

Building Concentric Coplaner coils

This document is intended to demonstrate one method of constructing Concentric Coplaner coils. While it is targeted toward the home hobby builder it is not as simple as the more popular DD coil configuration.

The Concentric coil configuration does however offer some advantages over the DD coil. Some of these advantages include cost of construction, lighter weight, easier pinpointing, greater detection distance for a given diameter, better discrimination and iron rejection.

Even though constructing the Concentric coil can be a little tricky, it will be demonstrated that it can be done successfully! In this example we will be building a coil to match a Tesoro coil for the popular TGSL project. While the specifications for a Tesoro coil are presented here, similar construction methods can be used for a multitude of coils.

To begin with, let us take look at our desired specifications for a TGLS coil:

Wire size: .25mm (30 AWG) enameled

Tx inductance: 6.0mH

Tx resistance: 18 - 25 Ohms

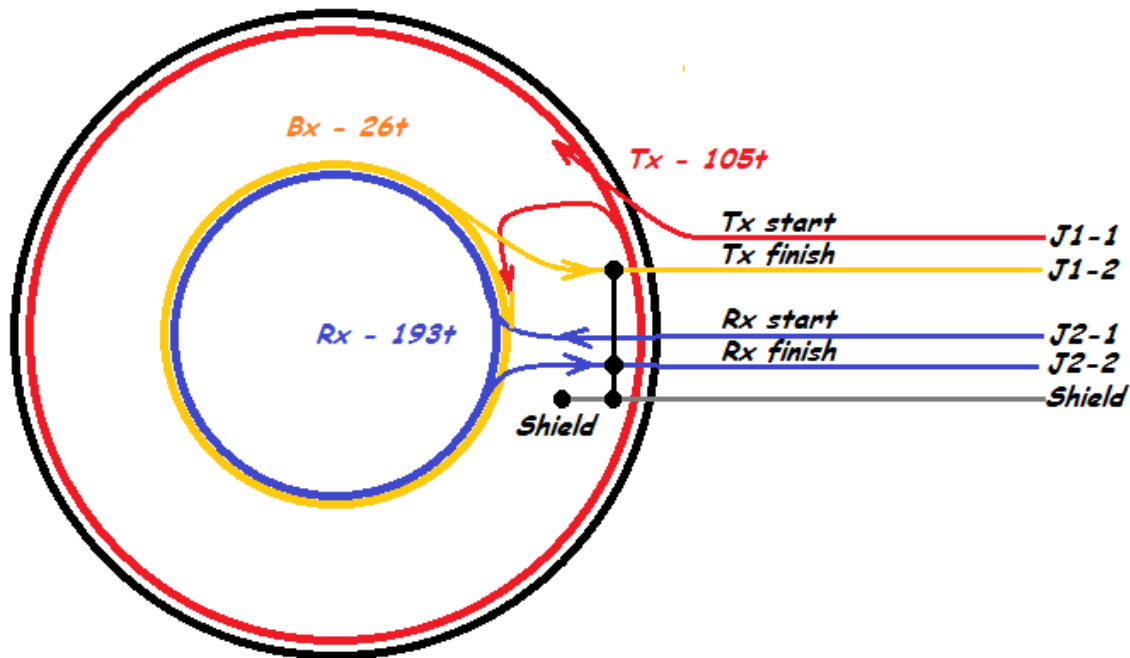
Tx resonance - About 14.5 kHz

Rx Inductance: 6.5mH

Rx resistance 18 - 25 Ohms

Rx resonance with 15nF - About 16.1 kHz

Now, let's take a look at the basic schematic of how we want to lay out our coil.



The important thing to note is winding direction and what end of the Tx coil is "hot" as this will affect coil nulling. The grounded end of our Tx coil must be closest to the Rx coil. Also note that the Tx and Rx coils are wound in the same direction, but the bucking coil (Bx) is wound opposite of the other coils. The Bx coil will be used to cancel the primary transmit field closest to the Rx coil. This is the way that we achieve "induction balance".

Figuring out Rx and Tx inductances are relatively easy, but the Bx coil wound in the opposite direction on top of the Rx coil will interact with the primary Tx coil inductance to some degree. This has the effect of subtracting overall inductance of the Tx coil. As it turns out, 26 turns wound in the opposite direction will subtract about .17mH from the primary Tx coil. Adding about 1 extra turn to the primary Tx coil will straighten out the inductance again.

