



# UM10891

## GreenChip TEA1995DB1294 synchronous rectifier controller demo board

Rev. 1 — 16 July 2015

User manual

### Document information

| Info            | Content                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Keywords</b> | TEA1995T, LLC converter, dual Synchronous Rectifier (SR) driver, SO8, high efficiency, power supply, TEA1995DB1294 demo board                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Abstract</b> | This user manual describes how the TEA1995DB1294 demo board can be used in a resonant converter. The demo board contains a TEA1995T SR controller in an SO8 package. In addition to the TEA1995T, the demo board contains two power MOSFETs. The demo board replaces the secondary side of the resonant converter, excluding the output capacitors and the feedback hardware. There are two versions of the demo board available. A version containing TO-220 MOSFETs (UM10891), and a second version using LFPK MOSFETs (UM10892). |



## Revision history

| Rev | Date     | Description |
|-----|----------|-------------|
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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.

This user manual describes the TEA1995DB1294 demo board. It provides a functional description, supported with instructions on how to connect the board to obtain the best results and performance. The TEA1995DB1294 demo board contains the secondary part of a single output LLC converter, excluding the output capacitors and the feedback control hardware. To use the TEA1995DB1294 demo board correctly, an LLC converter board in which the demo board can replace the secondary part, is required.

The TEA1995T is a dedicated controller IC for synchronous rectification on the secondary side of resonant converters. It incorporates two driver stages for driving the SR MOSFETs, which rectify the outputs of the central tap secondary transformer windings. The two gate driver stages have their own sensing inputs and operate independently.

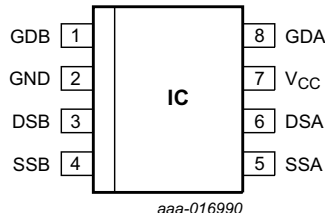


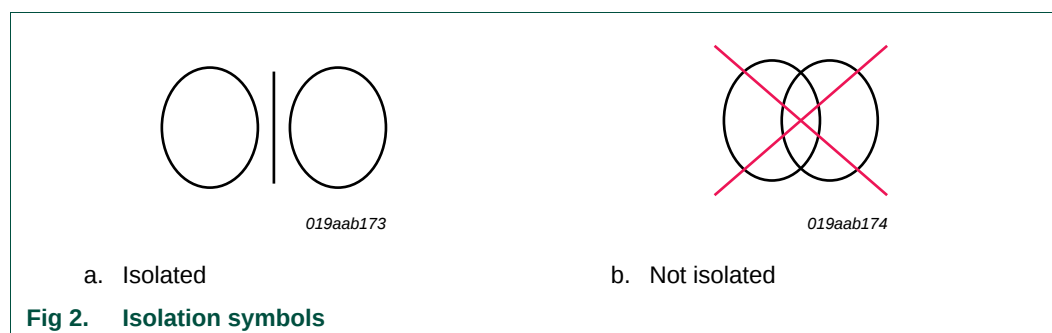
Fig 1. TEA1995T pinning configuration (SO8)

### 1.1 Features

- Adaptive gate drive for maximum efficiency at any load
- Supply current in no-load operation below 200  $\mu$ A
- Wide supply voltage range from 4.5 V to 38 V
- Dual synchronous rectification for LLC resonant in SO8 package
- Synchronous rectification for multi-output flyback converters
- Supports 5 V operation with logic level SR MOSFETs
- Differential inputs for sensing the drain and source voltages of each SR MOSFET
- SR control without minimum on-time
- Adaptive gate drive for fast turn-off at the end of conduction
- UnderVoltage LockOut (UVLO) with active gate pull-down

