Toroidal BALUN Info

The following detail is a slightly edited version of a page that appeared on my old OzGear web site..... Links to the webshop option have been removed but the remainder is basically unchanged.
Note that I am no longer operating OzGear or producing or selling any balun kits but the balun construction details are still relevant for home constructors.

The Amidon ferrite and iron powder toroids used here are now available in Australia from TTS Systems (http://www.ttssystems.com.au/products/amidon/amidon-products)

TRANSMITTER-RATED TOROIDAL BALUN KITS, TOROIDS

Balun kits : These transmitting RF balun (coined from "bal"anced to "un"balanced transmission line conversions) kits have been created by Ozgear as suitable for amateurs to use with antennas in the HF range. They are ideally suited for use in 1:1 ratios with half wave dipoles or yagis with a feed impedance of around 50 ohms. They should be housed in one of a multitude of styles of boxes (eg electrical junction boxes) or sealed tubes/conduits to provide protection from weather (UV (sun) / rain), provide physical strength for mounting or terminating, and prevent the general ingress of moisture including dew.

The use of a balun can (1) reduce the RF currents on the outer shield of coaxial cables and thus reduce or eliminate induced interference into consumer devices and (2) prevent feedline radiation causing skewing of antenna radiation patterns. Most modern semiconductor transmitters/transceivers require a good impedance match (ie a low SWR) and depending on the type of antenna connected, sometimes an impedance step-up or step-down matching requirement also exists. This can be accommodated in a few ways but the simplest for a nearly constant impedance load (ie. an antenna at/near resonance) is the balun in a correctly selected ratio. We have selected the 1:1 as the most relevant ratio to document in our kits as very few antennas actually have a feed impedance of around 200 ohms. Straight or trap dipoles and inverted-V antennas usually work out at about 60-70 ohms at the centre feed point at resonance - but altered in some installations by physical factors such as mounting height.

The kits here are a simplicity series - the documentation is for a simple 1:1 (only) bifilar-wound transformer to convert from an unbalanced coaxial feeder to a balanced antenna. For instance, there is no third winding to complete the path for the magnetising current - although this can be added if desired. This is not a page detailing the variants and techniques of baluns - the reference we use is the book "Transmission Line Transformers" by Jerry Sevick, W2FMI (Published by the ARRL) - but a product availability advice. There are a multitude of means to construct 'baluns' and various impedance ratios can be obtained by the introduction of trifilar and quadrifilar winding and different connection techniques. It is left to the constructor to either follow the supplied instructions or use some other relevant construction technique.

The iron powder toroid version (TBIP-1000) is very similar to the version previously marketed by Dick Smith Electronics under their catalogue D-5350 (also marked just as a D5350) and is made available for those who have used these before and want another. Our preference is for the ferrite toroid versions as these are more efficient below 10MHz. To provide some control over cost, these ferrite baluns are available in two power level versions at 400W PEP (TBF400) and 1000W PEP (TBF1000). Most users should find the 400W version adequate for their installations but be warned - the insulation on the wire used is rated to only a few hundred degrees centigrade - excessive RF power can cause the insulation to melt and it could fail. If you really require a 1KW PEP version, buy the TBF1000 with the different core and PEI wire and avoid the problem.

Note that these are kits of critical parts. The bag contains a toroidal core, enamelled wire and some instructions. We do not build them for you nor does any mounting or housing come in the kit. The wire lengths supplied allow for 1:1 baluns to be created. If you wish to make a 4:1 or other ratio balun, additional suitable gauge enamelled wire may be required depending on the construction technique (see our wire packs below if more wire is required) and can be ordered separately or along with the relevant balun kit.

We recommend that a layer of PTFE tape is placed on the cores before winding to prevent any arcing between the winding and the core. Plumbers thread sealing tape is normally PTFE and makes a good winding base.