So.. how many turns for the Bx coil do we need to cancel the magnetic field (seen by the Rx coil) from the primary Tx coil? It's a relationship of the area enclosed by the coils. For an Rx coil $\frac{1}{2}$ the diameter of the Tx coil, it will be a 4:1 ratio. So, 105 turns for the primary divided by 4 is 26.25! In practice, this result comes out fairly close.

So, for the coil size presented there, the *calculations* are already done for you.

Tx coil = 105 turns counter clockwise on a 95mm diameter form.

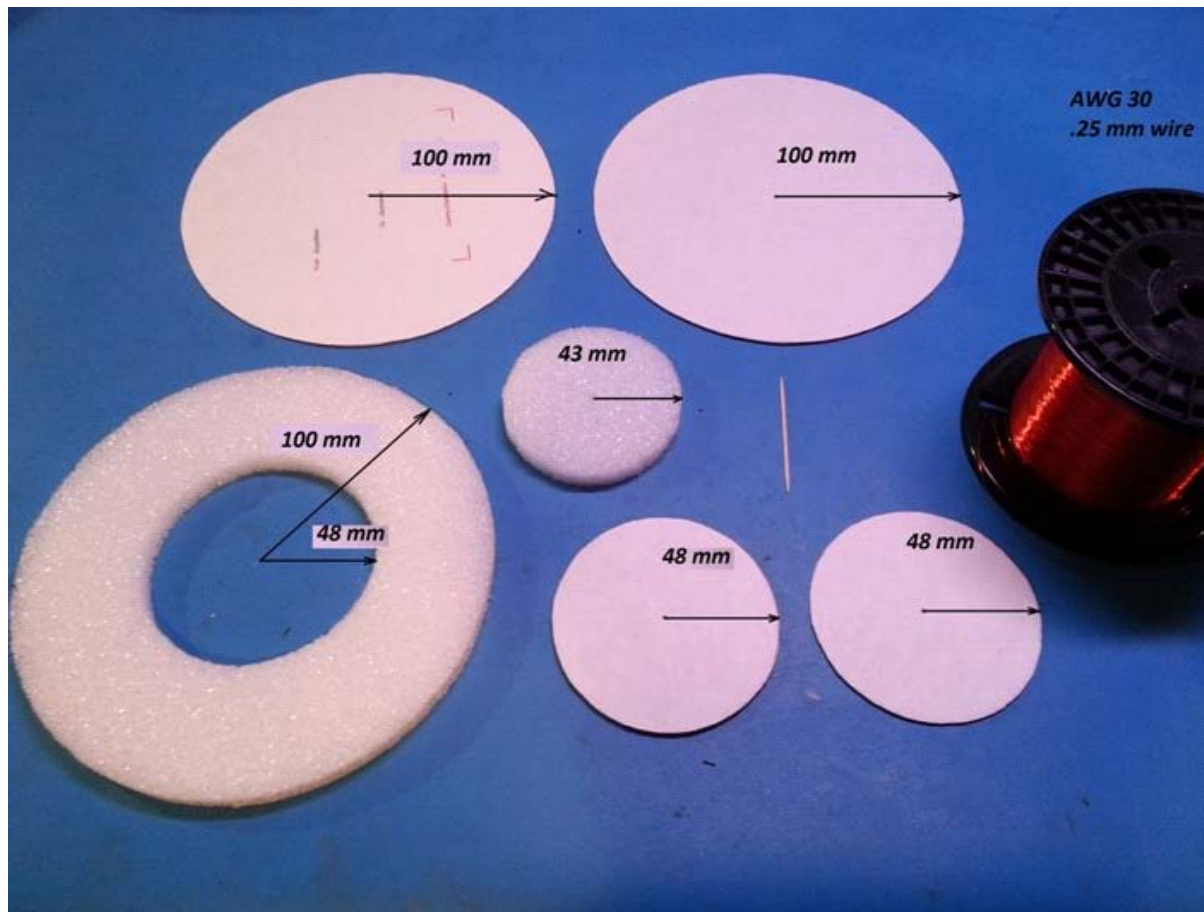
Rx coil = 193 turns counter clockwise on a 43mm diameter form.

