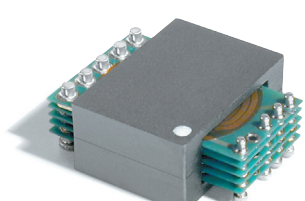
Planar Transformer Prototyping Kit

Designer's Kit C356



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Introduction

The Coilcraft Prototype Planar Transformer Kit is used by Coilcraft designers to provide fast turnaround of planar transformer samples. The kit allows the engineer to experiment with the number of turns, DCR, and the location of the windings within the assembly (interleaving). The pre-designed windings allow quick evaluations and designs that are ready-to-go for production. The prototype can be assembled, placed in the circuit and tested, with no tooling.

With this kit, you can design planar transformers for the following topologies and approximate power levels, based on 100 kHz switching frequency.

Full bridge and half bridge – 140 Watt
Push pull converter – 100 Watt
Forward converter – 50 Watt
Flyback – 25 Watt

The prototype transformers can have up to 12 primary turns and four secondary turns. Effective core area is 0.473 cm^2. Complete specifications for the core are listed on page 3. Primary to secondary isolation of the production parts is 1500 Vdc.

For engineers who prefer to build the planar magnetics and experiment, this kit is a very valuable tool. Each kit contains a sufficient number of parts to build as many as six prototypes. After a transformer design proves successful, the design can be submitted to Coilcraft. A sample transformer is built to be tested in circuit before a production run is started.

This document describes all the parts in the kit and provides information that covers assembling a prototype planar transformer or inductor. It does not offer information regarding design criteria. It is assumed that the engineer has a design concept and that the prototype will be used as a tool for testing.

A sample prototype is included, and may be used as a model. The core halves of the sample are held together with tape. Production planar magnetics manufactured by Coilcraft are permanently glued.

Kit Contents

The Prototype Planar Transformer Kit contains the following parts:

Core..... 12 halves
Primary Boards ..... 4 each of 4 types
Auxiliary Boards ..... 4 each of 6 types
Secondary Stamp 1 24
Secondary Stamp 2 12
Insulator Washers 35
Large Pins 35
Small Pins 35
3/8″ Tape (3M #1205)..... Approx. 50 cm
Super Glue ..... 1 tube
Metallic Marking Pen..... 1

One completed sample (48 V to 3.3 V / 30 A) built according to the assembly procedure on page 11.

Part Details

The completed prototype consists of a windings assembly and two core halves, as shown in Figure 1. The windings assembly is a combination of Primary Boards, Secondary Stamps, Insulator Washers, and if needed, an Auxiliary Board.

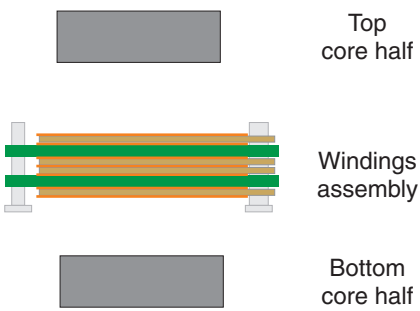


Figure 1. Major Components of a Planar Transformer

Each design requires a unique number of boards and stamps. The number and orientation of the boards and stamps are dependent on the turn counts and required DCR rating.

An insulator washer is used between each part of the windings assembly and between the windings assembly and each core half.

Core

This kit contains 12 core halves. Two pieces are needed for each prototype. The cores are not gapped. Specifications are as follows:

Effective area (A_e) = 0.473 cm^2; Minimum area (A_{min}) = 0.410 cm^2
Effective magnetic path length (l_e) = 2.64 cm
Effective volume (V_e) = 1.25 cm^3
A_L value for core set = 2500 $nH/turns^2$
Relative permeability = 1500 nom
Weight: 5.2 g per set (2 halves)
Flux density: Use the following as a guide when designing your prototype:
for <100 KHz, 2000 Gauss,
for 100 – 500 kHz, 1500 Gauss
for 500 kHz – 1 MHz, 750 Gauss

