AN2112

# LLC Transformer design for EMI

## Overview

RediSem IC's based on our patented bipolar transistor drive technology are designed to be used with resonant converters such as the LLC converter. As the LLC converter is inherently quiet, it is easy to pass EMI without the need for large EMI components. This guide provides suggestions how design the transformer so that the LLC converter has minimal common mode EMI. The design guide is applicable for APFC, PPFC and no PFC converters.

### Transformer Structure

The recommended transformer design is shown in the figures below. A screen layer is added between primary winding and secondary winding. The screen winding should be correctly connected to a quiet point of the primary circuit. This arrangement can cancel out most of the common mode noise, minimising conducted RF emissions.

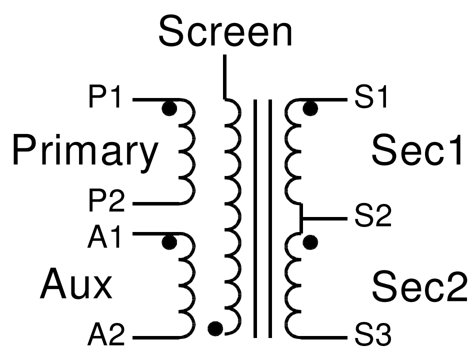


*Figure 1: Transformer Schematic*

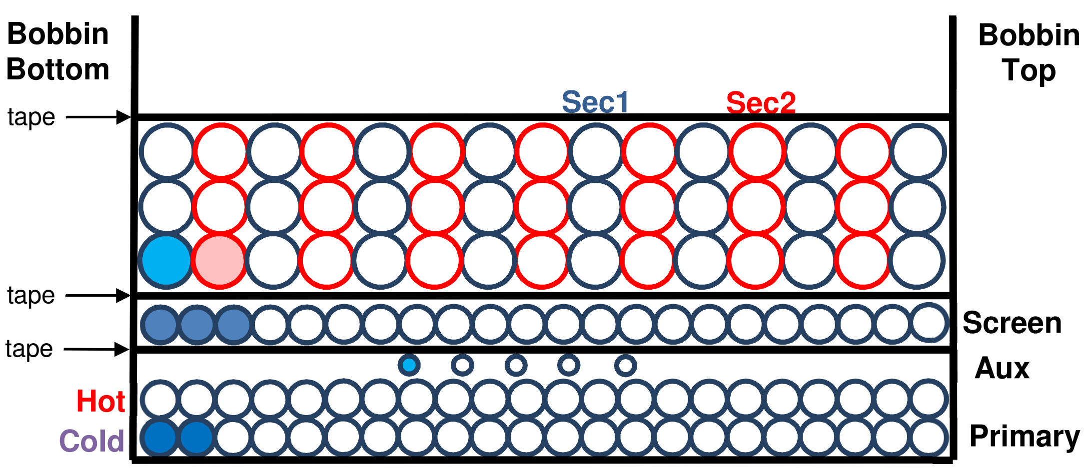


*Figure 2: Transformer Winding Arrangement (Vertical Bobbin)*

## Screen Winding

The starting point for design of the screen winding is given by the following formula:

$$N_{SCREEN} = \frac{4 \times N_{SEC}}{L_{SEC} \times M_{SEC}} = \text{ no of screen turns}$$

Where

$N_{SEC}$ = no of secondary turns
$L_{SEC}$ = total no of secondary layers
$M_{SEC}$ = no of secondary windings [1 or 2]

**Example**

For the 40W LED Driver example:

Application requirements:

$N_{SEC}$ = 19 turns
$L_{SEC}$ = 4 layers
$M_{SEC}$ = 2 secondary windings

$$N_{SCREEN} = \frac{4 \times 19}{4 \times 2} = 9.5 \text{ turns}$$

So, choose $N_{SCREEN} = 10$ turns

The screen should be wound as flat as possible, covering the whole winding window. Be careful with the winding direction of the screen. Use flat multi-filar (untwisted) wire to avoid introducing too much leakage inductance into the transformer.

### Optimising the Screen Winding

The procedure for optimising the screen winding is essentially an iterative trial and error method. Starting with the transformer screen calculated above, make small adjustments to the screen while measuring the RF emissions, concentrating on the frequency range of 300k~5MHz:

1. Measure the capacitance between the screen winding and both secondary windings using an LCR meter at 10kHz and call this value $C_{SCREEN}$.
2. Measure the peak of the conducted RF emissions.
3. Find a capacitor with value ≅ $C_{SCREEN}/4$ , you may use 2pF(five 10pF in series) and connect this temporarily between the transformer pins of SCREEN and secondary S2. Measure the peak of the conducted RF emissions again.
4. If the capacitor added across SCREEN to S2 can decrease the peak of the conducted RF emissions, then you should increase $N_{SCREEN}$. If the capacitor increases the peak of the conducted RF emissions, then you should decrease $N_{SCREEN}$.
5. Having decided the best position, try a few different capacitors to find the optimal value and call this $C_{NULL}$.
6. Calculate the changes in the number of screen turns required from this equation:
   $N_{SCREEN(NEW)} = N_{SCREEN(OLD)} \times (1 \pm \frac{C_{NULL}}{C_{SCREEN}})$
7. Repeat steps 2 through 7 until the screen winding is optimised. This can take two or three attempts to get it right.

### Horizontal and Vertical Transformer bobbin arrangement

The transformer winding arrangement in the previous sections has assumed a vertical bobbin structure, such as an RM or PQ type.  If a horizontal bobbin arrangement is to be used, such as an EF or EFD, then a different winding structure is recommended that is easier to manufacture and still gives excellent EMI results.

