SUPERIOR Toroid® TRANSFORMERS

INSTRUCTION FOR MAKING YOUR OWN TRANSFORMER FROM KITS

LIST OF CONTENTS:

WARNING:

MAINS SUPPLY TRANSFORMERS CAN BE DANGEROUS IF HANDLED IMPROPERLY!

DO NOT USE THIS KIT IF YOU AR UNCERTAIN ABOUT THE DANGERS OF HIGH VOLTAGES OR THE FIRE HAZARDS ASSOCIATED WITH IMPROPER USE OF TRANSFORMERS. WE WILL REFUND YOUR MONEY IF YOU RETURN THIS KIT TO US WITHIN 30 DAYS IN THE SAME CONDITION AS YOU RECEIVED IT.

DO NOT USE THIS KIT TO MAKE TRANSFORMERS FOR MORE THAN 250V RMS ON ANY WINDING OR PAIR OF WINDINGS, NOR FOR POTENTIAL DIFFERENCES OF MORE THAN 250V RMS BETWEEN PRIMARY AND ANY SECONDARY WINDING.

TOROID CORPORATION OF MARYLAND

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A. CHECK CONTENT OF KIT PACKAGE

Each kit contains:

1 toroidal core with primary winding(s) and mylar film insulation. (Check label to make sure it the right size.)

1 plastic bag containing mounting hardware and material for outer insulation etc.

This instruction booklet.

B. DESIGN YOUR SECONDARY WINDING.

TABLE I contains all the information you will need to determine wire area and number of turns for each winding.

TABLE II is used to select standard AWG wire sizes close to the calculated wire areas.

1. Design for RMS data.

Use the middle section of TABLE I when you design a winding to feed lamps or tube filaments, or AC motors such as fan motors.

Divide the desired RMS voltage by the figure given in column II to get the required number of turns (N) for the winding.

Divide the desired ampere load by the figure from column 9 to get the required wire area, then go to TABLE II to find the nearest standard wire size.

Finally multiply the number of turns (N) by the figure from column 7 to get the net length of this wire (Add 2 ft. for lead wires).

Repeat this procedure for each of your secondary windings.

Finally check that you have room for your windings in the center hole of the toroid by calculating the total copper area for all windings.

Calculate N x Actual Area for each winding, then take the sum for all secondary windings.

This sum must be smaller than the figure in column 6 for your kit, otherwise it may be difficult to wind the last turns of the last secondary winding or to apply the outer insulation.

Note that the figures in TABLE I are not exact, especially because you cannot get wire sizes that exactly fit the calculated areas. Final correction for output voltage can however, be made by adding or subtracting turns after testing, see Section E.

2. Design for DC Data

The last section of TABLE I gives the data you need to design windings which will give desired DC voltages and DC currents, assuming your secondary windings are connected to rectifier bridges with capacitor filtering.

DC current is the average (or mean) value of the current drawn from the capacitor loading the rectifier. Note that this is NOT the same as the RMS current in the transformer windings, because the RMS current accounts for the harmonics required to convert the AC current into a smooth DC. The RMS current is always larger than the DC current. The conversion factor ("Formfactor") depends mainly on the transformer size. Column 13 in TABLE I includes the effect of the Formfactor.

The DC voltage to be used in your transformer design is NOT the net DC voltage you want to see at your final load circuit. You have to add the voltage over the diodes, which to the transformer is not different from your useful voltage, and if you use a voltage regulator, you must also take into account the ripple voltage and the voltage drop over the regulator.

Figures 1 - 3 illustrate the three rectifier circuits that can be used with toroidal transformers, and Figures 1b - 1d illustrate the voltage waveforms in the rectifier circuit shown in Figure 1a. (The voltage waveforms are essentially the same if rectifiers per Figures 2 or 3 are used instead.)