Primary Boards

The four different Primary Boards can be combined in series (for more turns) or in parallel (for lower DCR). The kit includes Primary Boards with 3 turns, 4 turns, 5 turns and 6 turns. The following primary turns are possible:

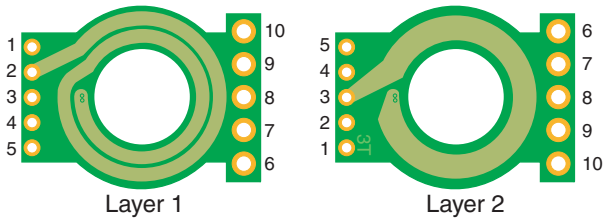
3 Turns
4 Turns
5 Turns
6 Turns
6 Turns (3 Turns + 3 Turns)
8 Turns (4 Turns + 4 Turns)
9 Turns (5 Turns + 4 Turns)
10 Turns (5 Turns + 5 Turns)
11 Turns (6 Turns + 5 Turns)
12 Turns (6 Turns + 6 Turns)

Using two 6 Turn Primary Boards in parallel results in half the DCR of using one 6 Turn Primary Board.

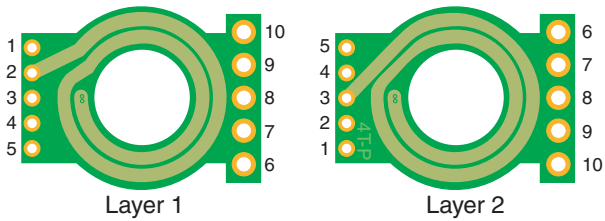
When using two Primary Boards in series, one board is inverted and the boards are connected together only at pin 3. Boards used in parallel are oriented the same way (the layers of each board face the same direction) and are connected together at pins 2 and 3 or at pins 3 and 4 when both are inverted.

Each Primary Board is marked with the number of turns on layer 2.

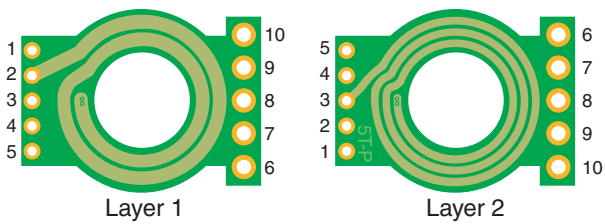
3 Turns Primary Board (equivalent to 24 AWG, typical DCR = 10 mΩ)



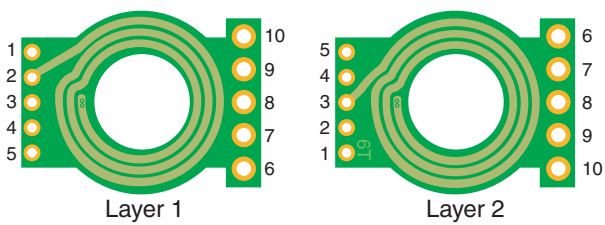
4 Turns Primary Board (equivalent to 25 AWG, typical DCR = 18 mΩ)



5 Turns Primary Board (equivalent to 26 AWG, typical DCR = 26 mΩ)



6 Turns Primary Board (equivalent to 27 AWG, typical DCR = 40 mΩ)

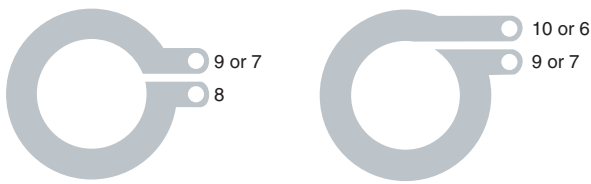


Secondary Stamps

Each Secondary Stamp is one turn. Stamps can be combined in series up to a total of four turns. The stamps can also be connected in parallel for lower DCR. Stamp 1 and Stamp 2 are identical electrically. Use the stamps that provide the pin connections suitable for your application.