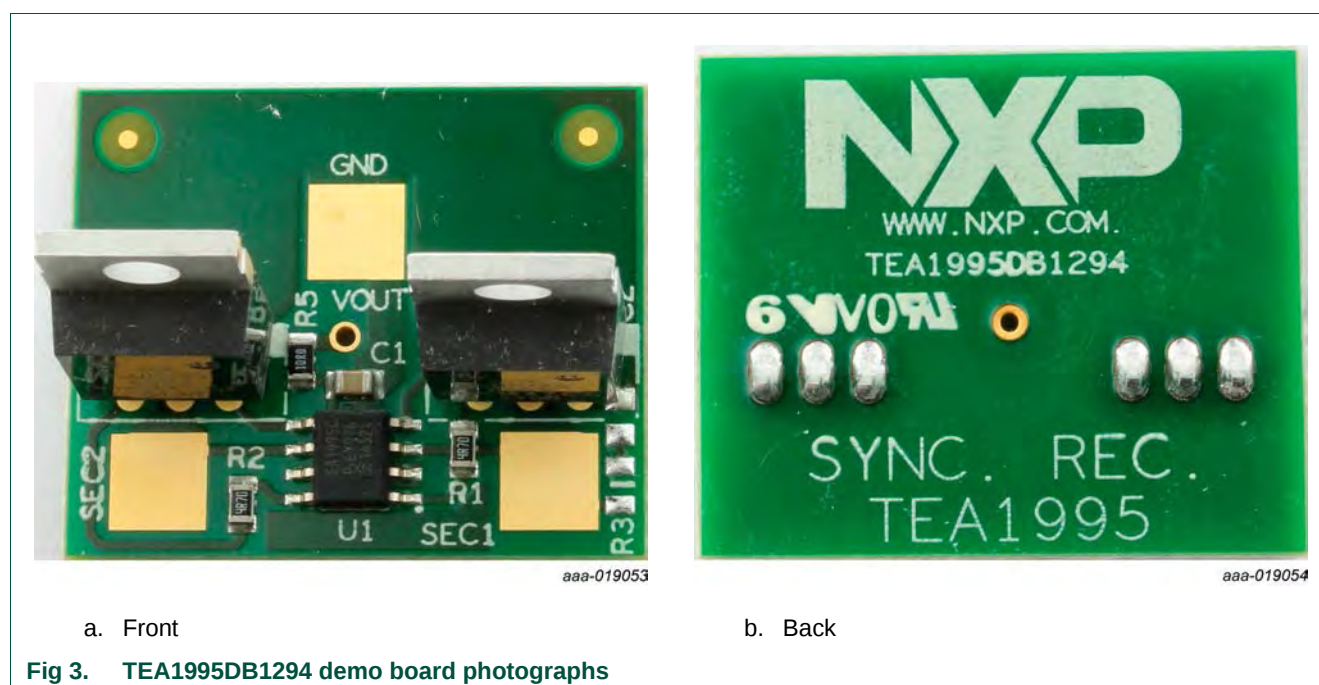
## 2. Safety warning

The board application is AC mains voltage powered. Avoid touching the board when power is applied. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Always provide galvanic isolation of the mains phase using a variable transformer. [Figure 2](#) shows the symbols that identify isolated and non-isolated devices.



## 3. TEA1995DB1294 photographs

The TEA1995DB1294 demo board consists of the TEA1995T in an SO8 package and two MOSFETs in a TO-220 package with a typical  $R_{DS(on)}$  of 3.0 mΩ. [Figure 3](#) shows the front side and back side of the demo board. The TEA1995DB1294 demo board is a single layer board, with plated-through vias for the  $V_{out}$  and MOSFET connections.