Add 1 volt per diode in series with the secondary winding. (This means 2 volt for a full bridge, 1 volt for each half of a center tap bridge, 1 volt for a dual-half wave circuit.) When this is done, you will have a capacitor voltage, measured with a DC voltmeter, equal to you net DC voltage.

Add 1/2 of the peak-to=peak ripple voltage ($U_r/2$), if you design for the lowest point of the ripple as seen on an oscilloscope. $U_r/2 = 2.8 \times I_{dc}/C$. (I in Amperes, C in mF (milliFarad) 1mF=1000μF. NOTE: $U_r/2$ should be less than 5% of the DC voltage on the capacitor in question.

Add the voltage drop required by a series regulator, if you use one (2.5V is a typical value for the lowest drop before clipping).

Add margin for low line (supply) voltage, if needed.

Use this "gross" DC voltage (U_{dc}) for each secondary as input data when you use TABLE I. Proceed exactly as for RMS calculation to determine length of wires, total copper area, etc. except that you use columns 13 - 15 instead of columns 9 - 11.

3. <u>Design for mixed RMS and DC</u>

If your transformer has windings for RMS output as well as rectifier windings, use the appropriate parts of TABLE I for each winding. You will automatically get the correct number of turns and the correct wire sizes as long as you use the correct section of TABLE I for each winding.

C. <u>GET MAGNET WIRE FOR THE SECONDARY WINDINGS.</u>

The wires to be used for your secondary windings are solid copper wire with heavy enamel as insulation. This kind of wire is called "magnet wire", and can be obtained from electrical supply houses or from local motor repair shops. Insulated stranded wire can also be used, but it takes up much more space than magnet wire and is thus not recommended.

D. <u>WIND THE SECONDARIES ON TOP OF THE INSULATED PRIMARY.</u>

Make sure the mylar insulation on the transformer is in good shape, without tears or cuts. Use regular office tape to fasten any end that tends to unravel.

Wind each magnet wire on to the transformer by threading it through the hole in the middle. Start near the lead wire from the primary, and wind with an even pitch so that the end of turn of the winding is as close as possible to the other size of the primary leads. Tighten each turn well to insure a compact winding that will not cause hum and rattling in the powered transformer.

If the winding has many turns and/or heavy wire, it can be arranged in several layers on the transformer by continuing past the primary leads every time that position is reached. The winding should be arranged so that it covers a number of full layers, each with an even pitch.

If the windings are in pairs, with the same wire size and same number of turns, use two parallel wires in "bifilar" fashion as described above for one wire. This method ensures that the two windings are closely coupled, and have exactly the same number of turns and the same length.

Start with the thickest wire or wire pair next to the primary and end with the thinnest wires as the outer layers. Take care to make the windings without peaks or valleys. Even windings are important to ensue low magnetic strayfield, and also look better than rough windings.

Short wires with some stiffness can be rolled into a small coil before you start threading them through the center hole. Long and thin wires can be rolled on to a shuttle, see Figure 4. The shuttle can be a piece of wood or heavy cardboard.

E. TEST THE WINDINGS

Before adding the outer mylar insulation, the transformer should be tested.

Connect the primaries as illustrated in Figure 5 for the test setup. Connect an AC mA-meter in series with the primaries to check the no-load current against the data in column 4 of TABLE I. A larger no-load current indicates short circuits in your secondaries. Correct this before proceeding.

Remove the mA-meter before loading your secondaries.

Next test under load, with all circuits operating. Any error in the voltages can then be corrected by adding or subtracting turns to each winding. The correction should be very small, if you have designed the transformer correctly. Adding or subtracting turns can be done by winding the lead wire for the winding in question through the center hole. Winding the same way as the winding itself increases the number, winding the opposite way is equivalent to decreasing the number of turns.

F. ADDING OUTER INSULATION.

After all the windings have been tested and corrections made where necessary, the black tape should be added as a tire tread on the outside perimeter of the transformer, and the customer label should be filled in and fastened to the black tape.