When using two stamps in series, one stamp is inverted when building the windings assembly. Each stamp is the equivalent of 16.5 AWG.

Secondary Stamps (typical DCR = 0.9 mΩ)



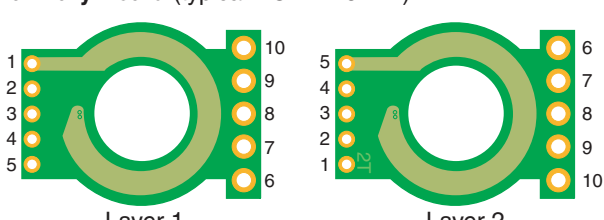
Auxiliary Boards

The Auxiliary Boards are suitable for most applications without the need to make combinations. The six auxiliary boards in the kit are:

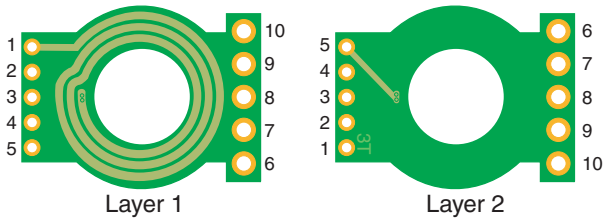
2 Turns
3 Turns
4 Turns
5 Turns
7 Turns
9 Turns

Each Auxiliary Board is marked with the number of turns on layer 2. The Auxiliary Board should be positioned at the top or bottom of the windings assembly.

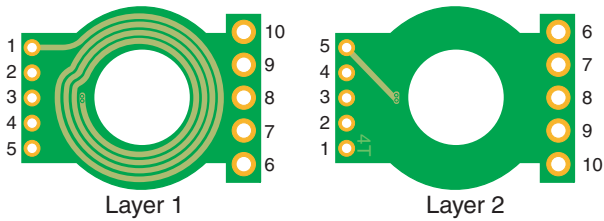
2 Turns Auxiliary Board (typical DCR = 16 mΩ)



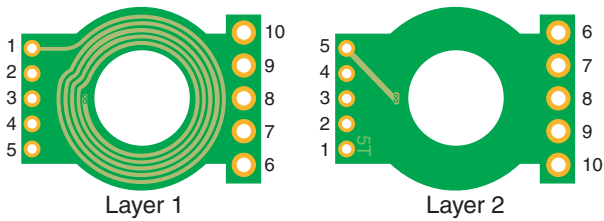
3 Turns Auxiliary Board (typical DCR = 85 mΩ)



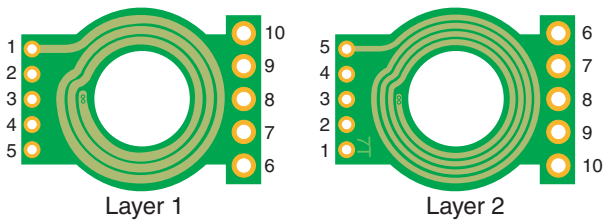
4 Turns Auxiliary Board (typical DCR = 82 mΩ)



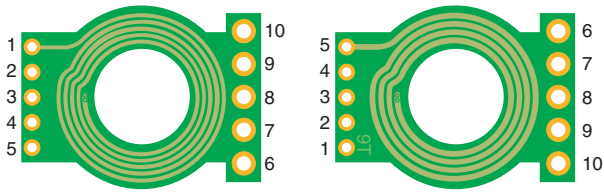
5 Turns Auxiliary Board (typical DCR = 140 mΩ)



7 Turns Auxiliary Board (typical DCR = 165 mΩ)



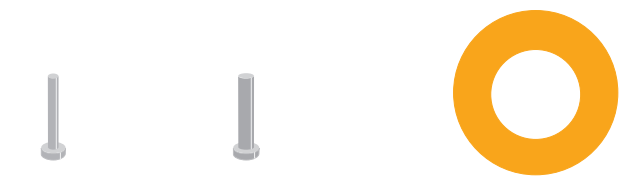
9 Turns Auxiliary Board (typical DCR = 250 mΩ)



Pins and Insulators

The pins are used to interconnect the boards and stamps and to surface mount the completed transformer to the PCB. An insulator must be used between each part of the windings assembly and between the windings assembly and each core half.

