LOW RF BAND BINOCULAR Z TRANSFORMER

I have tested the characteristics of a dual core transformer (binocular) in various ratios of impedance to be able to then use in various applications (for low power use under 0.5 Watts). I have been made accurate measurements of attenuation and return loss with the HP 8753A Vector Network Analyzer.

The bandwidth of my interest in this case is between 1 and 10 MHz, so the first action is to identify the type of suitable magnetic material which was found to be the N30.

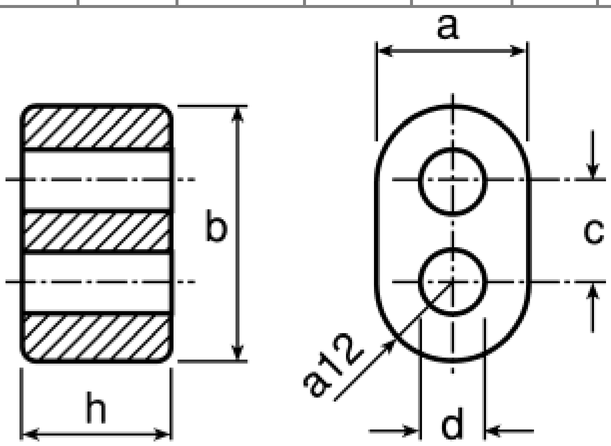
Core description

Double-aperture core material N30 for low frequency and pulse applications.

See also:
http://docs-europe.origin.electrocomponents.com/webdocs/00cb/0900766b800cb300.pdf

You can buy it from **RS Components** with code **212 – 0617** price under 1 Euro

costrut.	RS Code	Material	A_L (nH)	•1/A mm^{-1}	1_e mm	A_e mm^2	V_e mm^2
B62152A4X30	212-0617	N30	10000	0,54	15,3	28,4	435

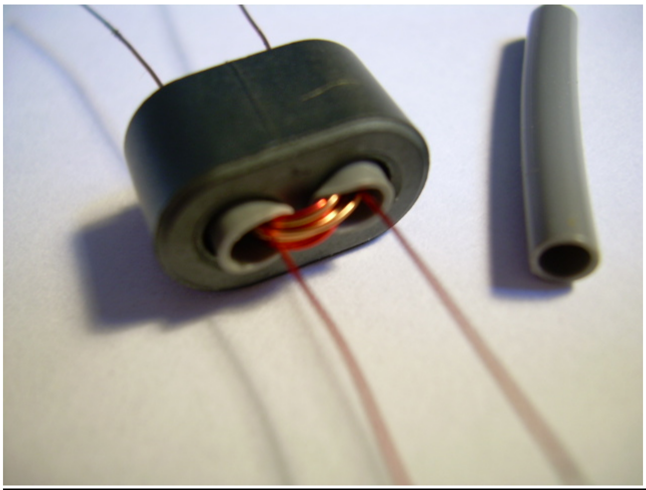


a =8.3mm   b =14.5mm   h =8.5mm

I suggest not buy cores of which are unknown because the results may be very different from the expectations, it is important the material is N30.