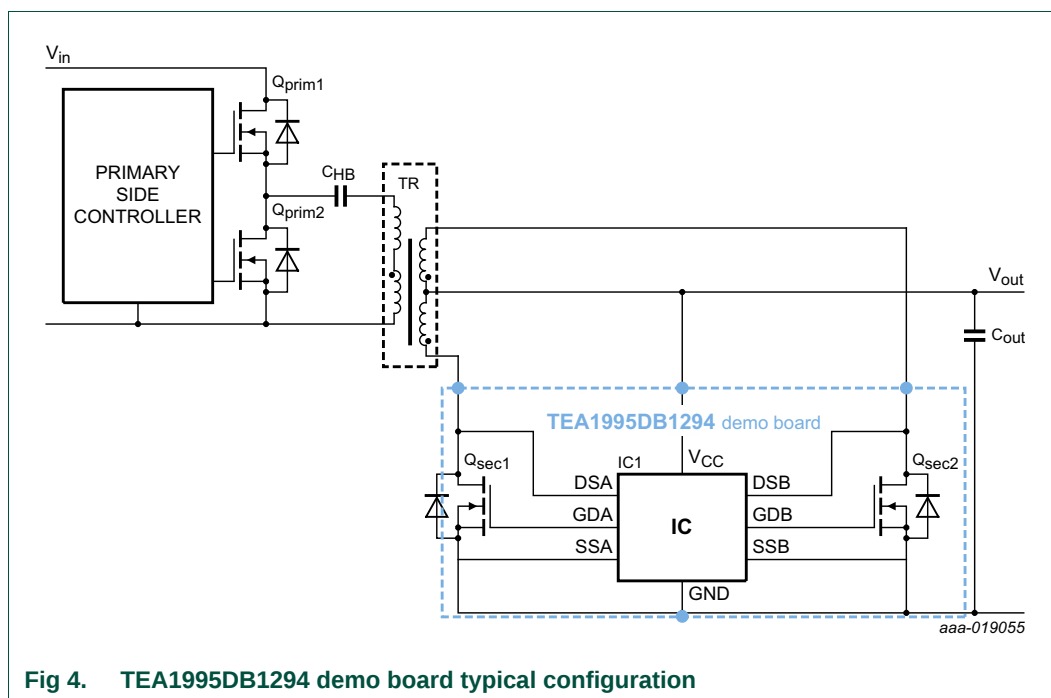
## 4. TEA1995DB1294 demo board setup

To ensure that the TEA1995DB1294 demo board can be used in various applications, two versions are available.

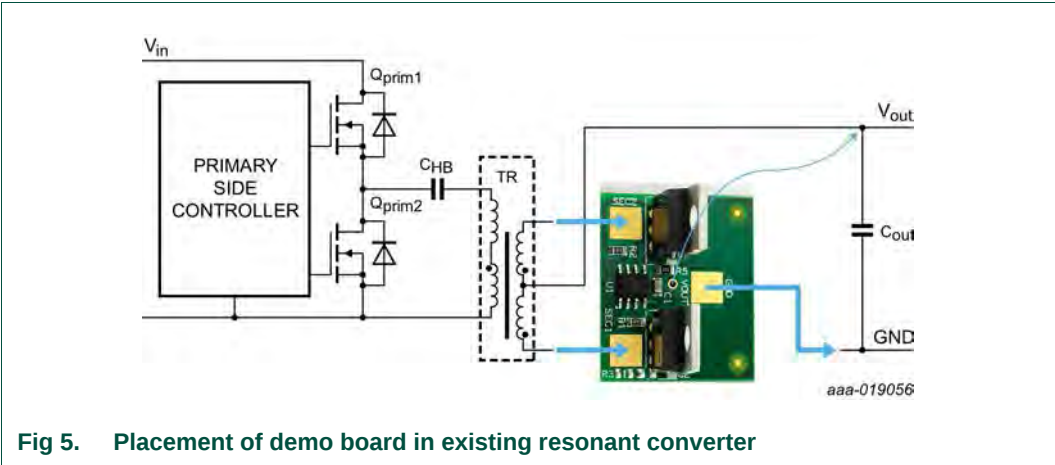
- The TEA1995DB1294 demo board contains two NXP Semiconductors power MOSFETs PSMN3R0-60PS (TO-220 package), intended for low output voltage (12 V) applications with relative high output currents.
- The TEA1995DB1295 demo board contains two NXP Semiconductors power MOSFETs (PSMN5R5-60PS; LPAK), intended for applications with a higher output voltage (19.5 V) and relatively lower output currents.

The demo boards can be incorporated into an existing resonant power supply.

[Figure 4](#) and [Figure 5](#) show the connection of the TEA1995DB1294 demo board to the secondary side of an LLC controller board. The demo board has 4 connections. Connect the 2 drain lines to the secondary outputs of the transformer. Connect the GND connection to the power ground of the main board. And connect the  $V_{CC}$  connection to the  $V_{out}$  terminal of the main board. Use thick wires for the drain and GND connections, as the currents in these tracks can be high. The  $V_{CC}$  can be connected to the  $V_{out}$  with a small wire. This wire is only required to supply the TEA1995T.



**Fig 4. TEA1995DB1294 demo board typical configuration**



## 5. Connecting the TEA1995DB1294 demo board

Figure 6 shows an example of the TEA1995DB1294 demo board used in a typical resonant adapter.



## 6. Operation

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### 6.1 Turn-on

The MOSFETs are turned on when the drain-source voltage drops to below the turn-on threshold ( $-400$  mV). The corresponding gate driver output turns on the external SR MOSFET. The gate of this MOSFET is rapidly charged to a level that exceeds its threshold level. After the turn-on phase, the regulation phase starts. There is no minimum on-time.