Bx coil = 26 turns (about) clockwise directly on top of the Rx coil.

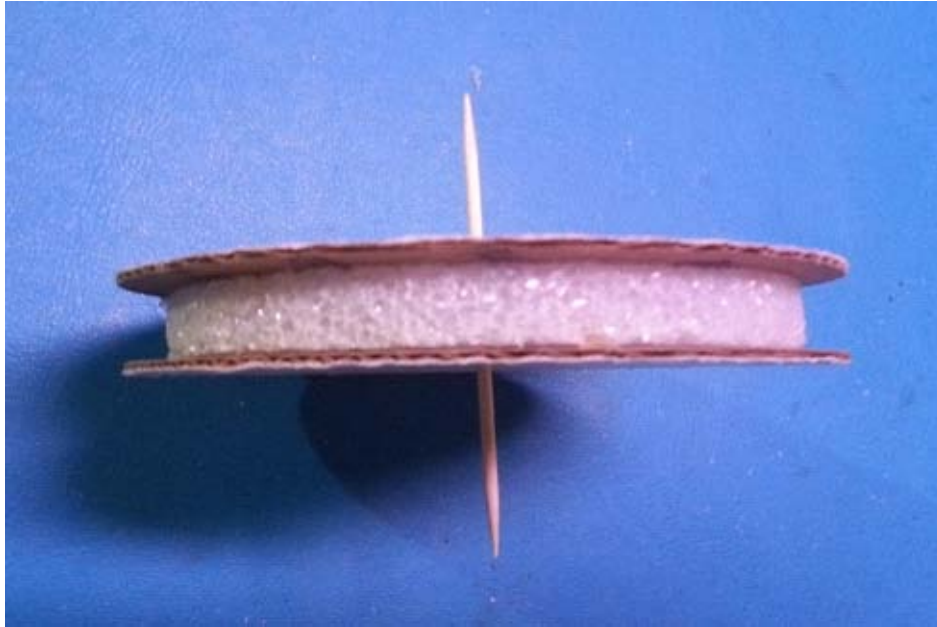
Materials list:

- Foam board - 1\2" (11mm) thick, 12" X 12". I used "large cell" foam that is relatively stiff and brittle from a craft store.
- Cardboard - anything thin and stiff.
- .25mm (30 AWG) wire - about 450 ft.
- USB-2 cable.
- Cable strain relief.
- Cyan glue.
- White glue.
- Black silicone sealer.
- Epoxy.
- 8" coil shells.
- Graphite spray.

Now, we will follow the diagram below to cut our materials:



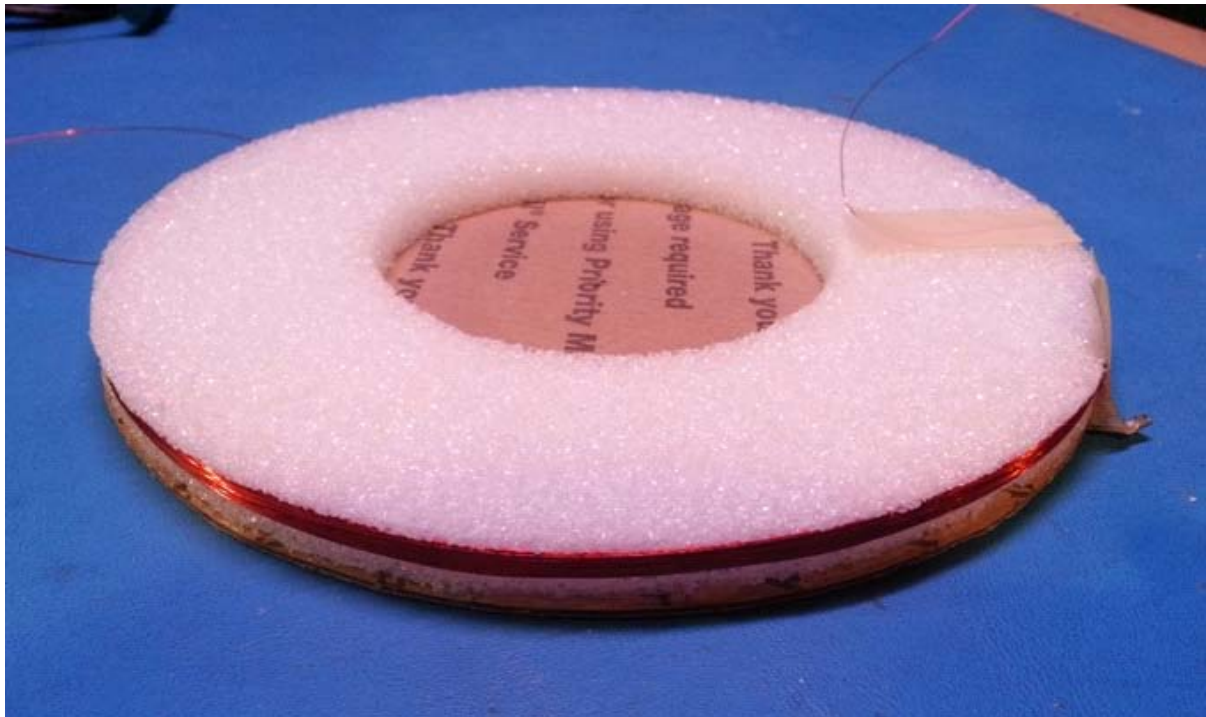
Shown below, we will assemble a spool for our Rx coil using a 43mm foam disk and two 48mm cardboard circles. Note: I sanded about 6mm off of the total thickness of the 43mm foam disk. This is so everything will fit together "flush" to the thickness of the 100mm disk. It will be apparent why we do this when we sandwich everything together later on.