The Small Pins (0.038″ diameter) are used for pins 1–5 and connect all the primaries and auxiliary windings. The Large Pins (0.058″ diameter) are used for pins 6–10 and connect all the secondary stamps.



Designing the Prototype

General

There are many combinations of boards and stamps that may be used in a design. The total number of parts that can be used in a windings assembly is limited by the core size. The cores can accommodate a windings assembly up to 5 mm high, including top and bottom insulators. Maximum thickness of each part is as follows: Primary boards: 0.64 mm; Auxiliary boards: 0.32 mm; Stamps: 0.46 mm, Insulators: 0.05 mm. Some of the combinations of parts that fit in the core are:

4 Primary Boards, 1 Auxiliary Board and 2 Stamps
2 Primary Boards, 1 Auxiliary Board and 4 Stamps
1 Primary Board, 1 Auxiliary Board and 6 Stamps

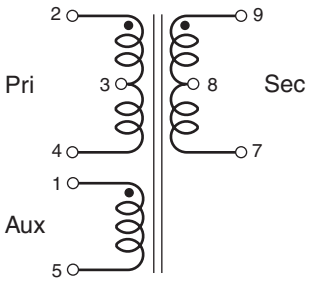
Familiarize yourself with each of the parts in the kit and determine the correct combination of parts needed to build your prototype. Before beginning the assembly take note of the pin connections for each layer of all the boards you plan to use.

Each Primary Board winding connects to pins 2 and 3. An inverted primary board connects to pins 4 and 3.

Secondary Stamp 1 connects to pins 7 and 8. An inverted Stamp 1 connects to pins 8 and 9. Secondary Stamp 2 connects to pins 9 and 10. An inverted Stamp 2 connects to pins 6 and 7.

Each Auxiliary Board connects to pins 1 and 5.

A typical schematic showing pin connections is shown in Figure 2. A typical dimensional drawing and recommended land pattern are shown in Figure 3.



Note: By using stamps as the primary and primary boards as the secondary, a step-up transformer, up to 1 : 12 turns ratio, can be created.

Figure 2. Typical Schematic

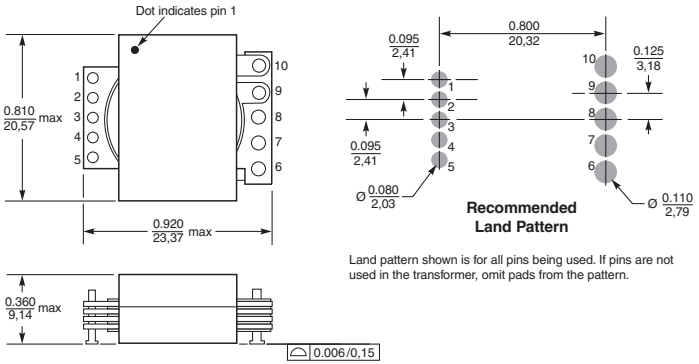


Figure 3. Typical Dimensional Drawing

Prototype Specifics

Determine how many Primary Boards and Secondary Stamps are needed to satisfy the number of turns in the design.

The number of turns for the primary winding can be determined by using the following equation:

$$N = \frac{V \times t \times 10^8}{A_e \times B}$$

where:

- N = number of turns
- V = Voltage
- t = time = (1 ÷ frequency) × duty cycle
- A_e = core area = 0.473 cm^2
- B = flux density (Gauss), see page 3 to determine flux density

The amount of current the prototype can handle depends on the number of stamps used in the secondary. Each stamp is the equivalent of 16.5 AWG.

Refer to the diagrams of the Primary Boards and Stamps and take note of the typical DCR rating of each. If the DCR requirement is met, the prototype can be built. If the DCR of the primary is higher than desired, double the number of Primary Boards and connect them in parallel. If the DCR of the secondary is higher than desired, double the number of stamps. Keep in mind the maximum number of parts that can fit in the core.