### 6.2 Regulation mode and turn-off

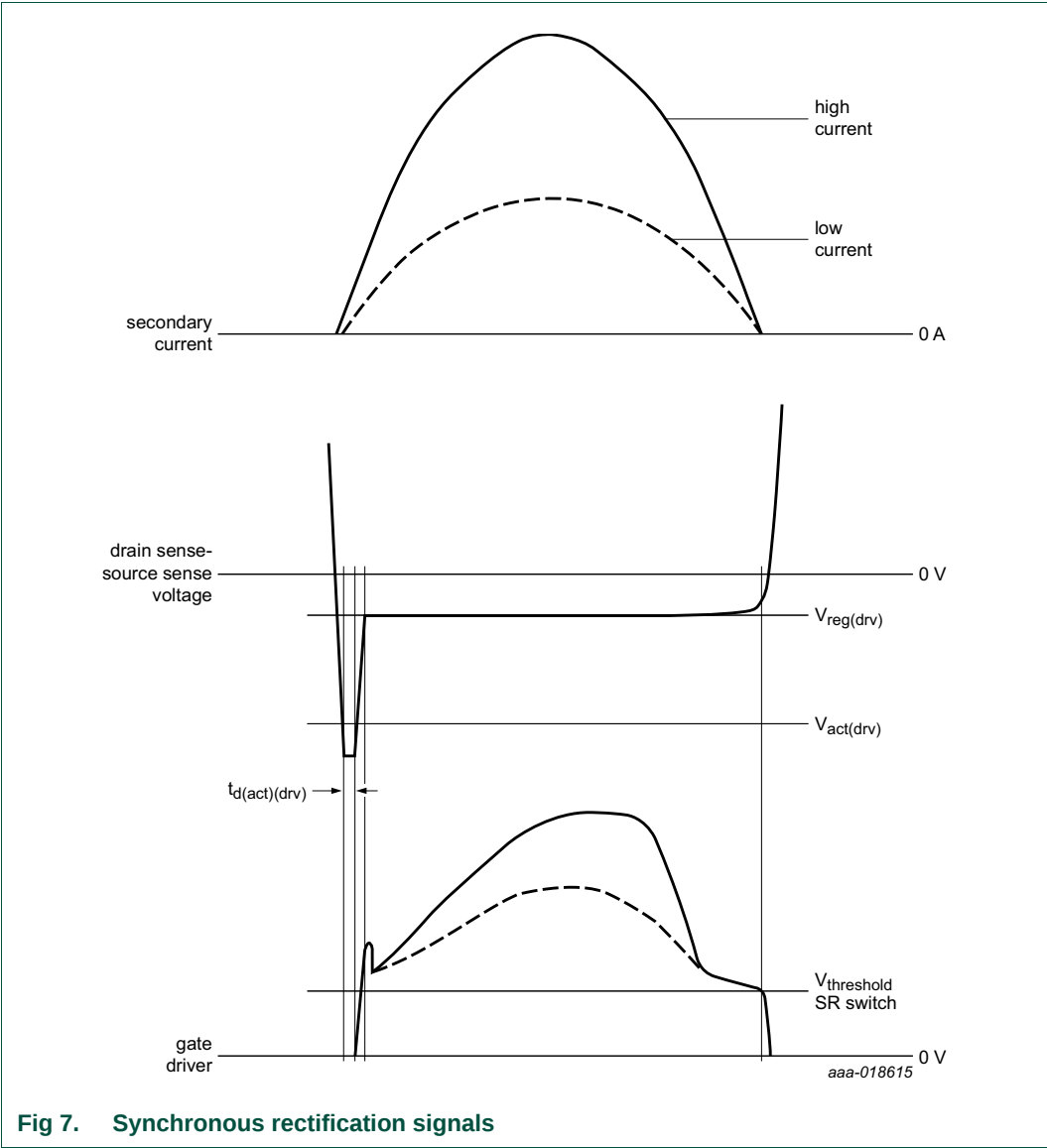
During regulation mode, the IC regulates the voltage difference between the drain and the source sense inputs to an absolute level of  $55$  mV. The corresponding gate driver output level is adjusted accordingly. In this mode, the gate driver voltage follows the waveform of the current through the external MOSFET. When the current drops to lower values, the corresponding gate driver output is discharged to a value just above the gate-source threshold level of the external MOSFET. The discharge enables a quick turn-off of the external MOSFET when the current reaches zero.

Especially at Continuous Conduction Mode (CCM) conditions, it is important to choose a MOSFET with a sufficiently low  $R_{DS(on)}$  value. It enables the discharge of the gate driver output to just above the gate-source threshold level of the external MOSFET. When the current drops to zero, this discharge makes a rapid switch-off possible. The rapid switch-off is very important for CCM conditions. It minimizes the reverse current and the related voltage overshoot on the drain terminal of the external MOSFET.

When the drain voltage exceeds  $150$  mV, the driver output voltage is actively pulled low.

