STARplug Universal application produces two DC voltages: 12 V and 5 V. The 12 V section consists of diode D9, capacitors C10, C12, C13 and inductor L3. The 5 V section consists of diode D6, capacitors C11, C14, C15 and inductor L4.

The output sections provide a good level of ripple filtering and noise suppression by using Π-configurations in both the 12 V and the 5 V section. In the default configuration, the GND terminals of the 12 V and the 5 V supplies are tied together. J4 and J6 are GND (0 V), J5 is +5 V and J3 is +12 V.

6.5 Feedback section

The feedback signal is taken from the 12 V supply but it can be changed to either the 5 V supply or a weighed combination of the 12 V and 5 V supplies (see Section 7.4).

In the default configuration, the feedback network on the secondary side consists of resistors R18, R17, R16; capacitors C18, C19, and voltage reference IC3 (TL431A). Resistors R18 and R17 form a voltage divider and determine the output voltage of the (12 V) supply. The programmed output voltage (12 V output – terminal J3) is calculated using Equation 2.

$$V_{out\_12V} = V_{REG} \cdot \frac{R17 + R18}{R17} \quad (2)$$

V_{REG} is the reference voltage of IC3 and for a TL431 this voltage is 2.5 V. R13 and C17 provide the supply power for the feedback network and R14 functions as a current limiter for the LED in the optocoupler IC2. The feedback signal is transferred across the isolation barrier through optocoupler IC2. On the primary side, the signal is fed to the TEA1522 REG pin via the current limiting resistor R7. When the optocoupler is in the off-state, the REG pin is pulled down by resistor R10, noise is filtered and a pole is added with capacitor C9. Zener diode D8 protects against the optocoupler failing (e.g. through ageing). In this case, the generated output voltage is limited by Zener diode D8 instead of rising in an uncontrolled way.

Remark: Refer to the *STARplug TEA152x data sheet*, the *TEA162x data sheet* and the *STARplug application note AN00055* for more detailed/accurate information on the operation of STARplug TEA152x/TEA162x ICs and dimensioning of STARplug circuits.

7. Alternative circuit options

7.1 Additional filtering capacitors in the rectification/filtering sections

In exceptional cases, two additional SMD capacitors (C2 and C5) placed in parallel to the electrolytic capacitors C3 and C4 help to suppress the EMI even more. See the circuit diagram shown in Figure 10 and the component changes given in Table 9.

7.2 Alternative snubber circuit

The D5/D6 diode-Zener snubber is usually a good solution for snubbering the leakage energy of the primary winding of the transformer. However, a cheaper RCD solution is sometimes preferred. The STARplug Universal demo board has a provision that allows the mounting of an RCD snubber circuit (D5, C7, R3, R4) instead of a diode-Zener snubber. The resistor “R” part of the RCD is split in two. The power dissipation and voltage drop is divided equally over these standard (1206 sized) SMD resistors.

The circuit diagram shown in Figure 11 and the component changes given in Table 10 describe the STARplug Universal application using a RCD snubber.

7.3 Primary feedback

The STARplug Universal demo board allows the implementation of primary feedback schemes in an isolated SMPS application. This feature is intended, for example, in low output power applications. The consequence of the primary feedback option when implemented on this board is that voltage regulation is (much) less accurate. However, as a trade-off, the cost savings can be significant.

To ensure reasonably good voltage regulation, it is essential that the magnetic coupling between the secondary winding and the auxiliary winding of the transformer is very good. This requirement can add considerable cost because of the transformer construction.

The circuit diagram shown in Figure 12 and the component changes given in Table 11 indicate that the circuit diagram is simplified and the parts list is shorter.

7.4 Alternative secondary side feedback

In the default configuration, only the 12 V rail of the STARplug Universal demo board is regulated. It can be desirable to regulate the 5 V output or a (weighted) combination of the 12 V and 5 V output depending on the application.

When regulation of only the 5 V output voltage is required, resistor R18 is removed from the PCB (set to $\infty\Omega$) and wire bridge B to H is installed in the output configuration block. The output voltage produced on the 5 V output terminals (J5, J6) is given in Equation 3. The 12 V output voltage on terminals (J3, J4) are now unregulated.

$$V_{out\_5V} = V_{REG} \cdot \frac{R17 + R20}{R20} \quad (3)$$

When a weighed combination of the 12 V and the 5 V output is regulated, the ratio (V_{ratio}) between the 12 V and the 5 V output is fixed by a factor of $V_{ratio} = 12/5 = 2.4$.

The only way to change this factor is by modifying the turns ratio on the secondary side of the T1 transformer. Both resistors R18 and R20 are affected in this case and their values need to be changed. Both wire bridges B to H and C to E must be installed. The mathematical expression for the (weighed) regulation on two output voltages is more complex than the expressions that apply to regulation on a single output voltage. The expression for weighed regulation is given in Equation 4 and Equation 5.

$$V_{out\_12V} = V_{REG} \cdot \frac{(R17 \cdot R18 + R17 \cdot R20 + R18 \cdot R20)}{\left(R17 \cdot R20 + R17 \cdot \frac{R18}{V_{ratio}}\right)} \quad (4)$$

$$V_{out\_5V} = \frac{V_{out\_12V}}{V_{ratio}} \quad (5)$$

In the default STARplug Universal demo board configuration, V_{REG} = 2.5 V (IC2 TL431 reference voltage) and V_{ratio} = 2.4 (i.e. the turns ratio between the 12 V and 5 V output on the secondary winding of transformer T1).

It can be seen that Equation 4 and Equation 5 transform into Equation 2 when R20 is removed (i.e. R20 = ∞Ω) and that they transform into Equation 3 when R18 is removed (i.e. R18 = ∞Ω).

When an SMPS application with output voltages 12 V and 5 V is designed, the balance between the values of R18 and R20 determines the weight that each of the output voltages has on the regulation. The weighting of the feedback regulation contribution of either voltage rails is given in Equation 6 and Equation 7.

$$Weight\ V_{out\_12V} = \frac{R17}{R18} \cdot \frac{V_{out\_12V} - V_{REG}}{V_{REG}} \cdot 100\ \% \quad (6)$$

$$Weight\ V_{out\_5V} = \frac{R17}{R20} \cdot \frac{V_{out\_5V} - V_{REG}}{V_{REG}} \cdot 100\ \% \quad (7)$$

Table 5 gives an overview of various R18 and R20 resistor combinations and weighting factors. R17 is left at its default value of 2.4 kΩ.

Table 5. R17, R18 and R20 exact component values for weighed regulation

Output weighting		Resistor values		
5 V	**12 V**	**R17**	**R18**	**R19**
0 %	100 %	2.4 kΩ	9.12 kΩ	∞Ω
5 %	95 %	2.4 kΩ	9.60 kΩ	48.00 kΩ
10 %	90 %	2.4 kΩ	10.13 kΩ	24.00 kΩ
20 %	80 %	2.4 kΩ	11.40 kΩ	12.00 kΩ
30 %	70 %	2.4 kΩ	13.03 kΩ	8.00 kΩ
50 %	50 %	2.4 kΩ	18.24 kΩ	4.80 kΩ
70 %	30 %	2.4 kΩ	30.4 kΩ	3.43 kΩ
80 %	20 %	2.4 kΩ	45.6 kΩ	3.00 kΩ
90 %	10 %	2.4 kΩ	91.2 kΩ	2.67 kΩ
95 %	5 %	2.4 kΩ	182.4 kΩ	2.53 kΩ
100 %	0 %	2.4 kΩ	∞Ω	2.40 kΩ

Table 5 lists a number of R18 and R20 resistance values that are not practical and generally, the regulation balance does not need to be defined so precisely. Table 6 lists a number of R17, R18, R20 combinations that are more practical, whilst keeping the idea of weighed regulation. The resistance values come from the E24 range. Small deviations (±1 %) in the output voltages are acceptable.