Tooth picks can be helpful keeping everything centered while the spool is glued together. Use white glue as Cyan glue can dissolve foam.



We will want to cut a small groove to accept our Tx winding on the 100mm form. To do this, you can use a hot soldering iron. You can cut the groove about 2.5 mm deep so that the final diameter of the Tx coil is about 95mm. Then, wind 105 turns of wire on the form counter clockwise. We can then test the running frequency by connecting it to the Tx circuit of the TGSL. It should run at 14.5kHz or just a bit lower. Later on when we add the bucking coil, the frequency will increase slightly.



We will then wind 195 turns counter clockwise on the 43mm spool to create our Rx winding. Be sure to mark the beginning and end of the Rx windings.

At this point, it's a good idea to verify our Rx coil inductance. We will target 6.5mH. One very easy method of doing this is to temporarily connect the Rx coil to the Tx circuit of the TGSL and measuring the running frequency.

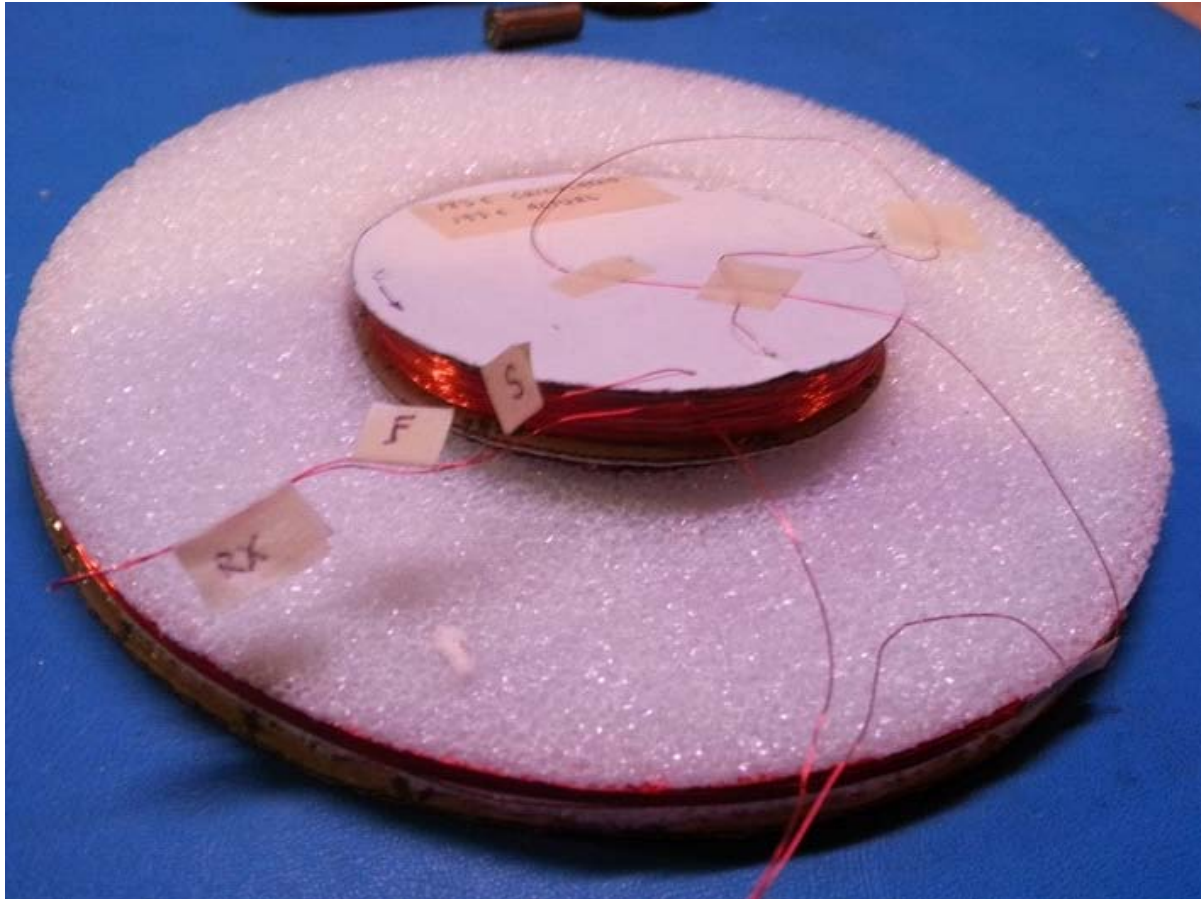
The equation for a Colpitts oscillator is as follows:

$$f_0 = \frac{1}{2\pi \sqrt{L \cdot \left(\frac{C_1 \cdot C_2}{C_1 + C_2}\right)}}$$

You can figure this out on your own, but I will just provide you with the answer. By connecting the Rx coil to our Tx circuit, it will oscillate at 13.9kHz. By using this method, I have been able to get phasing correct *every time*..

The Bucking coil is just an extension of the primary Tx windings wound clockwise around the Rx coil. This will be "about" 26 turns. We may have to add or remove a turn on the bucking coil to get the coil to null. In the following two pictures, you will see a small wire loop.

This is a small section of wire between the Tx and Bx coils that can be very helpful in final nulling. By moving around this small wire loop, the null can be fine tuned.



The above picture show the coil windings just before gluing the Rx coil spool in place. The coil windings must be secured so that no wires can move against one another. This can be accomplished by covering the windings with Cyan glue.. BUT, be very careful as too much Cyan glue can dissolve foam! A better solution is to fill the void around the Rx/Bx coil with epoxy. The same applies to the Tx windings. They must be secured with glue.



The USB-2 cable is fed through the **BOTTOM** of our coil arrangement and the leads are soldered. Then it will be time to do our final nulling adjustments. Quite simply, to null the coil, connect the Tx circuit to the TGS. Connect a DVM (on the lowest A.C. setting) to the bare leads of the USB-2 cable going to the Rx coil. Turn the TGS on and adjust the small wire loop to find the deepest null possible. Something less than 4mV should be achieved.