Finally the outer mylar wrapping should be added as a protective layer. Tape one end of the clear mylar strip to the inside of the center hole, and wind the strip in slightly overlapping turns on top of the secondary windings. Each turn of the mylar strip should be stretched tight before the next turn is started. Go around the transformer twice in this fashion, then cut off excess strip and fasten the end of the mylar strip with tape on the inside of the center hole.

G. USING THE TRANSFORMER

The finished transformer must be mounted on a solid support preferable on a metal chassis place, Which can serve as a heat sink. Place one of the rubber pads under the transformer, place the second rubber pad between the transformer and the metal mounting washer, and fasten the transformer to the chassis plate by means of a bolt or screw through the hole in the mounting washer.

The transformer primaries must be connected as illustrated in Figure 5, and proper terminals must be used for connections to the power supply. The transformer and its lead wires and terminals must be housed in a suitable enclosure, so that accidental touching of energized parts cannot occur.

The data in TABLE I is based on a transformer working at an ambient temperature of max 40 °C (104 °F), with top, bottom and cylindrical outer surfaces all contributing to cooling. The maximum temperature rise under these circumstances should be about 65 °C (150 °F), for a safe maximum temperature in windings of maximum 105 °C (220 °F).

A temperature sensing fuse designed to open permanently at 115-120 °C (240-250 °F), is mounted inside the transformer and connected via red lead wires. This fuse must be connected in series with the supply voltage as shown in Figure 5 to protect against the risk of fire caused by overheating of the transformer.

H. DESIGN EXAMPLES

1. Design for RMS Data

Make a transformer with a first winding for 6.3V RMS at 1.5A RMS and a second winding for 24V at 5A RMS.

Total VA: 6.3V x 1.5A + 24V x 5A = 129.45VA

The smallest kit with a VA rating larger than 129.45VA is kit #401.020. From TABLE I, line 2 we read off columns 9 and 11:

Max RMS current density is 3.9A/mm^2, thus winding #1 requires a copper area of 1.5/3.9 = .3846mm^2 and winding #2 requires a copper area of 5/3.9 = 1.282mm^2. The nearest AWG sizes are #21 (.4104mm^2) and #16 (1.291mm^2).

Volt per turn at full load is .20V/N. Winding #1 requires 6.3/.20 = 31.5 turns. Only full turns are possible, so we must choose either 32 turns, which gives 32 x .20 = 6.4V or 31 turns, which gives 31 x .20 = 6.2V. The normal choice would be the higher voltage, or 32 turns. Winding #2 requires 24/.20 = 120 turns, which is an integral number and will be our choice.

Total copper area is 32 x .4104 + 120 x 1.291 = 168.05mm^2. Column 6 gives a max copper area of 250mm^2, so we will have plenty of room.

From Column 7 we find that the length per turn of the secondary windings is .40 ft. We will thus need the following lengths of magnet wire:

.40 x 32 + 2 = 14.8 ft of AWG #21 (= .0375 lbs.)
.40 x 120 + 2 = 50.0 ft of AWG #16 (= .397 lbs.)

NOTE: In this case we had lots of room to spare, so we could select larger than the minimum wire sizes, if we so desire. The transformer will run very cool, because we draw only 130VA out of 200VA full load.

2. Design for DC Data

<u>Make a transformer to supply a rectifier which will give +/- 40V DC at a DC load of 5A.</u>

A center-tap bridge rectifier (see Fig. 2) is the best circuit for this application. Add 1V per 40V for diode drop.

U_{dc} = 2 x 41V, I_{dc} = 5A gives 2 x 41 x 5 = 410W DC. Column 12 tells us that kit #402.070 is the smallest unit that can handle this DC power.

From column 13, line 5 we read max current density 1.5A/mm², so we need a wire area of 5/1.5 = 3.33A/mm². TABLE II tells us that the nearest larger standard size magnet wire will be #11, but AWG #12 is so close to the desired copper area that we can use that instead.