6.3 Operational behavior

Figure 7 shows the corresponding SR waveforms.

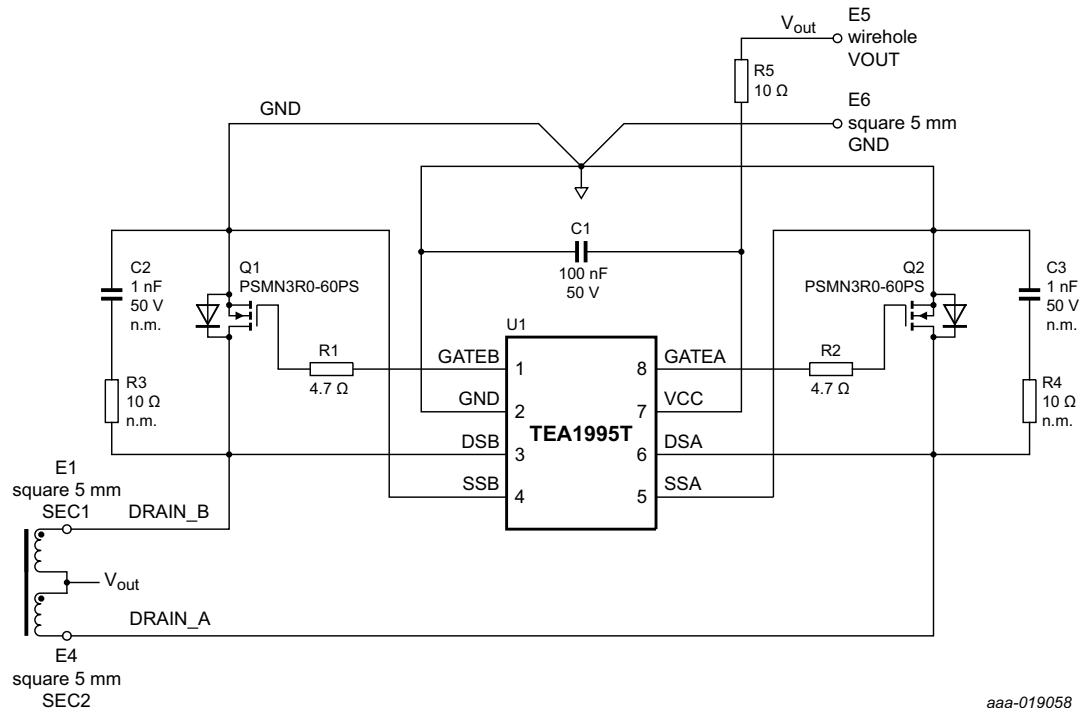


## 7. Schematic

[Figure 8](#) shows the schematic diagram of the TEA1995DB1294 demo board. Basically, the board consists of the TEA1995T SR and two SR MOSFETs. The TEA1995T acts as a dual controlled amplifier. For each side, the input is the voltage difference between drain and source. The corresponding gate driver signal is the output.

Resistors R1 and R2 are added to ensure easy layout design for a single-sided board. The resistor values must be in the range of  $0\ \Omega$  to  $10\ \Omega$ . Use the lowest value for the fastest turn-off time. Capacitor C1 is a decoupling capacitor for the  $V_{CC}$  of the TEA1995T. Connect it close to the IC. In combination with resistor R5, it acts as a simple RC filter.

Provisions are made for snubbers resistor R3/capacitor C2 and resistor R4/capacitor C3. The components are not mounted. However, if high-voltage spikes are present on the drain-source connections of the MOSFETs, they can be added.