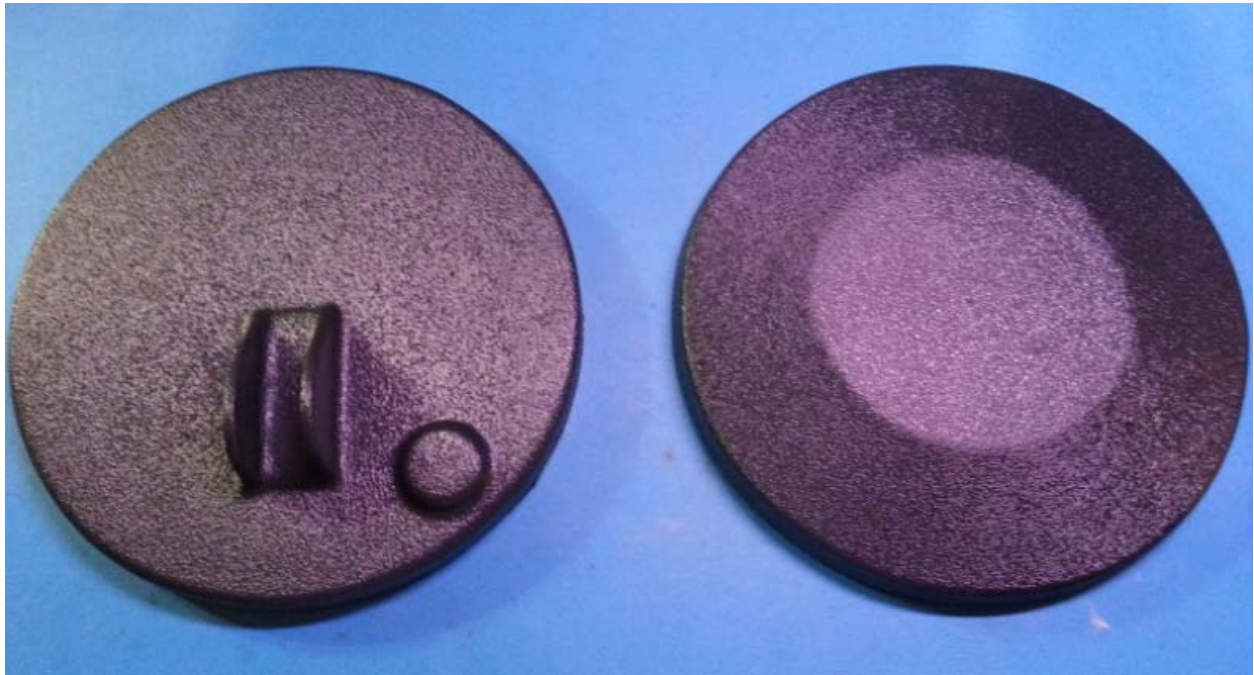
Alternately, you can use an oscilloscope an monitor pin #7 of U101a to find the best null. If you have a dual trace scope, adjust nulling so that the Tx signal *lags* the Rx signal by about 20 degrees, but is still very close to the null point. With a DD coil, the opposite should be true.

Finish the cardboard "sandwich" by gluing the top sheet of cardboard to the coil with white glue. This has the effect of making the whole arrangement very rigid. This is the same construction technique that many model airplane builders use to make wings that can withstand many "G" forces.



The next steps are the ones that can make or break the project - finding a suitable coil enclosure that will keep everything dry and clean. It just so happens that I like to vacuum form as well, so making shells is no problem. You may have to search the internet to find a source for shells. If you would like try making your own, you can follow another one of my guides listed under: "*TGSL_101 part 2*"

<http://www.geotech1.com/forums/showthread.php?15710-TGSL-Complete-Details>



In order for the coil to be stable and not react to the effects of ground capacitance, it *must* be shielded. There are two easy ways to accomplish this - either by building a shield on the inside of the shells or by building a shield directly on the cardboard. Either method will work. The cardboard can be sprayed with conductive graphite or the shells can be sprayed. For this project, I chose to spray the inside of the shells. A cheap source of graphite spray is a hardware store. This is a dry spray lube that can be picked up at a "Home Depot" hardware store for under \$5.00.



When applied, it leaves a conductive coating that has a resistance of about 35k Ohms from one end of the shell to the other. In this project, I masked off a small strip of tape that when removed, leaves a small gap in the conductive coating. I'm not really sure if this is required as I have built shells with and without a break using graphite and both methods work. In this case, I am using a break just because it is a best practice. Depending on how conductive the coating is, a break may be required to stop any eddy currents in the shield. I'm going to suggest doing it anyway.

An effective method of attaching a drain wire to the graphite shield is to mix a spot of DAP rubber contact cement with powdered graphite into a slurry. Then, glue the wire to the shield. It's conductive! This drain wire will then be soldered to the cable shield.



The top shell is shielded in the same manner with a drain wire of its own. The picture below shows the top shell before being sprayed. I will use an industrial strength double stick tape to secure my coil "sandwich" to the top of the shell. I just peel off the top layer of paper after graphite is applied to expose the sticky surface.



Finally, a strain relief is installed and the USB - 2 cable is routed.

The drain wire from the top is joined with the drain wire from the bottom. Then the two halves of the shells are jointed together and secured using black "RTV" silicon. As shown below.



Happy Building!

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