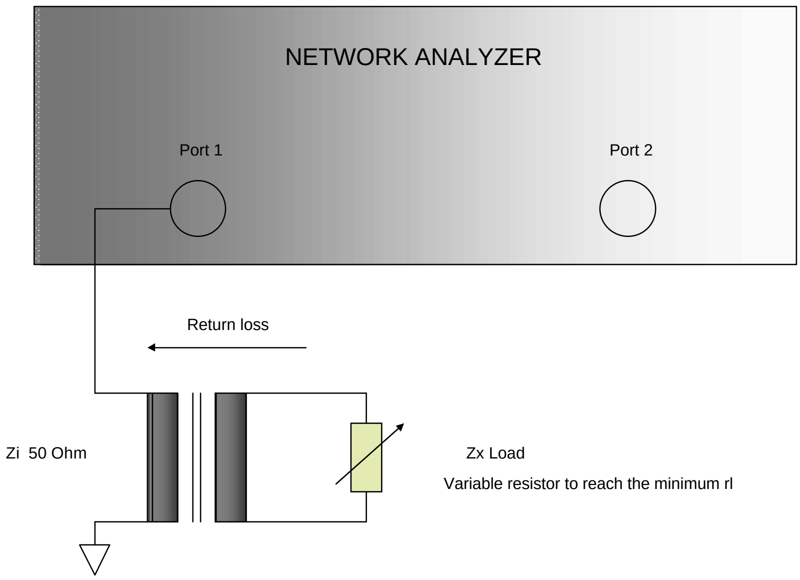
Transformer winding

Pay attention to winding the transformer. A pass through the two holes of the core is equivalent to a turn. The magnetic material is an electrical conductor and often wrapping the coils with a coated wire, it happens that the friction causes abrasion on enamel and the contact with the core. When it happen two or more times you have electrical short circuit that modify the characteristics of the device. To avoid this you can insert a tube of insulating material in the two holes and then wrap the wire.


winding example

Return loss test set

The return loss is the numerical value in dB of the RF energy is coming back to the generator. This means that more is the impedance mismatch, higher is the radio frequency comes back (SWR). The test was done using a network analyzer port 1 as in doing this is described. Same test can be done using an MFJ HF/VHF SWR analyzer reading SWR value instead the return loss in dB.



Single port VNA return loss measurement

The load, Zx was realized using a non-inductive trimmer with a small physical size of the maximum value of 500 ohms. In this way you can simulate loads from zero to its maximum value. For frequencies up to 30 MHz, the series inductance and stray capacity of the trimmer can be considered void.
The test is very simple, once connected the components as shown in the diagram, you turn the knob of the trimmer (Zx), until the VNA display shows a curve with the lowest values of rl (maximum negative value in dB).
When you finish this tuning, you can remove the resistor and measure it with an ohmmeter. The value read is equivalent to the output impedance of the transformer under test.
A good return loss is considered starting from 20db. More higher is this value, best is the impedance matching.

The following table represent the ratio Zo impedance / turns:

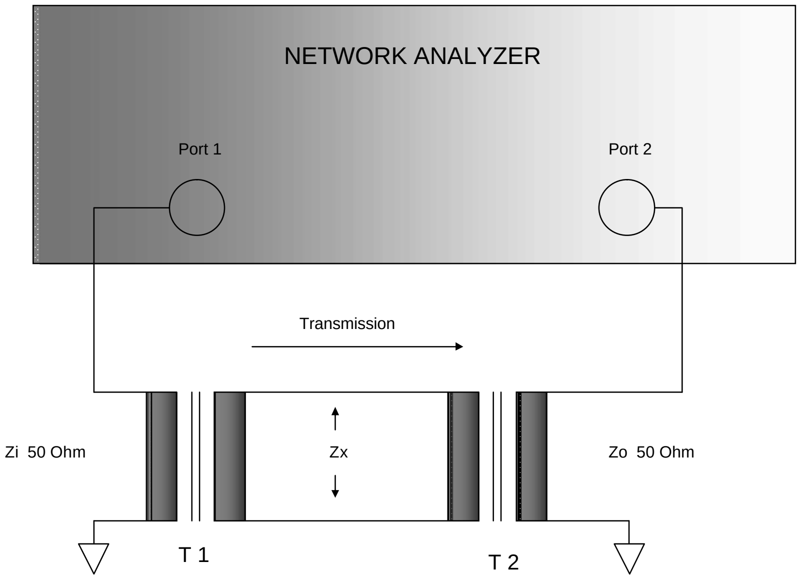
Pri turns	Sec turns	zi –zo Ohms	rl dB 1.8Mhz	rl dB 10Mhz	rl dB 20Mhz	rl dB 30Mhz
4	4	50 - 50	30	22	17	14
4	5	50 - 80	32	24	19	15
4	6	50 - 110	32	25	20	17
4	7	50 - 150	33	27	22	18
4	8	50 - 200	33	27	22	18
4	9	50 - 260	33	27	22	18
4	10	50 - 322	34	29	24	19
4	11	50 - 386	35	31	26	21
4	12	50 - 465	36	35	30	23

0.4mm enameled wire (#26 or #28 AWG)