Table 6. Practical R17, R18 and R20 exact component values for weighed regulation

Resistor values			output weighting		$5\ V_o$	$12\ V_o$
R17	R18	R20	5 V	12 V		
2.4 kΩ	9.1 kΩ	∞Ω	0 %	100 %	5.0 V	12.0 V
2.7 kΩ	11 kΩ	43 kΩ	6 %	94 %	5.0 V	12.0 V
2.4 kΩ	10 kΩ	24 kΩ	10 %	90 %	5.0 V	11.9 V
2.7 kΩ	13 kΩ	13 kΩ	21 %	79 %	5.0 V	12.0 V
2.4 kΩ	13 kΩ	8.2 kΩ	29 %	71 %	5.0 V	12.1 V
2.7 kΩ	20 kΩ	5.6 kΩ	49 %	51 %	5.0 V	12.0 V
2.4 kΩ	33 kΩ	3.3 kΩ	72 %	28 %	5.0 V	12.0 V
2.4 kΩ	47 kΩ	3 kΩ	81 %	19 %	5.0 V	12.0 V
2.4 kΩ	82 kΩ	2.7 kΩ	89 %	11 %	5.0 V	12.0 V
2.2 kΩ	100 kΩ	2.4 kΩ	92 %	8 %	5.0 V	12.0 V
2.4 kΩ	∞Ω	2.4 kΩ	100 %	0 %	5.0 V	12.0 V

Remark: The circuit corresponding to these alternative (weighed) secondary feedback values is shown in Figure 13. See Table 12 for the component changes involved.

7.5 Alternative output configurations

The output configuration block is used for selecting the output voltage configuration using wire bridges. In the default configuration, the output voltage is set to +12 V and +5 V (with regulation/feedback on the 12 V): +12 V on J3, +5 V on J5, 0 V on J4 and J6. This is achieved by inserting the wire bridges in the output configuration block between columns A and D, C and E, D and G, and G and K.

Screw terminal positions J3, J4, J5 and J6 are shown in Figure 6 and the default wire bridges in the output configuration block are shown in Figure 7. See Figure 17 and Figure 21 for an overview of the position of terminals and wire bridges.

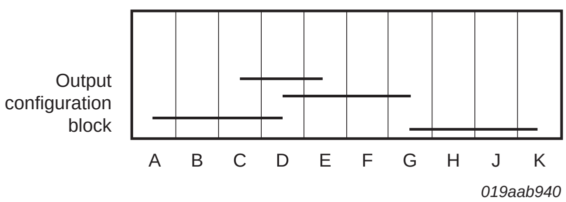

Fig 7. Default wire bridge settings for +12 V and +5 V output configuration block

Table 7 gives a series of output configurations that can be made by setting the wire bridges in the output configuration block. The list of Table 7 is not extensive because the number of configuration possibilities is very large. By carefully studying the circuit diagram in Figure 8, the user can to see how customized output configurations can be made.

Table 7. Examples of STARplug Universal output configuration in isolated mode

Supply	STARplug Universal output configuration					Modification	Configuration block wire jumpers
	J3	J4	J5	J6	Regulation		
+12 V/+5 V	+12 V	0 V	+5 V	0 V	on +12 V[1]	default configuration	A to D, C to E, D to G, G to K
+12 V/+5 V	+12 V	0 V	+5 V	0 V	on +5 V[1]	remove R18	A to D, B to H, C to E, D to G, G to K
+12 V/–5V	+12 V	0 V	0 V	–5 V	on +12 V[1]	-	A to D, C to E, D to G, G to J
+12 V/–5 V	+12 V	0 V	0 V	–5 V	on –5 V[1]	remove R18, R13 = 1 kΩ	A to K, B to C, C to H, D to G, G to J
+5 V/–12 V	0 V	–12 V	+5 V	0 V	on –12 V[1]	-	A to G, C to E, F to K, D to K
+5 V/–12 V	0 V	–12 V	+5 V	0 V	on +5 V[1]	remove R18, R13 = 1 kΩ	A to K, B to C, C to H, F to K, D to K
+17 V/+12 V	+12 V	0 V	+17 V	+12 V	on +12 V[1]	-	A to D, C to E, D to G, F to K
+17 V/+12 V	+12 V	0 V	+17 V	+12 V[1]	on +17 V	R18 = 18 kΩ, R20 = 62 kΩ, R13 = 3.3 kΩ	A to D, B to C, C to H, D to G, F to K
+17 V/+5 V	+17 V	+5 V	+5 V	0 V	on +5 V[1]	remove R18, R13 = 1 kΩ	A to D, A to K, B to C, C to H, G to J
+17 V/+5 V	+17 V	+5 V	+5 V	0 V	on +17 V[1]	R18 = 18 kΩ, R20 = 62 kΩ, R13 = 3.3 kΩ	A to D, A to K, G to J, B to C, E to C
+7 V/–5 V	+7 V	–5 V	0 V	–5 V	on –5 V[1]	remove R18, R13 = 1 kΩ	A to K, B to C, C to H, D to J, G to K
+7 V/–5 V	+7 V	–5 V	0 V	–5 V	on +7 V[1]	R20 = 8.2 kΩ, R13 = 1.5 kΩ	A to H, B to C, C to E, D to J, G to K

[1] Regulated voltage.

7.6 Self-supplied TEA152x application

When a STARplug IC from the TEA152x family is applied on the STARplug Universal demo board, there is an option which enables the SMPS IC to generate its own power supply using the built-in JFET. This is not available with TEA162x IC because these ICs do not have the built-in JFET. The advantage of this is that the auxiliary winding on transformer T1 is no longer needed reducing the cost.

The disadvantage is that generating the supply voltage through the built-in JFET causes an additional power loss. Therefore 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 STARplug IC, the auxiliary winding on the transformer also informs the IC’s AUX pin about the magnetization status of the transformer. When the auxiliary winding is no longer present, an alternative method is needed to inform the AUX pin about the magnetization status of the transformer. This can be done by capacitive coupling.

As the “hot” connections of the respective windings of the transformer T1 are in phase during operation, the voltage (or information) on the “hot” side of the primary winding can be used to indicate whether or not the transformer is demagnetized. Creating a capacitive coupling between the “hot” side of the primary winding and the STARplug IC AUX pin makes it easy to transfer this information.

A small capacitive coupling is enough because of the relatively high-impedance of the AUX pin. To guarantee that during start-up the voltage on the AUX pin is below 100 mV, the pin must be pulled to ground using a high-ohmic resistor (around 500 kΩ).

The capacitor is shown as C21 in Figure 14 acts as the capacitive coupler between the transformer "hot" side and the STARplug IC AUX pin. A typical value for this capacitor is 2 pF. Therefore the parasitic capacitance that can be created with the layout of the PCB is generally adequate to create sufficient coupling. Usually there is no need to mount the C21 capacitor.

The ~500 kΩ impedance between the IC AUX pin and GND is split in two resistor values, R6 and R11. R6 limits the current that can be injected into the AUX pin through the capacitive coupling (100 kΩ typical). Overcurrent into the AUX pin may damage the IC. The combination of R6 and R11 builds the impedance that pulls the AUX pin to ground during start-up (R11 = 390 kΩ typical).

When the STARplug IC is self-supplying via the built-in JFET, there is no longer any need for Zener diode D8 because the V_{CC} voltage will never rise high enough. This also means the protection described in Section 6.5 is no longer active. A defective or strongly degraded optocoupler IC2 results in an uncontrolled rise of the output voltage(s) of the SMPS.

See Table 13 for the component changes involved.

7.7 Non-isolated SMPS application with a regulated +12 V output

If an non-isolated SMPS is designed with a regulated +12 V (DC) output, the STARplug IC supply voltage (V_{CC}) can be delivered by the secondary side of the transformer. The transformer does not need an auxiliary winding. In addition, the demagnetization information supplied to the AUX pin can also be delivered by the secondary side of the transformer. Voltage information feedback via the voltage reference (IC3) and an optocoupler (IC2) is no longer needed.

Wire bridges "Non-iso Dmg2" and "Non-iso FB1" must be installed, and Y-capacitor C16 must be replaced with a wire bridge ("Non-iso GND"). See Figure 17 and Figure 21 for the locations of these wire bridges.

The 5 V output voltage supply section can either be used to generate +5 V, –5 V, or +17 V, by installing the correct wire bridges in the output configuration block. The configuration shown in Figure 15 produces +12 V (on J3) and +5 V (on J5), while J4 and J6 are tied together at 0 V (GND) level. Only implement this option when there is no auxiliary winding on the transformer or when the auxiliary winding of the transformer has no galvanic connection to resistor R6 (e.g. by cutting the appropriate transformer pin).

The circuit diagram shown in Figure 15 and the component changes given in Table 14 describe the non-isolated STARplug Universal application with a regulated +12 V output.

7.8 Non-isolated SMPS application with a regulated –5 V output

If a non-isolated SMPS application that has a regulated –5 V (DC) output is designed, the STARplug IC supply voltage (V_{CC}) must be delivered either by the auxiliary winding of the transformer or using the self-supply option of the TEA152x IC (see Section 7.6). The demagnetization information can be supplied either by the auxiliary winding (preferred, if present) or through capacitive coupling as described in Section 7.6.