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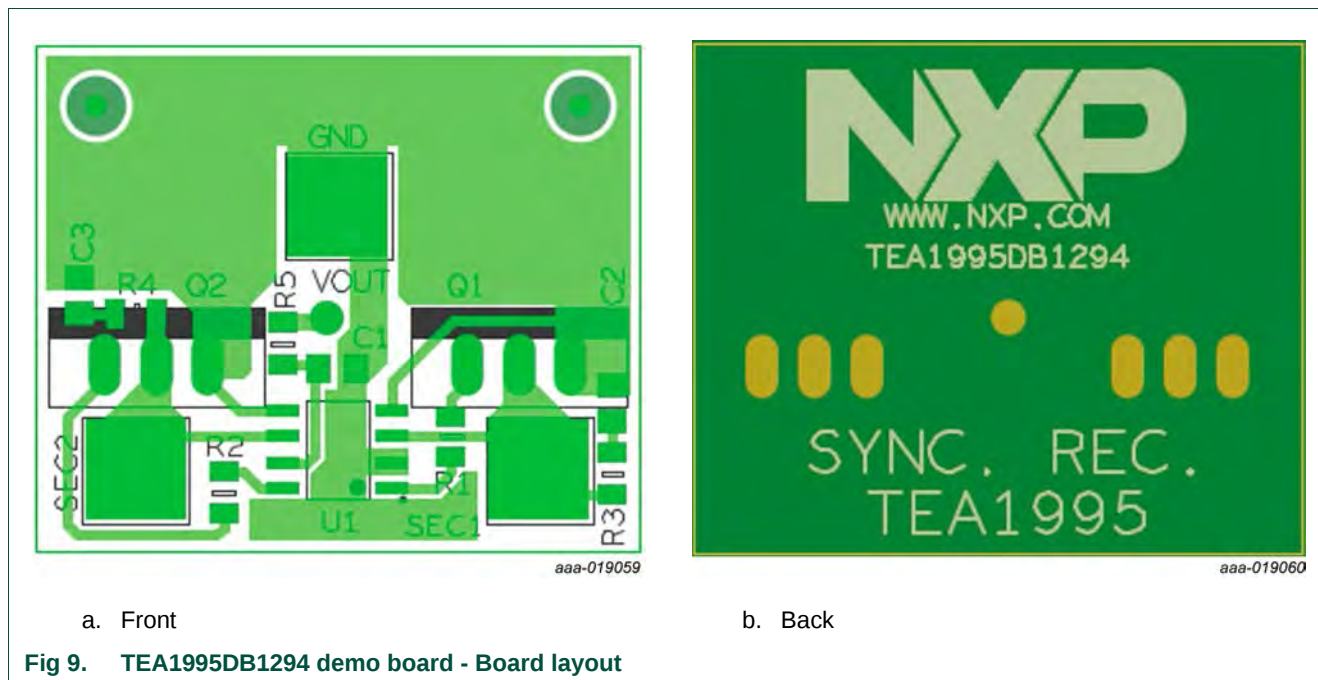
**Fig 8. TEA1995DB1294 demo board schematic**

## 8. Bill Of Materials (BOM)

Table 1. TEA1995DB1294 bill of materials

| Reference | Description and values                          | Part number  | Manufacturer       |
|-----------|-------------------------------------------------|--------------|--------------------|
| C1        | capacitor; 100 nF; 50 V; 0805                   | -            | -                  |
| C2        | capacitor; not mounted; 1 nF; 0805              | -            | -                  |
| C3        | capacitor; not mounted; 1 nF; 0805              | -            | -                  |
| Q1; Q2    | MOSFET; $R_{on} = 3.0 \text{ m}\Omega$ ; TO-220 | PSMN3R0-60PS | NXP Semiconductors |
| R1        | resistor; 4.7 $\Omega$ ; 0805                   | -            | -                  |
| R2        | resistor; 4.7 $\Omega$ ; 0805                   | -            | -                  |
| R3        | resistor; 10 $\Omega$ ; 0805                    | -            | -                  |
| R4        | resistor; not mounted; 10 $\Omega$ ; 0805       | -            | -                  |
| R5        | resistor; not mounted; 10 $\Omega$ ; 0805       | -            | -                  |
| U1        | IC; TEA1995T; SO8                               | -            | NXP Semiconductors |

## 9. TEA1995DB1294 board layout



Some important guidelines for a good layout:

- Keep the trace from the DSA/B pin to the MOSFET drain pin as short as possible.
- Keep the trace from the SSA/B pin to MOSFET source pin as short as possible.
- Keep the area of the loop from the DSA/B pin to MOSFET drain to MOSFET source to the SSA/B pin as small as possible. Make sure that this loop overlaps the power drain track or power source track as minimal as possible and the 2 loops do not cross each other.
- Keep tracks from GD pins to gate of MOSFETs as short as possible.
- Decouple pins  $V_{CC}$  and GND as close to the IC as possible with a small (100 nF) capacitor.
- Use separate clean tracks for the  $V_{CC}$  pin and GND. If possible, use a small ground plane underneath the IC, which is good for heat dispersion.
- Keep the ground and source sense tracks separated. Use separate tracks for each source sense connection and connect the IC ground to the ground plane on the PCB.

## 10. NXP Semiconductors Power MOSFETs

[Table 2](#) gives a selection of NXP Semiconductors MOSFETs that are suited to be used for SR applications. The complete Power MOSFET selection guide can be found at: [www.nxp.com/products/mosfets](http://www.nxp.com/products/mosfets).