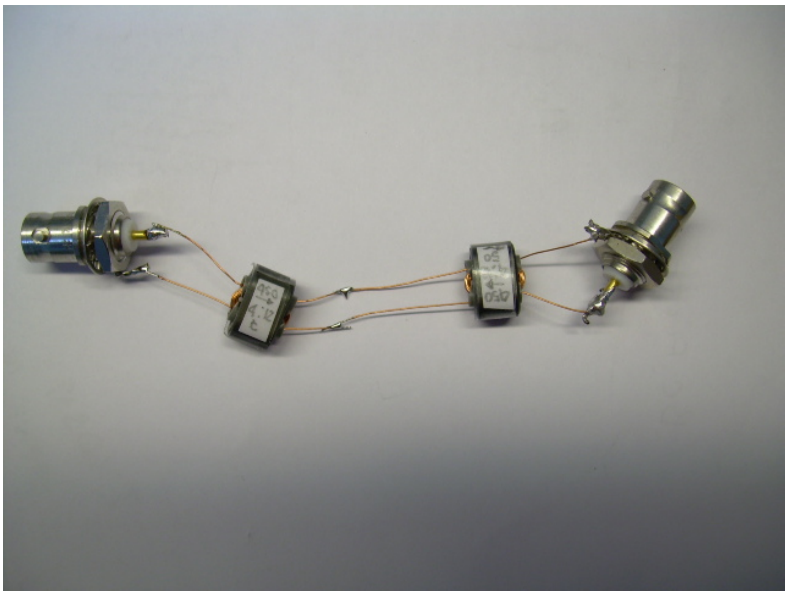
In the sky-blue area show the more interesting performance for this impedance transformer. The high frequency limit is due the magnetic material type.

Insertion loss test set

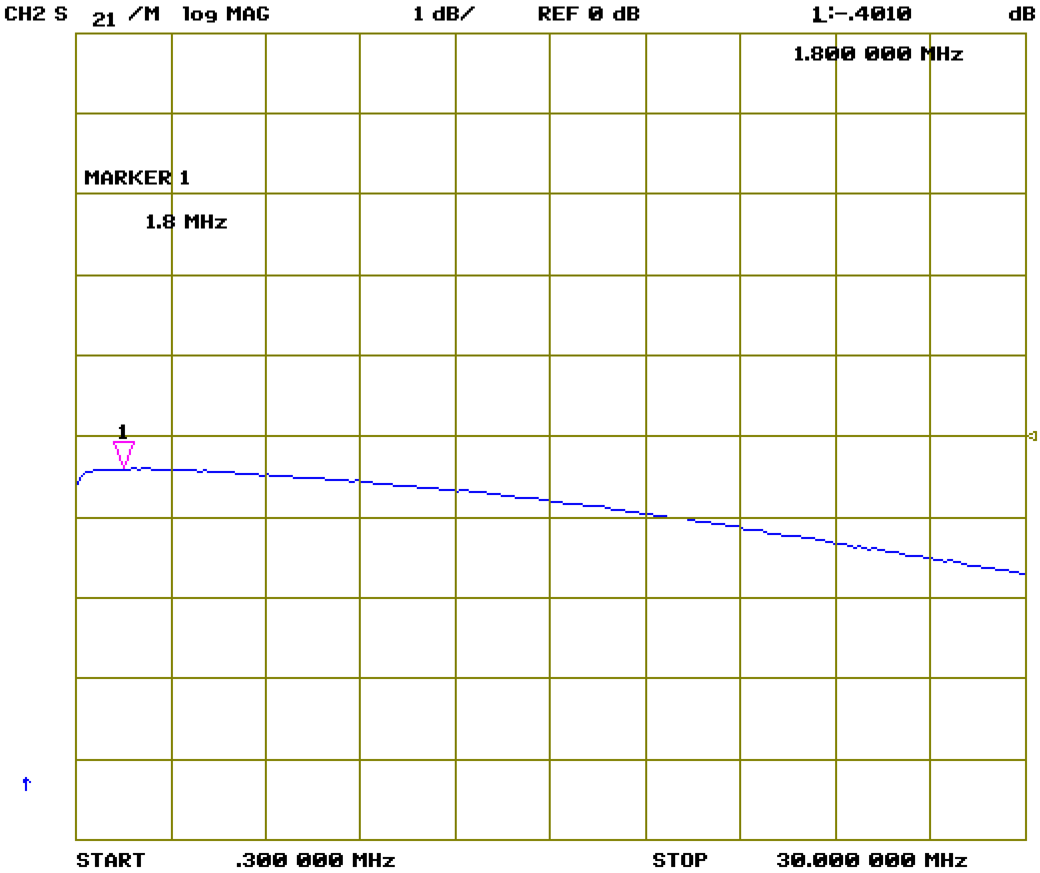
Now we want to measure the insertion loss. The insertion loss is the attenuation of the radio frequency crossing in the device from the input to the output measured in dB or SWR.
The measurement is done using the two VNA Ports, which is why you cannot use the MFJ, but the test can be done using a calibrated signal generator as the input source and a power meter as output level meter.
In the VNA case, Port -1 is the signal generator, and Port -2 the receiver / detector.
Since the two Ports of the measuring instruments have a 50 ohms as characteristic impedance but we have a device with one different port impedance- One of the most widely used method is to use two identical transformers connect together using the Zx side. In this way we will have a DUT, **D**evice **U**nder **T**est with a 50 Ohm input and output. The measured attenuation will be twice that of single device and making "Loss dB: 2" will have the desired value.