Voltage information feedback via an optocoupler (IC2) is not needed but the negative output voltage must be translated into a control signal for the STARplug IC REG pin. This is done with a circuit consisting of an NPN transistor (Q2), a PNP transistor (Q1), a Zener diode (D12) and a few passive components.

In this example, the demagnetization information is provided by the auxiliary winding of the transformer. Wire bridge “Non-iso FB2” must be installed and Y-capacitor C16 must also be replaced with a wire bridge (“Non-iso GND”). See Figure 17 and Figure 21 for the locations of these wire bridges.

The 12 V output voltage supply section can be used to either generate +12 V, +7 V, or –17 V or as a fully independent (floating) 12 V supply voltage. All the options can be achieved by installing the appropriate wire bridges in the output configuration block.

The configuration shown in Figure 16 produces –5 V on J6 (and J4), +7 V on J3 and 0 V (GND) on J5. J4 and J6 are tied together and are at the –5 V level. The input rectification stage in this example is a half-wave rectifier that uses a single diode (D1). The common-mode input filter (L1, C1) is eliminated. This makes it possible to have the neutral wire from the mains (terminal J1) connected to the 0 V (GND) level of the output stage (terminal J5). This is especially useful for applications using a –5 V supply to drive triacs in the third quadrant (such as most White Goods applications).

The circuit diagram shown in Figure 16 and the component changes given in Table 15 describe the non-isolated STARplug Universal application with a regulated –5 V output.

7.9 Combining options and features

Options and features can be combined as described in Section 7 to Section 7.8. A new combination of options and features need to be checked so that the specific combination does not cause an electrical conflict. If needed, contact NXP Semiconductors application support for additional application help.