Construction hints : (1) To make the winding easier, we suggest that after you have determined the centre of the wire and removed kinks (as per the instruction sheet) then feed about half the folded-over wire through the centre of the toroid and wind forward half the total turns. Then use the other end to wind the balance of turns. This means that you are only ever winding with half the total winding wire length - instead of the whole length when you are starting and trying to feed it neatly through the hole. It usually results in a much tidier bifilar winding on the core. (2) Mark the wires with a quick shallow nip with cutters or pliers just near the end corresponding to the wire number eg 1 shallow mark for point #1, 2 shallow marks for point #2, etc - it makes the job easier when cutting or terminating them as the wires are already identified and are less likely to be connected incorrectly. (3) Wind the bifilar /trifilar /quadrifilar windings over only about 270 to 330 degrees of the circumference of the core - do NOT use the full 360 degrees.**

The technical parameters of the cores we use are listed below the kit info to assist you in determining any other uses for the cores.

 Taping core with PTFE tape FT-240-61 core used	 Bifilar winding technique - thread two wires "as one" - without significant gaps for the entire length of the specified turns.	 Typical kit contents TBF1000 illustrated - core, wire and instructions.

Toroidal balun – 400W PEP - 1.5 to 30 MHz

This kit contains a FT-140-61 (36mm) ferrite toroid, at least 1.5 metres of 1.25mm polyurothane grade 1 (PUR1) insulated winding wire and instructions. When used in a 50 ohm 1:1 balun configuration, it can handle up to 400 Watts PEP with low insertion loss. Recommended for use with antennas 1.5 to 30MHz at 100w to 400W PEP. Note that application of excessive power can cause insulation breakdown. If in doubt, use the higher power kit. Core not recommended for RFI suppression.

(Note: the PUR1 insulation on the 1.25mm wire in this kit is removed by application of a hot soldering iron)
Instruction sheet (/~vk4adc/web/images/UserFiles/File/balun/TBF400Balun.PDF)

Toroidal balun – 1000W PEP - 1.5 to 30 MHz

This kit contains a FT-240-61(61mm) ferrite toroid, at least 2 metres of 1.6mm PEI insulated winding wire and instructions. When used in a 50 ohm 1:1 balun configuration, it can handle up to 1000 Watts PEP with low insertion loss. Recommended for use with antennas 1.5 to 30MHz, operating at higher power levels where even high temperature rise will not cause wire insulation breakdown. Core not recommended for RFI suppression.

(Note: the PEI insulation on the 1.6mm wire in this kit is removed by scraping then tinning with a hot soldering iron)
Instruction sheet (/~vk4adc/web/images/UserFiles/File/balun/TBF1000Balun.PDF)

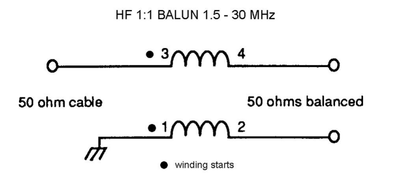
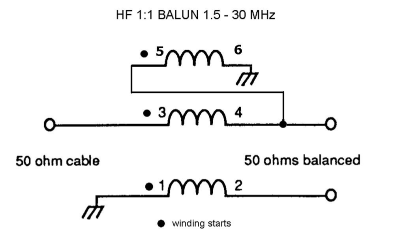
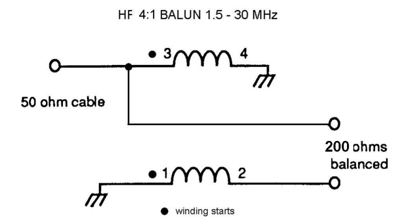
Toroidal balun – 1000W PEP - 10 to 30 MHz

This kit contains a T-200-2, a 51mm iron-powder toroid, at least 2.5 metres of 1.25mm polyurothane grade 1 (PUR1) insulated winding wire and instructions. When used in a 50 ohm 1:1 balun configuration, it can handle up to 1000 watts PEP with reasonable insertion loss. Recommended for use with antennas 10 to 30 MHz, or for RFI suppression on your audio equipment by wrapping as many turns of your speaker or input leads as will fit through the core. Not recommended for use below 10MHz unless the balun turns are changed and then upper limit may be affected. Note that application of excessive power can cause insulation breakdown. (Product similar to the old DSE D-5350 kit)