Primary turns _____ Required DCR _____

Secondary turns _____ Required DCR _____

Auxiliary turns _____

Current handling _____

Assembling the Prototype

Select all the parts needed to build the prototype, including an insulator washer to be used between each part of the prototype. The following points should be taken into account in order to assemble a prototype that will closely match the final production planar component.

- To minimize leakage inductance, make sure that the boards, stamps and insulators are sandwiched tightly together. The tighter all the parts are to each other, the lower the leakage inductance.

- Interleave parts as much as possible. Plan the placement of parts so that Primary Boards are separated by Stamps. In the sample transformer, each Primary Board is placed between two Stamps. The more interleaving that can be accomplished, the lower the leakage inductance.

The following precautions must be observed when building a prototype.

- An Insulator must be used between each part of the windings assembly and between the assembly and each half of the core. If an insulator is missing, the transformer will short.
- All parts in the windings assembly must be assembled so the center holes are concentric. If the pins securing the parts together are not perpendicular to all the boards and stamps, the winding assembly is skewed and an internal short can occur.
- The completed windings assembly must be glued to the bottom core half. If the assembly is allowed to float in the core, an internal short can occur.

Note: The winding assembly of the sample transformer is intentionally not glued to the core. This allows the winding assembly to be removed from the core to be studied.

Study the exploded view of the sample transformer and plan the order and orientation of parts used in the prototype. Lay out all the parts in the correct order and orientation. Review the assembly procedure for the sample transformer. Once you are comfortable with the procedure, assemble your prototype.

Sample Transformer

Description

The sample transformer has a 12-turn primary and a 2-turn secondary. The sample uses two stamps in parallel for each turn in order to lower DCR. It does not have an Auxiliary Board. Figure 4 shows a schematic and top view of the sample.

Note: The windings assembly of the sample transformer has not been glued to the core. Feel free to remove the tape securing the core halves and remove the windings assembly to inspect.

Primary turns	**12**	Required DCR	**60 mΩ**
Secondary Turns	**2**	Required DCR	**0.9 mΩ**
Secondary current	**30 A**		

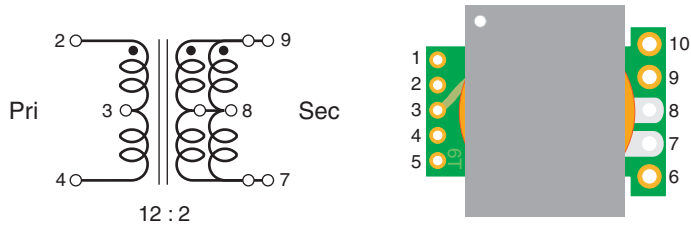


Figure 4. Sample Transformer

An exploded view of the sample transformer is show in Figure 5. The sample transformer provided with the kit consists of the following parts:

- Two 6 Turn Primary Boards in series.
- Four stamps — two stamps in parallel for each turn in series.
- Seven insulators.
- Six pins (3 large, 3 small).
- One Core set (2 halves).

Assembly Procedure

Refer to Figure 5 and use the following procedure to assemble the sample transformer.

1. Place one half of the Core on a clean working surface.

   Note: Make sure that the centers of all parts are concentric.

2. Glue an insulator into the core.
3. Orient a Stamp 1 so that the terminals extend out of the core as shown in the detail in Figure 5. Make sure the terminal holes will align with pins 7 and 8 of the Primary Board.
4. Place the stamp over the insulator.
5. Working from the bottom, insert two Large Pins (pins 7 and 8) into Stamp 1.

   Note: The bottom of the pins must be flush with the bottom of the core in order to surface mount the completed prototype.

6. Ensure the pins are positioned so they are flush with the bottom of the core and solder them to Stamp 1.
7. Place an insulator over the stamp.