8. Schematics

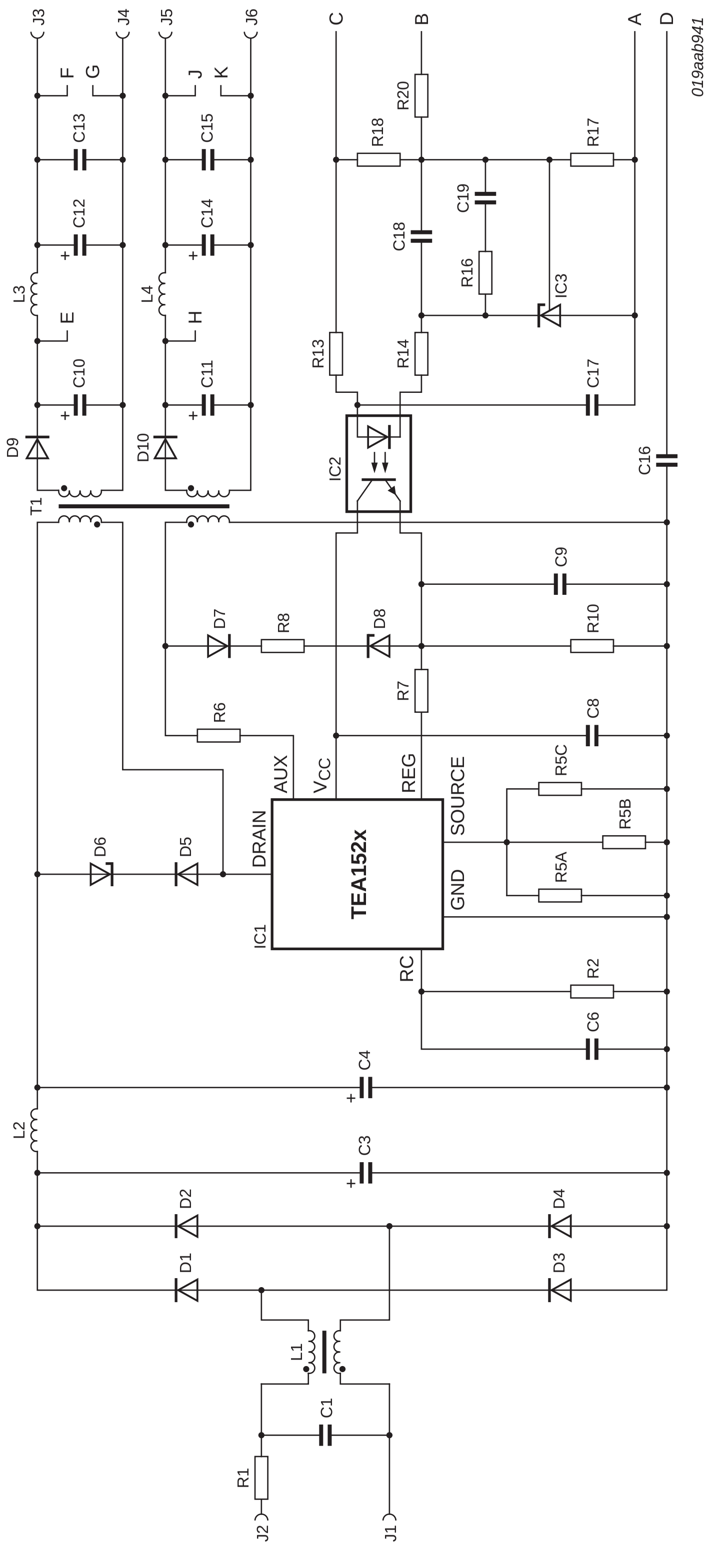

Fig 8. STARplug Universal with output configuration block connections shown

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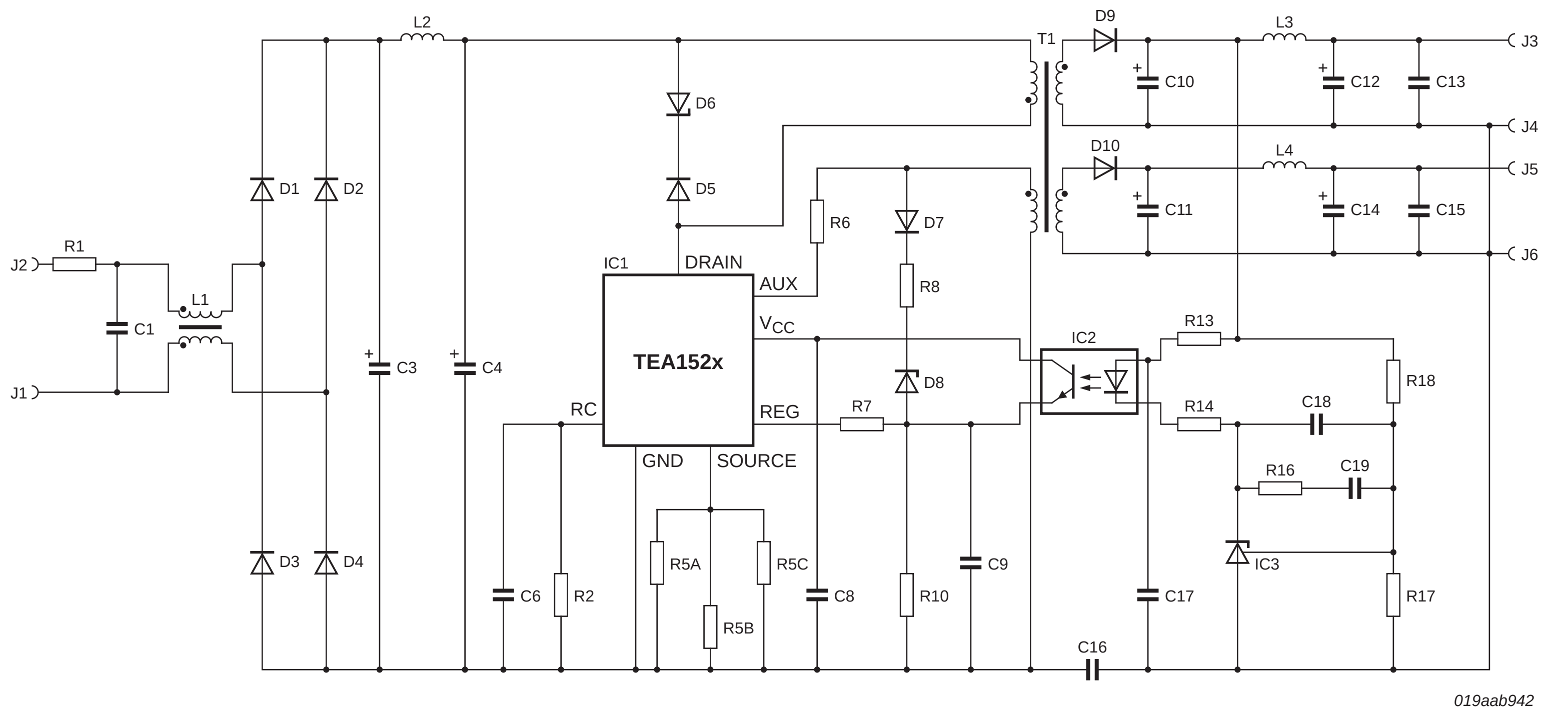
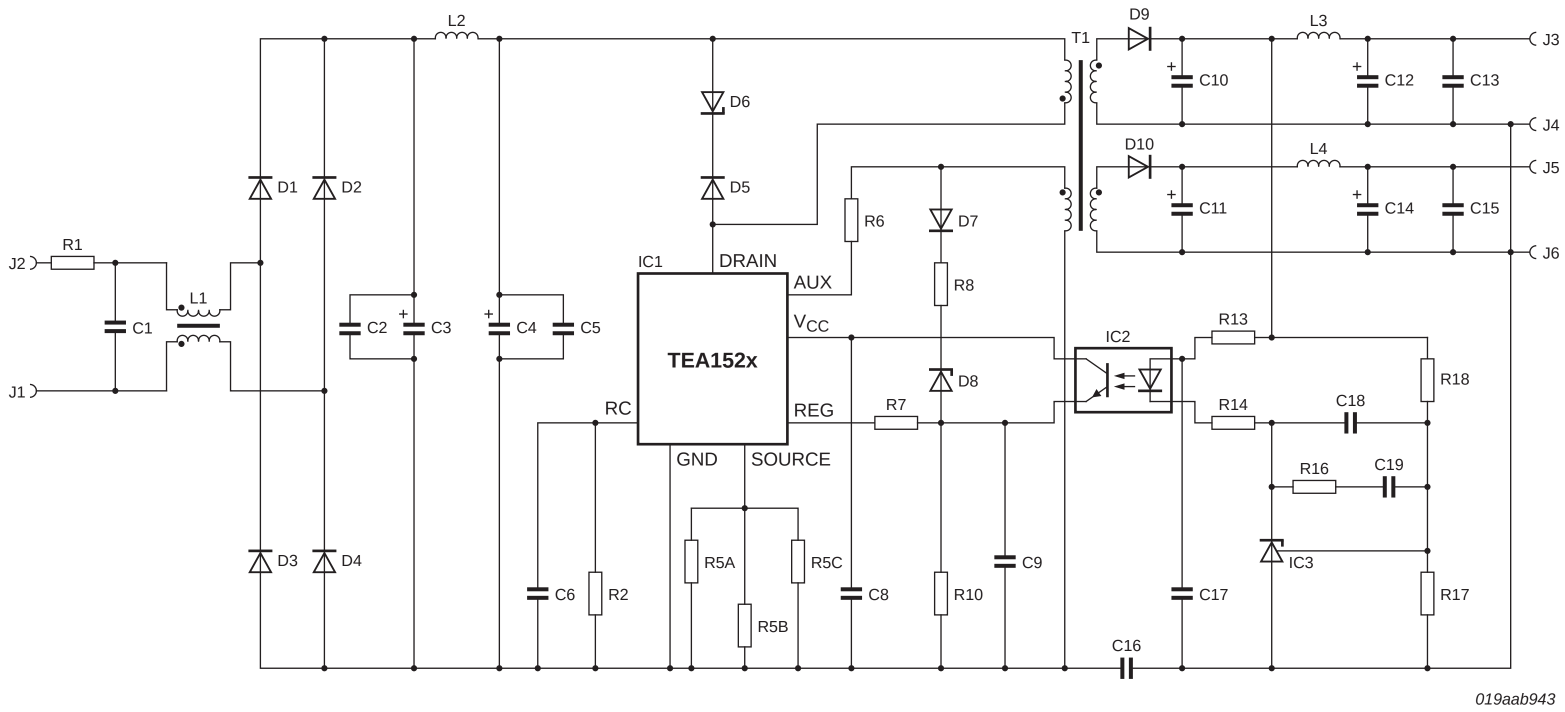


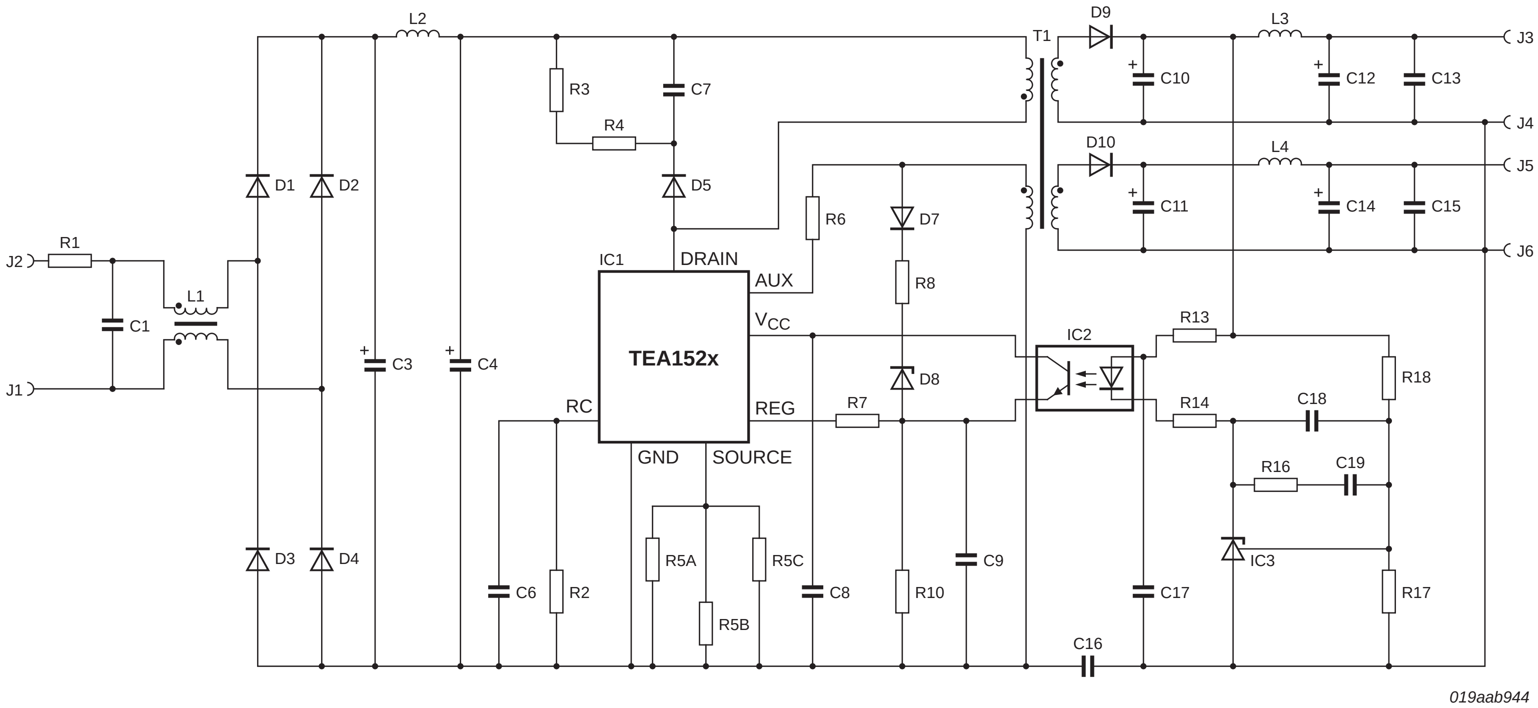
In the STARplug Universal default configuration the following wire bridges must be installed in the output configuration block: A to D; C to E; D to G and G to K.