TABLE I, column 15 gives volt per turn at full load = .57V/N, so N = 41/.57 = 71.92 turns. Fractions of turns are impossible, so we choose 72 turns for each half of the secondary.

Total copper area is 2 x 72 x 3.31 = 476.64mm², which is less than max copper area per column 6 of TABLE I, so we are in good shape.

The length per turn is .55 ft (TABLE I, column 7), so we need a total length of magnet wire of 2 x .55 x 72 + (2 x 2) = 83 ft, which from TABLE II, line 3 is 83/50 = 1.7 lbs. by weight of AWG #12 magnet wire.

The two secondaries in this transformer must have <u>exactly</u> the same number of turns, so bifilar winding is recommended. The center tap is formed when the last end of one secondary is connected to the beginning of the other.

In order to keep the ripple voltage lower than 5% of 41V (=2V), we need a capacitor which can be determined from the formula: 2 = 2.8 x 5/C, which resolves to C = 7 mF or 7000µF. This is the minimum capacitance, so a 2 x 4, 700µF capacitor with tolerance +/- 20% will be suitable. Maximum no-load voltage will be .623V per turn according to TABLE I column 14, so the capacitor must be rated for 72 x .623 x 1.1 = 49.34V continuous duty. (The 1.1 multiplier takes into account a possible 10% overvoltage on the power supply line).

The calculation above assumes that you design for the average DC voltage on the capacitor. (See Fig. 1C).

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3. Design for regulated DC voltage.

If you in example 2 need +/- 40V <u>regulated</u> DC at 5A DC, you would have to add $U_r/2$ (2V) plus regulator drop (2.5V min.), for a total U_{dc} = 45.5V to avoid clipping in the regulator.

If the regulator must work without clipping down to 90% of rated supply voltage, you need this 45.5V at 90% supply voltage. Multiply the date in columns 12,14 and 15 by .90 before you use them for 90% supply, then proceed as described in example 2:

Total power = 2 x 45.5 x 5 = 455W. This is larger than 460 x .9 = 414W.
We need kit #402.140 in this case.
N = 45.5/(.94 x .90) = 53.78 turns (54 turns)
Wire area = 5/1.0 = 5mm^2, AWG #10
Wire length is 2 x (54 x .68 + 2) = 77.4 ft. (2.46 lbs.)
Total copper area = 2 x 54 x 5.26 = 568 mm^2 (OK)

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TABLE I

	Primary Data				Secondary Windings		RMS Secondary Data				DC Secondary Data			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
									Volt per turn				Volt per turn	
Transformer Kit #	Nom. Line 60Hz Volt	Number of Turns	Max. No load Current mA	Wire Size AWG/mm	Total Copper Area mm^2	Length of one turn tt/m	Max. Load VA	Max. RMS current density A/mm^2	No Load V_o/N	Full Load V_l/N	Max. Load W	Max. DC current density A/mm^2	No Load V_o/N	Full Load V_l/N
401.008	117	780	10	#24/.50	160	.42/.11	80	4.9	.150	.13	60	2.4	.187	.15
401.020	117	531	22	#20/.80	250	.40/.12	200	3.9	.220	.20	140	2.1	.312	.27
401.040	117	265	44	#17/1.18	250	.55/.17	400	3.9	.442	.42	260	1.9	.624	.57
402.070	2 x 117	2 x 264	2 x 29	#17/1.18	520	.55/.17	700	3.2	.441	.42	460	1.5	.623	.57
402.140	2 x 117	2 x 164	2 x 55	#14/1.60	880	.68/.21	1400	2.3	.714	.69	880	1.0	1.010	.94

TABLE II

AWG #	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Area, mm^2	10.54	8.367	6.633	5.260	4.173	3.310	2.624	2.082	1.651	1.309	1.039	.823	.653	.518	.410	.326	.258	.205	.162	.129	.102	.081	.064
Ft. per lbs. wt.	---	19.8	25.0	31.5	39.7	50.0	62.9	79.2	99.7	126	158	199	251	314	295	502	629	787	990	1,256	1,575	1,992	2,469

Wire sizes outside the range of TABLE II are not suitable for winding on transformer kits. Use two or ore wires in parallel as substitue for areas larger than #7 AWG.