**Table 2.** Extract from NXP Semiconductors Power MOSFETs Selection Guide

| Type number   | Package name | $V_{DS(max)}$<br>(V) | $R_{DS(on)(max)}$ at<br>$V_{GS} = 10\text{ V}$<br>(m $\Omega$ ) | $I_{D(max)}$<br>(A) | $Q_{GD}$ (typical)<br>(nC) | $Q_{G(tot)}$<br>(typical)<br>(nC) |
|---------------|--------------|----------------------|-----------------------------------------------------------------|---------------------|----------------------------|-----------------------------------|
| PSMN1R0-40YLD | LFPAK56      | 40                   | 1.1                                                             | 100                 | 17                         | 59                                |
| PSMN1R4-40YLD | LFPAK56      | 40                   | 1.4                                                             | 100                 | 13                         | 45                                |
| PSMN1R5-40ES  | I2PAK        | 40                   | 1.6                                                             | 120                 | 32                         | 136                               |
| PSMN1R5-40PS  | TO-220AB     | 40                   | 1.6                                                             | 150                 | 32                         | 136                               |
| PSMN1R6-40YLC | LFPAK56      | 40                   | 1.55                                                            | 100                 | 15.3                       | 59                                |
| PSMN1R8-40YLC | LFPAK56      | 40                   | 1.8                                                             | 100                 | 10.9                       | 45                                |
| PSMN1R9-40PL  | TO-220AB     | 40                   | 1.7                                                             | 150                 | 40.9                       | 230                               |
| PSMN2R1-40PL  | TO-220AB     | 40                   | 2.2                                                             | 150                 | 29.6                       | 168.9                             |
| PSMN2R2-40PS  | TO-220AB     | 40                   | 2.1                                                             | 100                 | 25                         | 110                               |
| PSMN2R6-40YS  | LFPAK56      | 40                   | 2.8                                                             | 100                 | 14                         | 63                                |
| PSMN2R8-40PS  | TO-220AB     | 40                   | 2.8                                                             | 100                 | 17                         | 71                                |
| PSMN3R3-40YS  | LFPAK56      | 40                   | 3.3                                                             | 100                 | 11.2                       | 49                                |
| PSMN4R0-40YS  | LFPAK56      | 40                   | 4.2                                                             | 100                 | 7                          | 38                                |
| PSMN4R5-40PS  | TO-220AB     | 40                   | 4.6                                                             | 100                 | 8.8                        | 35                                |
| PSMN5R8-40YS  | LFPAK56      | 40                   | 5.7                                                             | 90                  | 7.8                        | 28.8                              |
| PSMN8R0-40PS  | TO-220AB     | 40                   | 7.6                                                             | 77                  | 3.8                        | 17                                |
| PSMN8R3-40YS  | LFPAK56      | 40                   | 8.6                                                             | 70                  | 4.5                        | 20                                |
| PSMN2R0-60ES  | I2PAK        | 60                   | 2.2                                                             | 120                 | 32                         | 137                               |
| PSMN2R0-60PS  | TO-220AB     | 60                   | 2.2                                                             | 120                 | 32                         | 137                               |
| PSMN2R5-60PL  | TO-220AB     | 60                   | 2.6                                                             | 150                 | 41.2                       | 223                               |
| PSMN2R6-60PS  | TO-220AB     | 60                   | 2.6                                                             | 150                 | 43.7                       | 140                               |
| PSMN3R0-60ES  | I2PAK        | 60                   | 3                                                               | 100                 | 28                         | 130                               |
| PSMN3R0-60PS  | TO-220AB     | 60                   | 3                                                               | 100                 | 28                         | 130                               |
| PSMN3R3-60PL  | TO-220AB     | 60                   | 3.4                                                             | 130                 | 31                         | 175                               |
| PSMN3R9-60PS  | TO-220AB     | 60                   | 3.9                                                             | 130                 | 33                         | 103                               |
| PSMN4R2-60PL  | TO-220AB     | 60                   | 3.9                                                             | 130                 | 27                         | 151                               |
| PSMN4R6-60PS  | TO-220AB     | 60                   | 4.6                                                             | 100                 | 14.8                       | 70.8                              |
| PSMN5R5-60YS  | LFPAK56      | 60                   | 5.2                                                             | 100                 | 11.2                       | 56                                |
| PSMN7R0-60YS  | LFPAK56      | 60                   | 6.4                                                             | 89                  | 9.6                        | 45                                |
| PSMN7R6-60PS  | TO-220AB     | 60                   | 7.8                                                             | 92                  | 10.6                       | 38.7                              |
| PSMN8R5-60YS  | LFPAK56      | 60                   | 8                                                               | 76                  | 7.7                        | 39                                |
| PSMN3R3-80ES  | I2PAK        | 80                   | 3.3                                                             | 120                 | 27                         | 139                               |
| PSMN3R3-80PS  | TO-220AB     | 80                   | 3.3                                                             | 120                 | 27                         | 139                               |
| PSMN3R5-80ES  | I2PAK        | 80                   | 3.5                                                             | 120                 | 27                         | 139                               |