Fig 9. STARplug Universal - default configuration



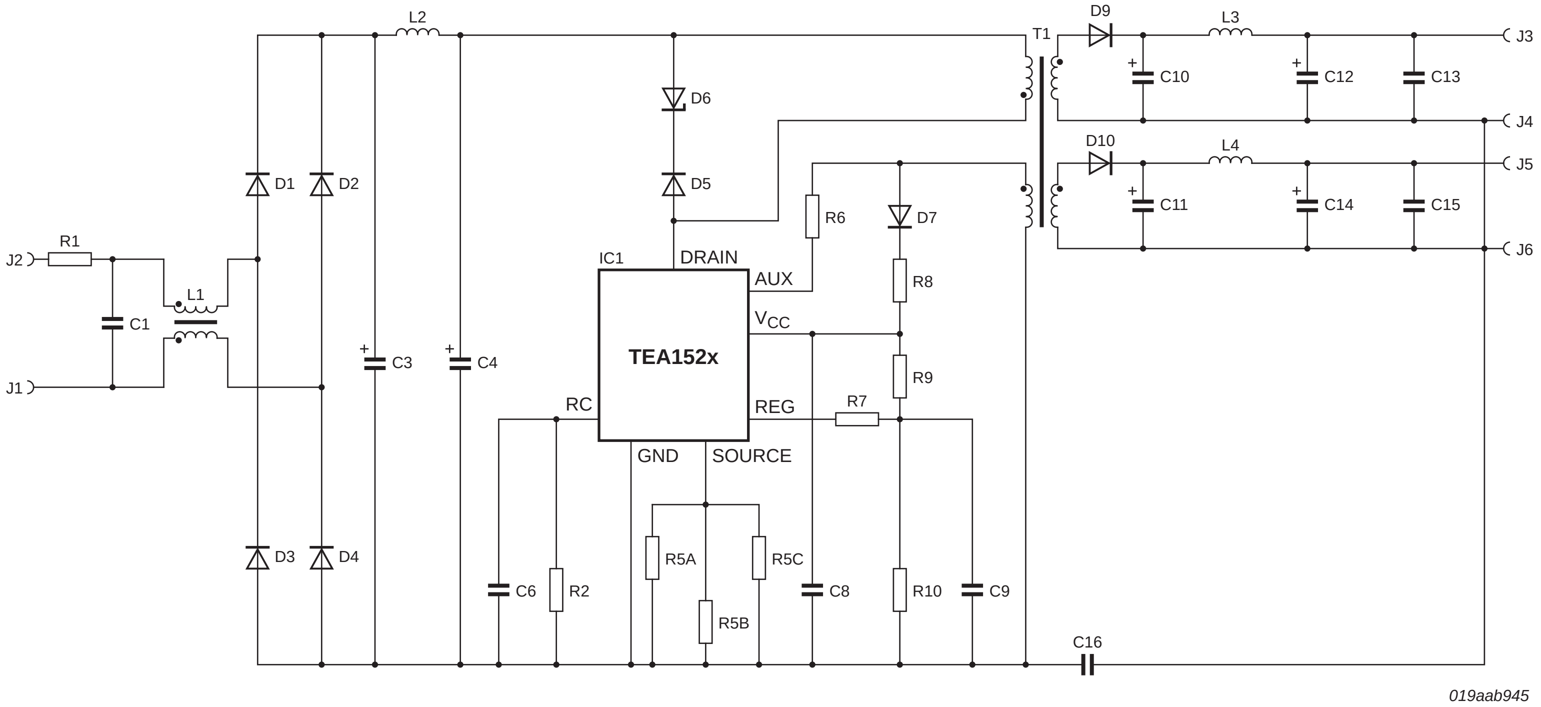
In the STARplug Universal default configuration the following wire bridges must be installed in the output configuration block: A to D; C to E; D to G and G to K.

Fig 10. STARplug Universal with additional filtering



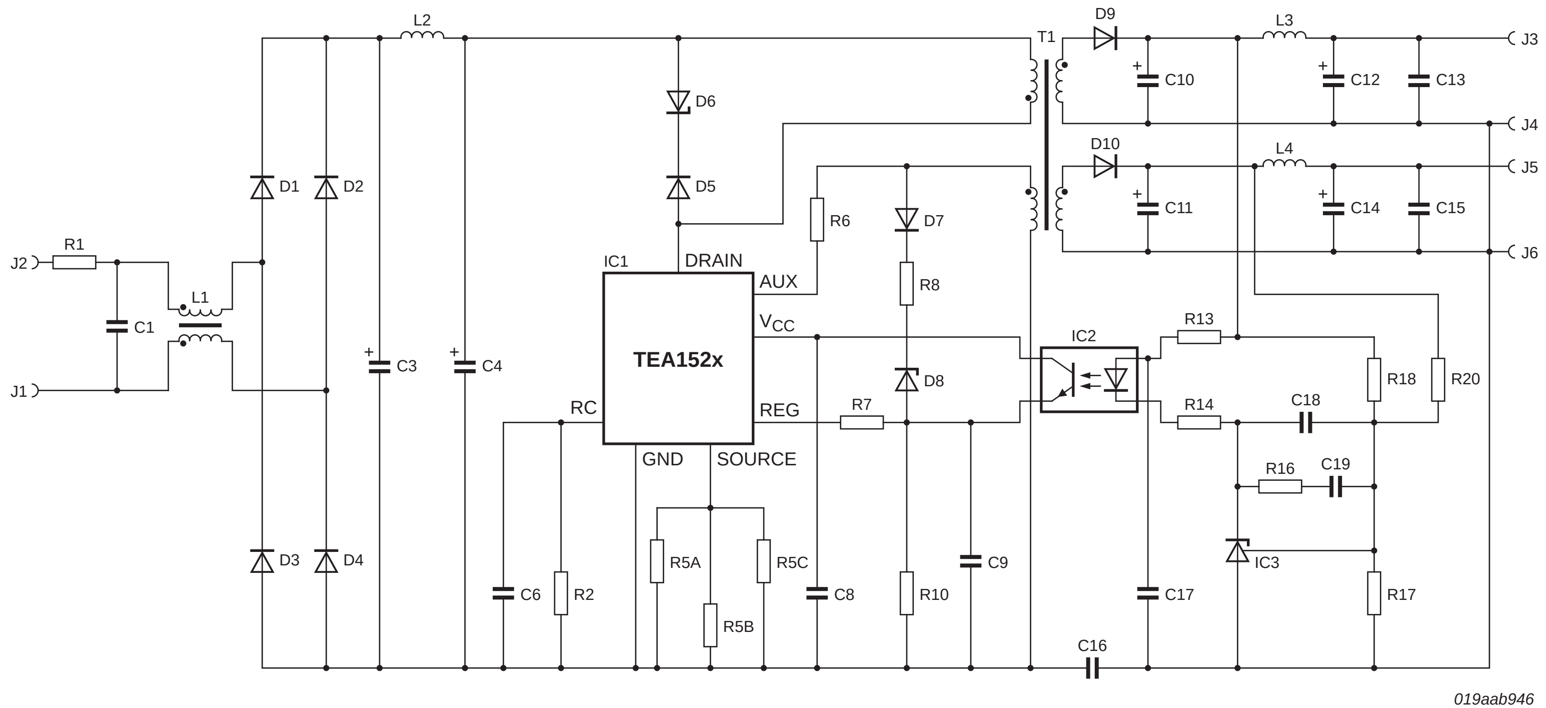
In the STARplug Universal default configuration the following wire bridges must be installed in the output configuration block: A to D; C to E; D to G and G to K.