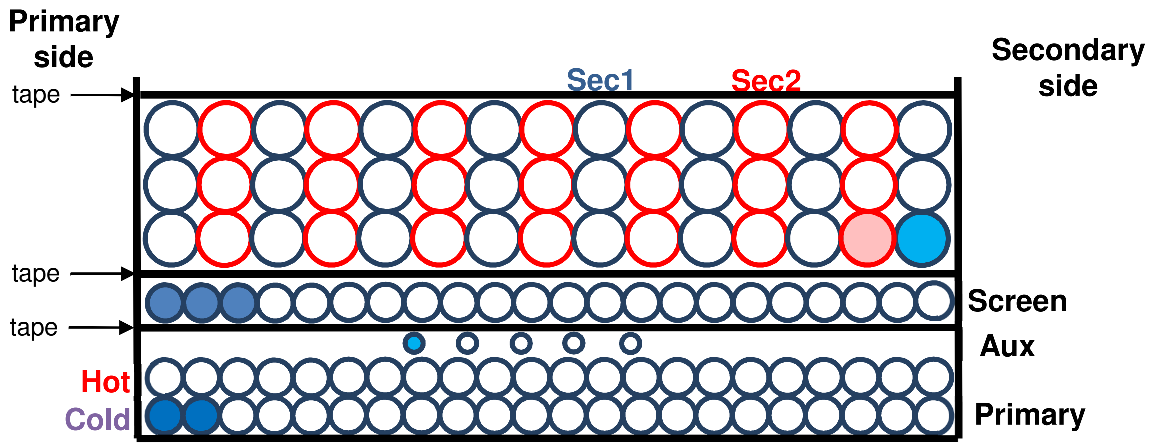


*Figure 3: Transformer Winding Arrangement (Horizontal Bobbin)*

**Transformer construction without a screen**

It is not difficult to minimise EMI, even when a screen is not used. Selecting the correct order of windings can easily reduce EMI by 20dB. The principle is to try and match the primary and secondary windings voltages as much as possible so there no voltage across the coupling capacitance. Follow some principles when constructing the transformer:

- Keep the noisy end of the primary winding away from the secondary winding
- Start with the noisy end of the primary winding
- If you are not sure which is the noisy end, swap the winding start and finish around and re-test the EMI
- It is often better to have 2 (or more) primary wires in parallel so that they match the TEX-E secondary better

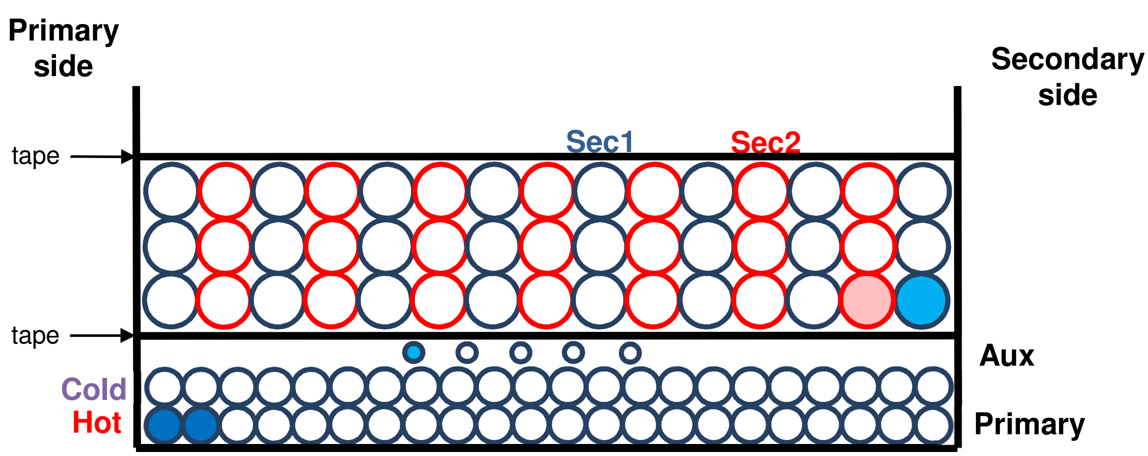


*Figure 4: Transformer Winding Arrangement without a screen*

# About RediSem

RediSem designs and supplies semiconductor ICs for energy efficient power management applications. RediSem uniquely combines extensive experience in power electronics with in-depth knowledge of IC design and manufacturing and works with the world's top suppliers and customers. RediSem's unique patented IC and converter technologies deliver maximum efficiency and performance, while reducing overall bill of materials cost through the use of bipolar transistors.

RediSem's range of LED control ICs can be used with RediSem's patented single stage LED control solution to provide very high efficiencies with low EMI – all with a single IC. When combined, these features deliver a low cost, high performance LED driver solution.

RediSem's fluorescent driver controller ICs achieve the advanced performance of MOSFET drivers by using bipolar transistors at a fraction of the BOM cost. RediSem's range of SMPS (Switched Mode Power Supply) control ICs enables low-cost LLC converters with bipolar transistors that deliver very high efficiencies already meeting DoE Level VI regulations, have low standby power and have much lower EMI compared to flyback converters.

All RediSem ICs are supported by comprehensive turn-key application designs enabling rapid time to market. For further information please use our contact details below

# Contact Details

**RediSem Ltd.**
301-302 IC Development Centre
No 6 Science Park West Avenue
Hong Kong Science & Technology Park
Shatin, New Territories
Hong Kong

Tel. +852 2607 4141
Fax. +852 2607 4140
Email: info@redisem.com
Web: www.redisem.com

# Disclaimer