(Note: the PUR1 insulation on the 1.25mm wire in this kit is removed by application of a hot soldering iron)
Instruction sheet (/~vk4adc/web/images/UserFiles/File/balun/TBIP1000Balun.PDF)

Typical Balun configurations :

(Mouse-over the pictures to see them in a larger size)

		
Simple balun configuration as per wire length and instructions supplied in the kit	Alternate balun configuration with 3rd winding connection for allow for magnetising current. Note that winding 5/6 must be trifilar but can be a smaller wire gauge as the actual current through the wire is smaller.	Typical 4:1 balun option still using the same length wire as supplied in the kit but connected differently. Connection details are NOT currently included with the supplied 1:1 kit instructions.

Notes : The wire size and how the turns are wound will affect the characteristic impedance of the balun. To provide correct impedance transformations and provide the standard value of Z(in) around 50 ohms, the wire must be bifilar (or trifilar as appropriate) wound with the turns very closely spaced (to each other). Some references recommend that all wires actually be twisted with a linear twist rate before winding on the balun core to ensure correct characteristic impedances - but amateurs (being experimenters) will do it their way anyway.

For 50 ohm characteristic impedance baluns using bifilar windings, wind a twine spacing between each bifilar pair of wires.eg WWSWWS.. (wire, wire, spacer, wire, wire, spacer,.....)

For 75 ohm characteristic impedance baluns using bifilar windings, wind a twine spacing between each wire turn. eg WSWSWS.. (wire, spacer, wire, spacer, wire, spacer, wire,.....)

Reference : "Transmission Line Transformers" by Jerry Sevick, W2FMI (Published by the ARRL)

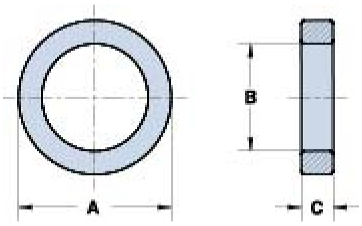
TOROID MATERIAL - ELECTRICAL AND PHYSICAL DATA

Dimensions in bold type are in millimeters, *italic numbers are nominal in inches.*

Physical and Magnetic Properties

Core Size	**A**	**B**	**C**	**l_e (cm)**	**A_e (cm)^2**	**V_e (cm)^3**
Ferrite Toroid Core Physical Data						
FT-140-61	**35.6**/*1.40*	**23.0**/*.900*	**12.7**/*.500*	9.020	.806	7.270
FT-240-61	**61.0**/*2.40*	**35.6**/*1.40*	**12.7**/*.500*	14.4	1.57	22.61
Iron Powder Toroid Core Physical Data						
T-200 series	**50.8**/*2.00*	**31.8**/*1.25*	**14.0**/*.550*	13.0	1.27	16.4

Magnetic Dimensions: l_e mean path length; A_e cross section area; V_e volume



Core: Wire Size vs Turns

Core Size	**Wire Size (awg) vs Turns ***											
	14	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**
FT-140-61	36	42	60	77	97	125	158	201	255	318	403	507
FT-240-61	60	77	98	123	156	198	250	317	400	499	631	793
T-200-2	53	67	86	108	137	172	217	270	338	418	529	658

single layer winding - enamelled copper wire

Toroid Core A_L Values

Core Number	**A_L Value**
FT-140-61	140.0 **(mH/1000 turns)**
FT-240-61	173.0 **(mH/1000 turns)**
T-200-2	120.0 (uH/100 turns)