Table 2. Extract from NXP Semiconductors Power MOSFETs Selection Guide

| Type number   | Package name | $V_{DS(max)}$<br>(V) | $R_{DS(on)(max)}$ at<br>$V_{GS} = 10\text{ V}$<br>(m $\Omega$ ) | $I_{D(max)}$<br>(A) | $Q_{GD}$ (typical)<br>(nC) | $Q_{G(tot)}$<br>(typical)<br>(nC) |
|---------------|--------------|----------------------|-----------------------------------------------------------------|---------------------|----------------------------|-----------------------------------|
| PSMN3R5-80PS  | TO-220AB     | 80                   | 3.5                                                             | 120                 | 27                         | 139                               |
| PSMN4R3-80ES  | I2PAK        | 80                   | 4.3                                                             | 120                 | 28                         | 111                               |
| PSMN4R3-80PS  | TO-220AB     | 80                   | 4.3                                                             | 120                 | 28.4                       | 111                               |
| PSMN4R4-80PS  | TO-220AB     | 80                   | 4.1                                                             | 100                 | 25                         | 112                               |
| PSMN5R0-80PS  | TO-220AB     | 80                   | 4.7                                                             | 100                 | 21                         | 87                                |
| PSMN6R5-80PS  | TO-220AB     | 80                   | 6.9                                                             | 100                 | 16                         | 71                                |
| PSMN8R2-80YS  | LFPAK56      | 80                   | 8.5                                                             | 82                  | 12                         | 55                                |
| PSMN8R7-80PS  | TO-220AB     | 80                   | 8.7                                                             | 90                  | 11                         | 52                                |
| PSMN4R3-100ES | I2PAK        | 100                  | 4.3                                                             | 120                 | 49                         | 170                               |
| PSMN4R3-100PS | TO-220AB     | 100                  | 4.3                                                             | 120                 | 49                         | 170                               |
| PSMN5R0-100ES | I2PAK        | 100                  | 5                                                               | 120                 | 49                         | 170                               |
| PSMN5R0-100PS | TO-220AB     | 100                  | 5                                                               | 120                 | 49                         | 170                               |
| PSMN5R6-100PS | TO-220AB     | 100                  | 5.6                                                             | 100                 | 43                         | 141                               |
| PSMN7R0-100ES | I2PAK        | 100                  | 6.8                                                             | 100                 | 36                         | 125                               |
| PSMN7R0-100PS | TO-220AB     | 100                  | 6.8                                                             | 100                 | 36                         | 125                               |
| PSMN8R5-100ES | I2PAK        | 100                  | 8.5                                                             | 100                 | 33                         | 111                               |
| PSMN8R5-100PS | TO-220AB     | 100                  | 8.5                                                             | 100                 | 33                         | 111                               |
| PSMN6R3-120ES | I2PAK        | 120                  | 6.7                                                             | 70                  | 61.9                       | 207.1                             |
| PSMN6R3-120PS | TO-220AB     | 120                  | 6.7                                                             | 70                  | 61.9                       | 207.1                             |
| PSMN7R8-120ES | I2PAK        | 120                  | 7.9                                                             | 70                  | 50.5                       | 167                               |
| PSMN7R8-120PS | TO-220AB     | 120                  | 7.9                                                             | 70                  | 50.5                       | 167                               |

## 11. Abbreviations

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Table 3. Abbreviations

| Acronym | Description                                       |
|---------|---------------------------------------------------|
| CCM     | Continuous Conduction Mode                        |
| MOSFET  | Metal-Oxide Semiconductor Field-Effect Transistor |
| SR      | Synchronous Rectifier                             |
| UVLO    | UnderVoltage LockOut                              |

## 12. References

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- [1] TEA1995T data sheet — *GreenChip dual synchronous rectifier controller*

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