Fig 11. STARplug Universal with RCD snubber



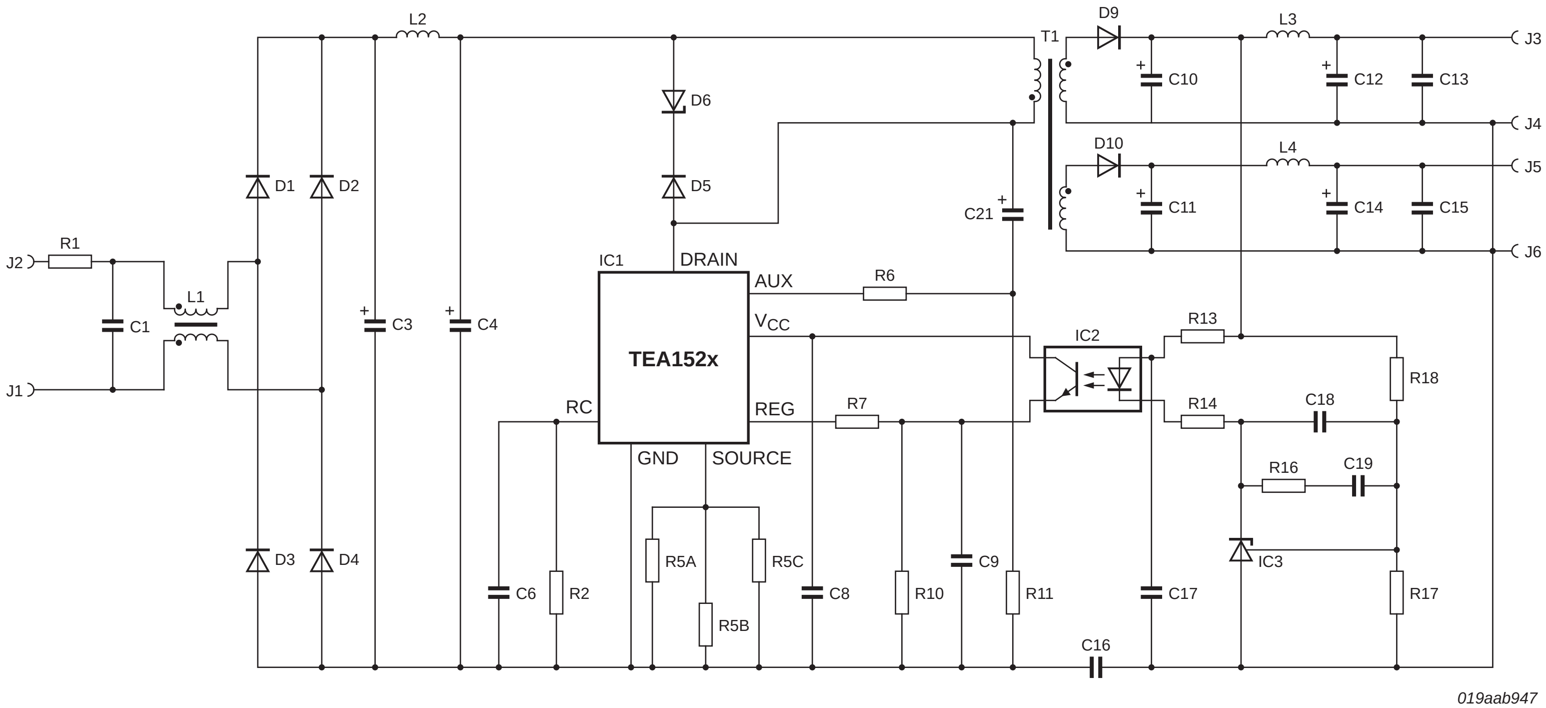
In the STARplug Universal default configuration the following wire bridges must be installed in the output configuration block: D to G and G to K.

Fig 12. STARplug Universal with primary feedback



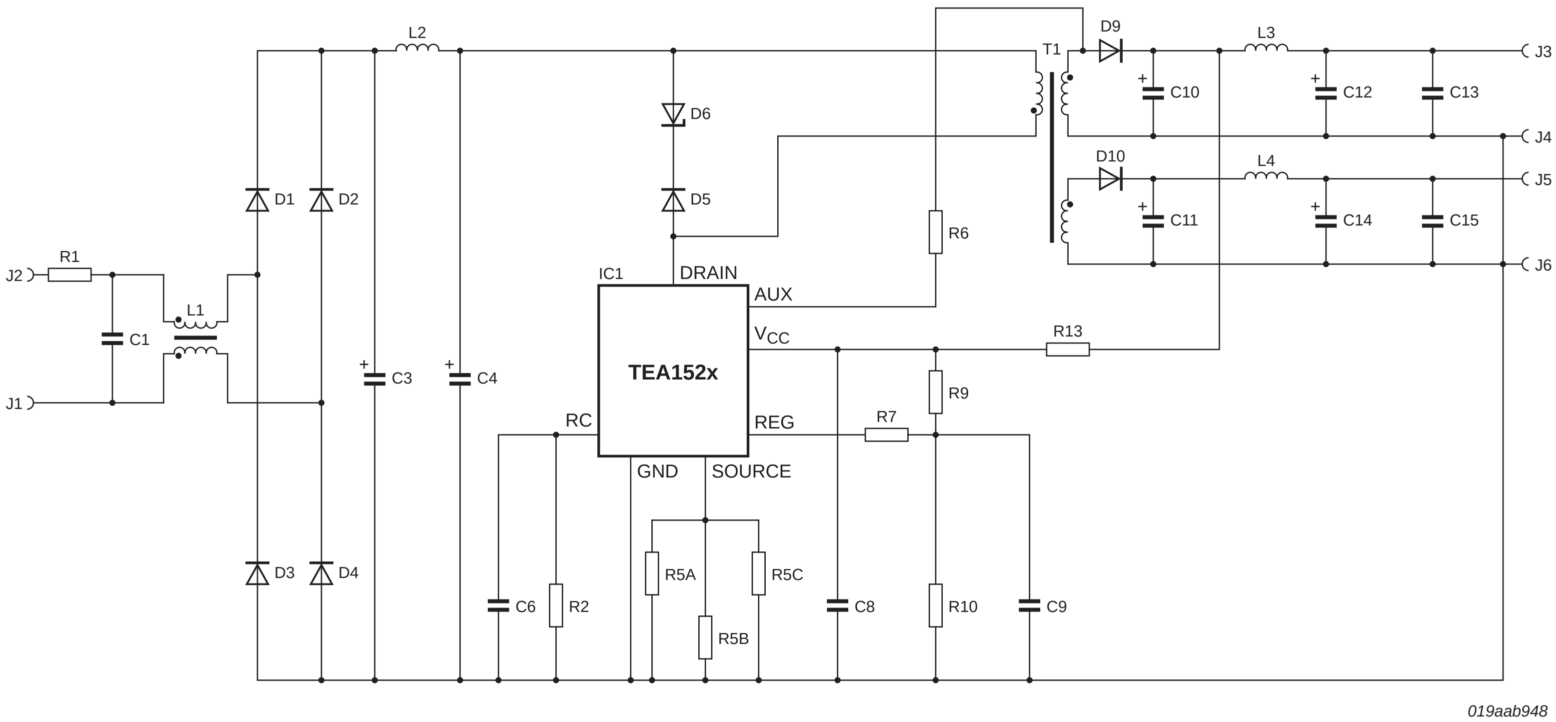
In the STARplug Universal default configuration the following wire bridges must be installed in the output configuration block: A to D; B to H; C to E; D to G and G to K.

Fig 13. STARplug Universal with alternative secondary feedback



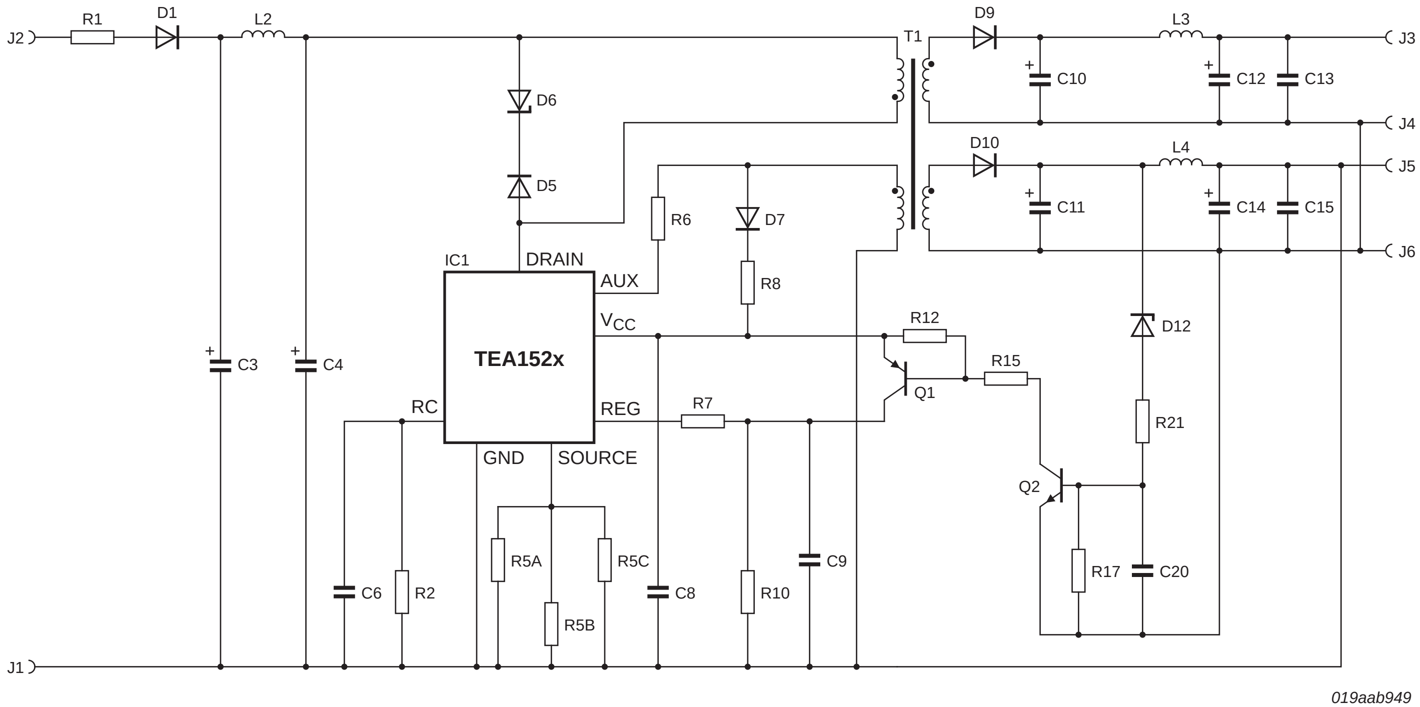
In the STARplug Universal default configuration the following wire bridges must be installed in the output configuration block: A to D; C to E; D to G and G to K.