Ferrite Formula

$$N = 1000\sqrt{\frac{\text{desired } L\,(\text{mH})}{A_L\,(\text{mH}/1000\text{ turns})}}$$

$$L\,(\text{mH}) = \frac{A_L \times N^2}{1{,}000{,}000}$$

N = number of turns

Iron Powder Formula

$$N = 100\sqrt{\frac{\text{desired } L\,(\text{uH})}{A_L\,(\text{uH}/100\text{ turns})}}$$

$$L(\text{uH}) = \frac{A_L \times N^2}{10{,}000}$$

N = number of turns

** The iron powder toroid material in the T-200-2 has the low value of permeability of 10 whereas the ferrite (#61 material) permeability is 125, which means the T-200-2 requires more turns to achieve the "rule-of-thumb" which says that the winding should have a reactance of at least 4 times the load impedance at the lowest operating frequency. 4 x 50 =200 ohms inductive reactance required. At 7MHz the winding would have to be a minimum of 4.5uH and at 10MHz 3.2uH. The total length of wire in the winding should not exceed 1/10 wavelength at the highest operating frequency (30MHz) due to possible resonances occuring. Lower permeability materials (iron powder or ferrite) can operate at higher flux density without saturation - hence higher rf power. The T-200-2 is almost impossible to saturate in amateur use.

To assist amateurs with varying wire sizes/gauges, the following AWG Conversion for stranded wire graphic table provides some conversion information between the types of wire measurements :

Mouse-over for larger view...

AWG Conversion to stranded wire

A.W.G. (B+S)		SOLID WIRE EQUIV.		STRANDED WIRE EQUIVALENTS No. STRANDS/WIRE DIA. = mm²									
GAUGE	AREA mm²	SIZE	mm²		mm²		mm²		mm²		mm²		mm²
26	0.128			7/.15	0.124	7/.16	0.148						
25	0.162												
24	0.205	0.5	0.20	7/.20	0.22	14/.14	0.22						
23	0.255												
22	0.322	0.64	0.32	7/.25	0.34	7/.26	0.37	14/.20	0.44				
21	0.411												
20	0.516	0.80	0.50	19/.18	0.48	16/.20	0.50	10/.25	0.49	7/.30	0.49	7/.32	0.56
19	0.653			30/.18	0.76	24/.20	0.75	9/.30	0.64				
18	0.823			19/.24	0.86	16/.26	0.85	11/.30	0.78	11/.32	0.88	7/.40	0.88
17	1.039	1.13	1.00	32/.20	1.00	16/.30	1.13	14/.32	1.13	7/.43	1.00		
16	1.308			50/.18	1.27	19/.29	1.25	16/.32	1.28	7/.50	1.37		
15	1.652	1.38	1.50	84/.15	1.48	30/.25	1.47	26/.3	1.84				
14	2.088			64/.20	2.00	26/.32	2.08						
13	2.629	1.78	2.50	140/.15	2.48	84/.20	2.60	50/.25	2.48	41/.30	2.90	7/.67	2.47
12	3.302			41/.32	3.30								
11	4.156			56/.3	3.96	65/.3	4.59	7/.85	3.97				
10	5.271			84/.3	5.93	65/.32	5.22	7/1.04	5.90				
9	6.629												
8	8.350			112/.3	7.9	94/.32	7.56	100/.32	8.0				
7	10.544			322/.2	10.1	77/.4	9.7	7/1.35	10.0				
6	13.292			192/.3	13.6	171/.32	13.7						
5	16.755			511/.2	16.0	126/.4	15.8	7/1.70	15.9				
4	21.137			287/.3	20.3	247/.32	19.8						
3	26.653			792/.2	24.9	364/.3	25.7	209/.4	26.3				
2	33.606			1121/.2	35.2	455/.3	32.1						
1	42.384			492/.32	39.5								
0	53.454			1596/.2	50.2	703/.3	49.6	612/.32	49.2				
00	67.399			2212/.2	69.5	910/.3	64.3	988/.3	69.8				
000	84.905			1204/.3	85.1	1332/.3	94.1						
0000	104.091			1482/.3	104.0								

Note: To establish mm² of stranded cables not listed above, use this formula:
Conductor dia² x 0.785 x No. of strands
i.e. 30/0.25 = 0.25² x 0.785 x 30 = 1.47mm²

Click here for a larger view or to download. (/~vk4adc/web/images/UserFiles/Image/balun/awgconversions.jpg)