Two port VNA insertion loss measurement



The test I have done is on 50 to 110 and 50 to 465 Ohm transformer. The following screenshot of the VNA display represent the response of the measure. The value is for two 50 to 110 ohms connected back to back and the insertion loss measured-., for a single device, it has to be divided by two.



1dB/division. Zero on midpoint of the screen. Marker show 1.8MHz 0.40 db (two coupled transformer)

Insertion loss

zi –zo Ohms	att dB 1.8Mhz	attdB 10Mhz	att dB 20Mhz	att dB 30Mhz	*Capacitance Coupling Pf
50 - 110	0.2	0.3	0.5	0.85	3.8
50 - 465	0.2	0.25	0.3	0.36	9.7

0.4mm enameled wire (#26 or #28 AWG)
* capacitance between the two coils

Loop Antenna transformer

For use as impedance balanced transformer with the loop antenna It is essential to have a lowest capacitive coupling between primary and secondary windings.

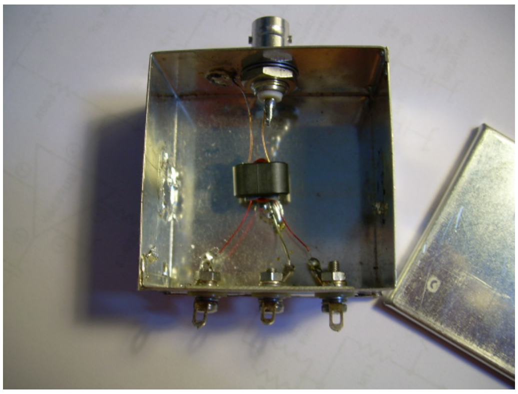
To have a 4:12 turns,1:9 ratio, you can wind two separate wires, or four wires; in this case one for the 50 Ohm side and other three wire in series to have a total count of 12 turns.

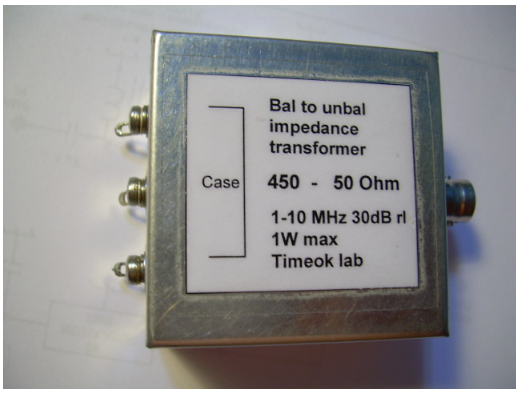
To have a transformation ratio of 9:1 you can use two methods: two windings 4 and 12 turns or 4 coils of four turns each; one for low Zin and three in series to reach 12 turns. In the first case, only some of the secondary coils are in contact with the secondary effect of a small capacitive coupling, while in the latter case all the secondary winding and close with the primary increasing the coupling capacitance.

capacitive coupling on 50:110 ohm transformer

The ratio of theoretical coupling capacity is 1: 3 for the two windings and 1:1 for the 4 windings with an obvious vantage for the two single coils style.
I believe that the use of two or more core to increase the core size does not bring any significant improvement on coupling capacity or insertion loss.
A trick to reduce the capacity is to use, for the less turns coil, a wire with large insulation thickness, so this help to increase the physical distance between primary and secondary then a less capacity.

Some example:





loop preamplifier/coupler

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