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INSTRUCTIONS FOR TRANSFORMER KITS

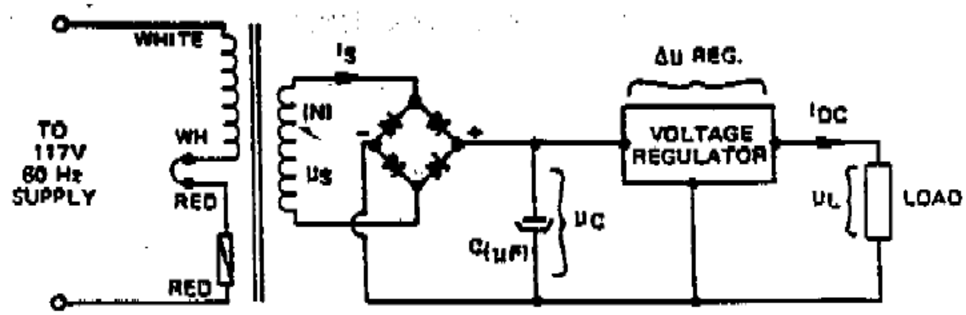

FIG. 1a

BRIDGE RECTIFIER WITH FILTER CAPACITOR AND VOLTAGE REGULATOR

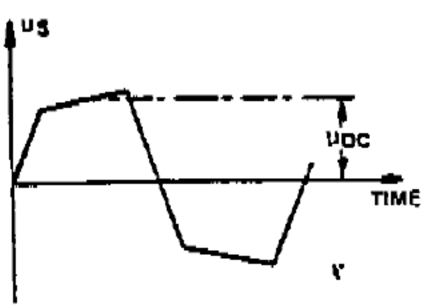

FIG. 1b

VOLTAGE ON SECONDARY AS SEEN ON OSCILLOSCOPE

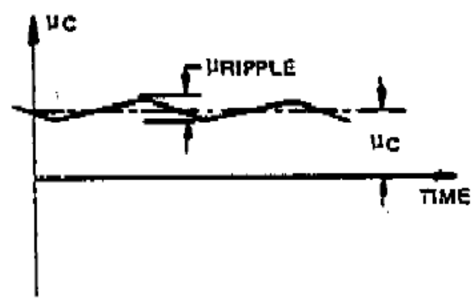

FIG. 1c

VOLTAGE ON CAPACITOR AS SEEN ON OSCILLOSCOPE

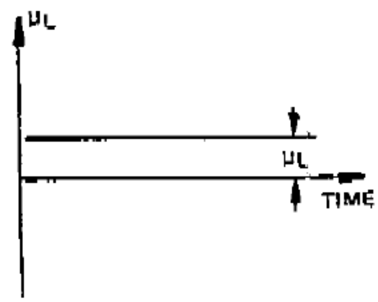

FIG. 1d

VOLTAGE AFTER REGULATOR AS SEEN ON OSCILLOSCOPE

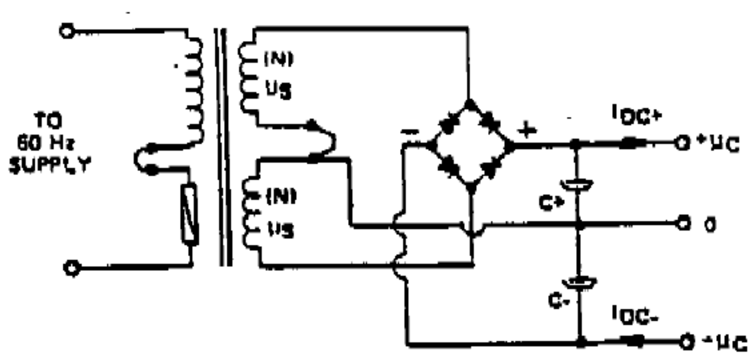

FIG. 2

CENTER-TAP BRIDGE RECTIFIER