Fig 14. STARplug Universal - self-supply option



In the STARplug Universal default configuration the following wire bridges must be installed in the output configuration block: A to D; C to E; D to G and G to K.
Additionally, the following “Non-iso” wire bridges must be installed: Non-iso Dmg2; Non-iso FB1; Non-iso GND (remove Y-capacitor C16, install the wire bridge instead).

Fig 15. Non-isolated STARplug Universal with regulated +12 V output



In the STARplug Universal default configuration the following wire bridges must be installed in the output configuration block: A to D; C to E; D to G and G to K. Additionally, the following “Non-iso” wire bridges must be installed: Non-iso FB1; Non-iso GND (remove Y-capacitor C16 and install the wire bridge instead).

Fig 16. Non-isolated STARplug Universal with regulated −5 V output

9. Component lists

Table 8. Default component list

Part reference	Description	Package	Remarks
IC1	NXP TEA1522T; NXP TEA1522P	SO14; DIP8	SO14 version; DIP8 version
SOCK1	DIP8 IC socket	(DIP8)	DIP8 version only
IC2	Vishay SFH6156-4	SMD-4	-
IC3	NXP TL431AQDBZR	SOT23	-
Q1[1]	NXP BC857	SOT23	-
Q2[1]	NXP BC847	SOT23	-
D1	Vishay S1M	DO214-AC	-
D2	Vishay S1M	DO214-AC	-
D3	Vishay S1M	DO214-AC	-
D4	Vishay S1M	DO214-AC	-
D5	Vishay RS1J	DO214-AC	-
D6	Vishay BZG03C180	DO214-AC	-
D7	NXP BAS321	SOD323	-
D8	NXP BZX384-C22	SOD323	-
D9	Vishay 10MQ100NPBF	DO214-AC	-
D9B[1]	alternative in SOD323		-
D9C[1]	alternative in SMB		-
D9D[1]	alternative in TO220	TO220	-
D10	NXP PMEG6010CEJ	SOD323	-
D10B[1]	alternative in SMA		-
D10C[1]	alternative in SMB		-
D10D[1]	alternative in TO220	TO220	-
D11[1]	NXP BZX384-B12	SOD323	-
D12[1]	NXP BZX384-B5V1	SOD323	-
T1	custom made transformer		Würth Order no. 750871530
L1	choke PLA10A; 2 × 36 mH		PLA10AN3630R3D2B
L2	inductor ELC06D; 1 mH		22R105C
L3	inductor ELC06D; 10 μH		22R103C
L4	inductor ELC06D; 10 μH		22R103C
C1	100 nF; 400 V	6E pitch	-
C2[1]	47 nF; 500 V	1812	-
C3	electrolytic capacitor; 10 μF; 400 V	2E pitch	maximum diameter: 10.5 mm
C4	electrolytic capacitor; 10 μF, 400 V	2E pitch	maximum diameter: 10.5 mm
C5[1]	47 nF; 500 V	1812	-
C6	330 pF; 50 V	0805	-
C7[1]	1 nF; 500 V	1206	-
C8	220 nF; 50 V	1206	-
C9	22 nF; 50 V	0805	
C10	electrolytic capacitor; 470 μF; 25 V	2E pitch	maximum diameter: 10.5 mm

Table 8. Default component list *…continued*

Part reference	Description	Package	Remarks
C11	electrolytic capacitor; 470 μF; 10 V	2E pitch	maximum diameter: 10.5 mm
C12	electrolytic capacitor; 470 μF; 25 V	2E pitch	maximum diameter: 10.5 mm
C13	100 nF; 25 V	0805	-
C14	electrolytic capacitor; 470 μF; 10 V	2E pitch	maximum diameter: 10.5 mm
C15	100 nF; 25 V	0805	-
C16	Y-capacitor; 2.2 nF; 2 kV	4E pitch	-
C17	100 nF; 50 V	1206	-
C18	5.6 nF; 50 V	0805	-
C19	22 nF; 50 V	0805	-
C20[1]	22 nF; 50 V	0805	-
C21[1]	2.2 pF; 500 V		see Section 7.6
R1	33 Ω; 1 W; carbon	6E pitch	-
R2	7.5 kΩ	0805	-
R3[1]	47 kΩ; 0.5 W	1206	-
R4[1]	47 kΩ; 0.5 W	1206	-
R5	1.5 Ω; 0.25 W	1206	-
R5B	1.5 Ω; 0.25 W	1206	-
R5C[1]	-	1206	-
R6	100 kΩ	0805	-
R7	2.2 kΩ	1206	-
R8	10 Ω	0805	-
R9[1]	22 kΩ	0805	-
R10	5.6 kΩ	0805	-
R11[1]	390 kΩ	0805	-
R12[1]	2.2 kΩ	0805	-
R13	2.4 kΩ	0805	-
R14	1 kΩ	1206	-
R15[1]	22 kΩ	0805	-
R16	24 kΩ	0805	-
R17	2.4 kΩ; 1 %	0805	-
R18	9.1 kΩ; 1 %	0805	-
R19[1]	100 Ω	0805	-
R20	2.4 kΩ; 1 %	0805	-
R21[1]	100 Ω	0805	-
JP0	0 Ω (SMD jumper)	1206	DIP8 version only
J1; J2	2-pole terminal block	2E pitch	Phoenix: 1729128
J3; J4	2-pole terminal block	2E pitch	Phoenix: 1729128
J5; J6	2-pole terminal block	2E pitch	Phoenix: 1729128

[1] Not mounted

Table 9. Component list modification for additional filtering

Part reference	Description	Package	Remarks
C2	47 nF; 500 V	1812	-
C5	47 nF; 500 V	1812	-

Table 10. Component list modification for alternative (RCD) snubber

Part reference	Description	Package	Remarks
D6[1]	Vishay BZG03C180	DO214-AC	-
C7	1 nF; 500 V	1206	-
R3	47 kΩ; 0.5 W	1206	-
R4	47 kΩ; 0.5 W	1206	-

[1] Not mounted

Table 11. Component list modification for primary feedback

Part reference	Description	Package	Remarks
IC2[1]	Vishay SFH6156-4	SMD-4	-
IC3[1]	NXP TL431AQDBZR	SOT23	-
D8[1]	NXP BZX384-C22	SOD323	-
C17[1]	100 nF; 50 V	1206	-
C18[1]	5.6 nF; 50 V	0805	-
C19[1]	22 nF; 50 V	0805	-
R9	22 kΩ	0805	-
R13[1]	2.4 kΩ	0805	-
R14[1]	1 kΩ	1206	-
R16[1]	24 kΩ	0805	-
R17[1]	2.4 kΩ; 1 %	0805	-
R18[1]	9.1 kΩ; 1 %	0805	-
R20[1]	2.4 kΩ, 1 %	0805	-

[1] Not mounted

Table 12. Component list alternatives for (weighed) secondary feedback

Part reference	Description	Package	Remarks
R17	[1]	0805	-
R18	[1]	0805	-
R20	[1]	0805	-