8. Position a 6 Turns Primary Board so that Layer 1 faces up. Align terminals 7 and 8 with the pins inserted into Stamp 1. Slide the board down over the pins onto the insulator.
9. Working from the bottom, insert three Small Pins (pins 2 ,3 and 4) and one Large Pin (pin 9) into the board.

   Note: The bottom of the pins must be flush with the bottom of the core in order to surface mount the completed prototype.
10. Solder all pins to the board.
11. Place an insulator over the board.
12. Orient another Stamp 1 in the same direction as Stamp 1 installed in step 3. Slide the stamp down over pins 7 and 8 and onto the insulator over the board.
13. Solder the stamp to pins 7 and 8 to complete one turn of the secondary.
14. Place an insulator over the stamp.
15. Invert a Stamp 1 and slide it down over pins 8 and 9 and onto the insulator. Solder the stamp to pins 8 and 9.
16. Place an insulator over the stamp.
17. Position a 6 Turns Primary Board so that Layer 2 faces up. Align terminals 2, 3 and 4 with the small pins and terminals 7, 8 and 9 with the large pins. Slide the board down over the pins onto the insulator.
18. Solder the board to all six pins.
19. Place an insulator over the board.
20. Invert a Stamp 1 and slide it down over pins 8 and 9 and onto the insulator over the board.
21. Solder the stamp to pins 8 and 9 to complete the second turn of the secondary.
22. Glue the windings assembly to the insulator in the bottom half of the core.
23. Place an insulator over the top stamp. Glue the insulator to the windings assembly.
24. Align the top core half with the bottom core half making sure that the cores are oriented in the same direction. Secure the core halves with about 8 cm of tape.
25. Use the supplied marking pen and place a dot in the corner of the top core to indicate pin 1.

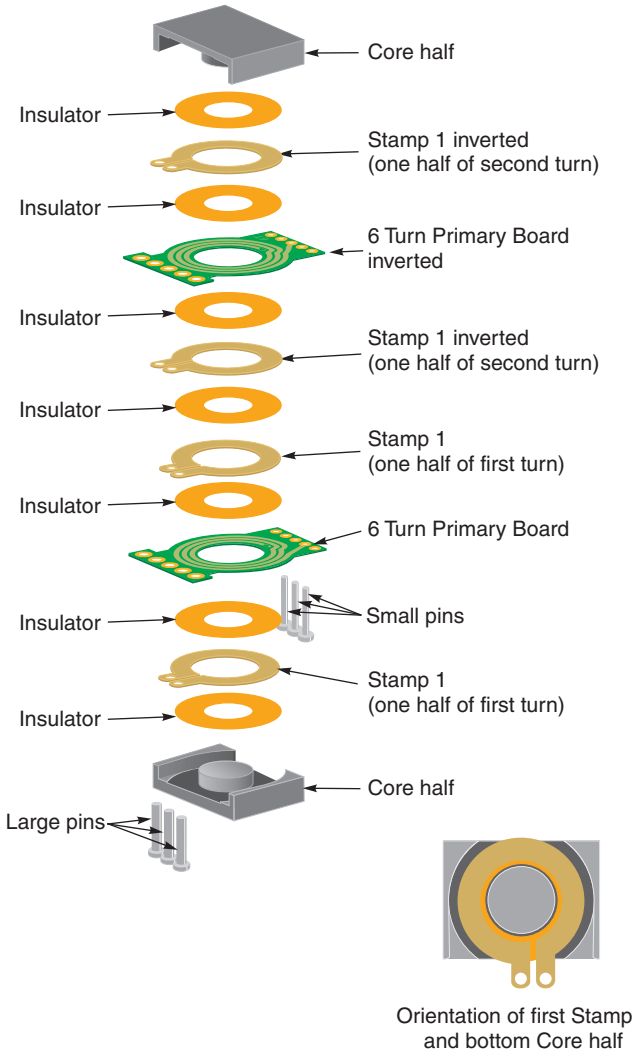


Figure 5. Exploded view of the Sample Transformer

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