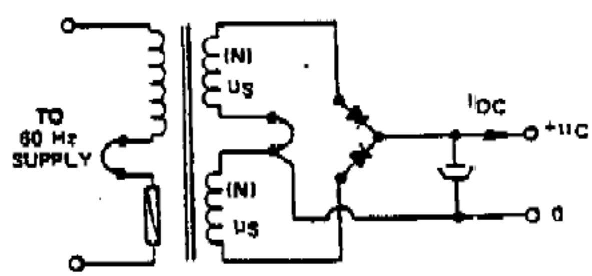

FIG. 3

DUAL HALF-WAVE RECTIFIER (= 1/2 OF CENTER-TAP BRIDGE)

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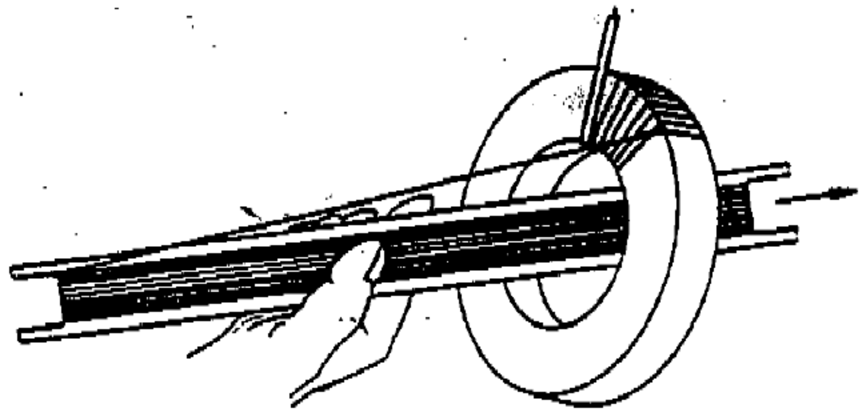

FIG. 4

WINDING WITH SHUTTLE FOR WIRE

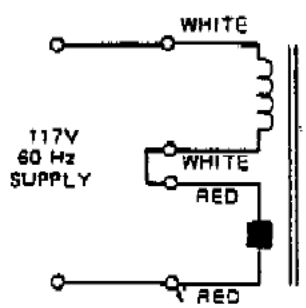

FIG. 5a

PRIMARY & FUSE CONNECTION FOR 117V (KITS #401.XXX)

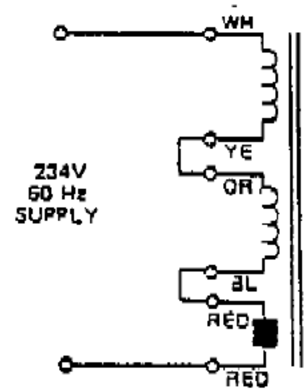

FIG. 5b

PRIMARIES & FUSE CONNECTED FOR 234V (KITS #402.XXX)

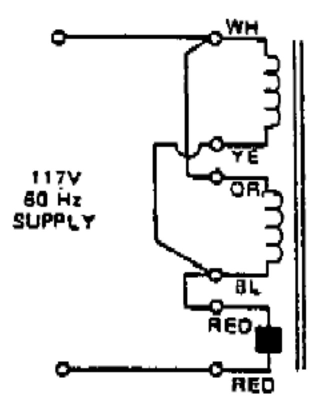

FIG. 5c

PRIMARIES & FUSE CONNECTED FOR 117V (KITS #402.XXX)

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