[1] See Table 6

Table 13. Component list modification for self-supplied TEA152x

Part reference	Description	Package	Remarks
D7[1]	NXP BAS321	SOD323	-
D8[1]	NXP BZX384-C22	SOD323	-
T1	transformer without auxiliary winding		cut the auxiliary winding on the original transformer
C21	2.2 pF; 500 V		does not need to be physically mounted [2]
R8[1]	10 Ω	0805	-
R11	390 kΩ	0805	-

[1] Not mounted

[2] See Section 7.6

Table 14. Component list modification for non-isolated SMPS with regulated +12 V output

Part reference	Description	Package	Remarks
IC2[1]	Vishay SFH6156-4	SMD-4	-
IC3[1]	NXP TL431AQDBZR	SOT23	-
D7[1]	NXP BAS321	SOD323	-
D8[1]	NXP BZX384-C22	SOD323	-
C17[1]	100 nF; 50 V	1206	-
C18[1]	5.6 nF; 50 V	0805	-
C19[1]	22 nF; 50 V	0805	-
T1	transformer without auxiliary winding		cut the auxiliary winding on the original transformer
R8[1]	10 Ω	0805	-
R9	22 kΩ	0805	-
R13	10 Ω	0805	-
R14[1]	1 kΩ	1206	-
R16[1]	24 kΩ	0805	-
R17[1]	2.4 kΩ; 1 %	0805	-
R18[1]	9.1 kΩ; 1 %	0805	-
R20[1]	2.4 kΩ; 1 %	0805	-

[1] Not mounted

Table 15. Component list modification for non-isolated SMPS with regulated −5 V output

Part reference	Description	Package	Remarks
IC2[1]	Vishay SFH6156-4	SMD-4	-
IC3[1]	NXP TL431AQDBZR	SOT23	-
Q1	NXP BC857	SOT23	-
Q2	NXP BC847	SOT23	-
D12	NXP BZX384-B5V1	SOD323	-
D8[1]	NXP BZX384-C22	SOD323	-
C17[1]	100 nF; 50 V	1206	-

Table 15. Component list modification for non-isolated SMPS with regulated –5 V output

Part reference	Description	Package	Remarks
C18[1]	5.6 nF; 50 V	0805	-
C19[1]	22 nF; 50 V	0805	-
C20	22 nF; 50 V	0805	-
R12	2.2 kΩ	0805	-
R13[1]	2.4 kΩ	0805	-
R14[1]	1 kΩ	1206	-
R15	22 kΩ	0805	-
R16[1]	24 kΩ	0805	-
R18[1]	9.1 kΩ; 1 %	0805	-
R20[1]	2.4 kΩ; 1 %	0805	-
R21	100 Ω	0805	-

[1] Not mounted

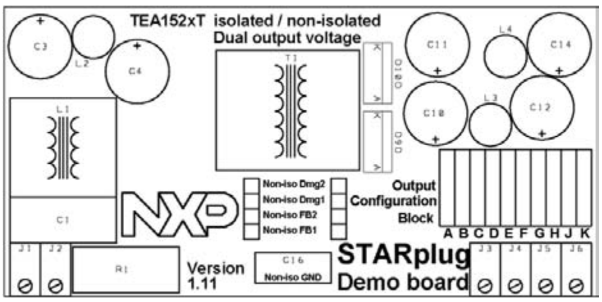
10. Printed-circuit board

The STARplug Universal demo board PCBs (both the SO14 and the DIP8 version) are single-sided boards. Dimensions for both are 99 mm × 49 mm. Both demo boards are produced on 1.6 mm FR4 with single-sided 1 oz. copper (35 μm). FR2 can also be used as the PCB material.

The PCBs can accommodate a number of implementations of the NXP Semiconductors STARplug Universal SMPS as outlined in Section 6, Section 7, Section 8 and Section 9.

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

10.1 STARplug Universal SO14 demo board



019aab950

Fig 17. Top silk screen (top view)

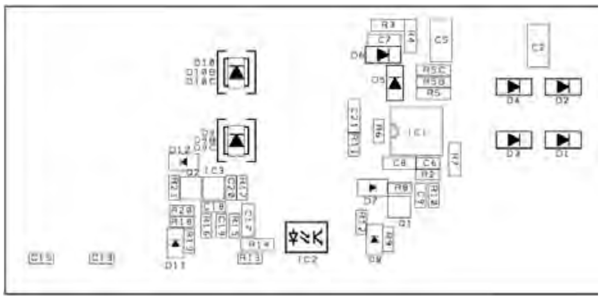


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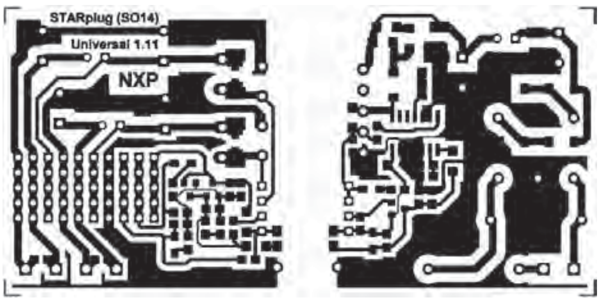
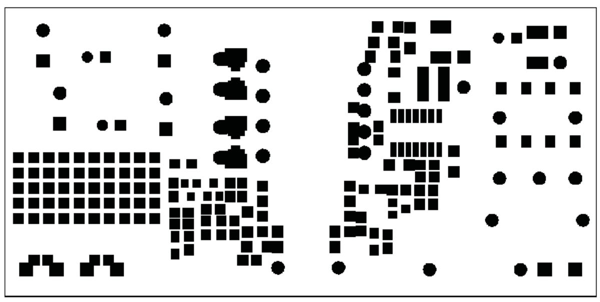
Fig 18. Bottom silk screen (bottom view)



019aab952

Fig 19. Bottom copper (bottom view)



019aab953

Fig 20. Bottom solder mask (bottom view)

10.2 STARplug Universal DIP8 demo board

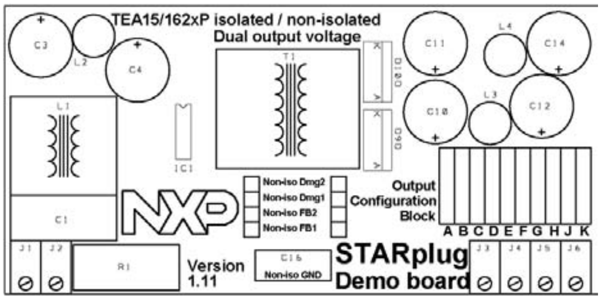


Fig 21. Top silk screen (top view)

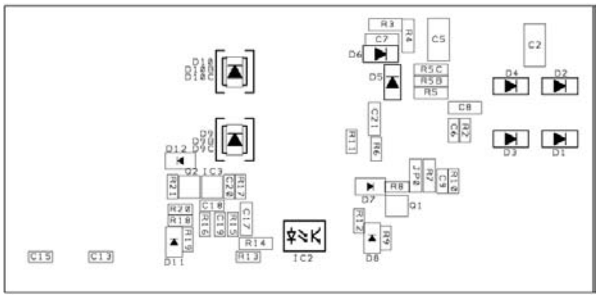


Fig 22. Bottom silk screen (bottom view)

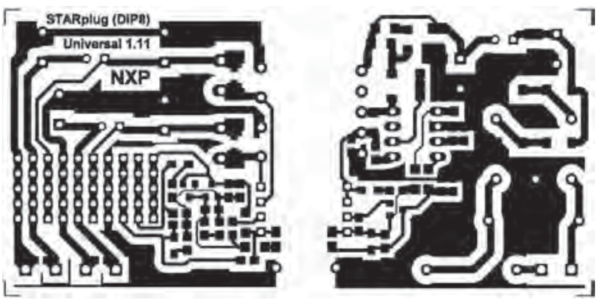
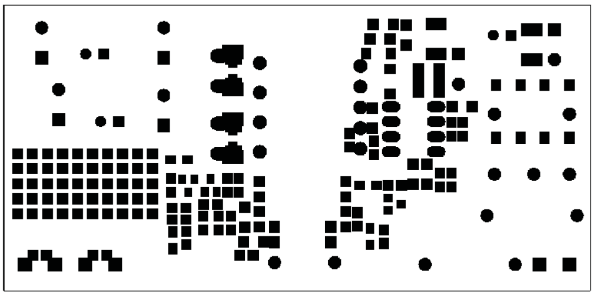


Fig 23. Bottom copper (bottom view)



019aab957

Fig 24. Bottom solder mask (bottom view)

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12. Contents

Date of release: 20 July 2011
Document identifier: UM10377