

GQRP Club

Main links: **Club Sales** **Join GQRP** **Club News**

Menu

Home

Sprat Magazine

About GQRP

Who's Who

Club Diary

Links

QRP Frequencies

Members Pages

Technical Pages

Internet Conference

Club Awards

Club Services

Rishworth QRP Convention

[Technical Page 2](#)

A Short Guide to Harmonic Filters for QRP Transmitter Output. - George Dobbs G3RJV

A Complete Do-It-Yourself Kit with just a few simple calculations.

Although by their very nature, QRP transmitters radiate less power, the output from such a transmitter does require adequate filtering. Usually to keep the circuit compact, these transmitters have a final stage run in Class C and being driven hard with RF power. Of itself, this is a recipe for high harmonic output and a well designed low pass filter is essential. For many years I have used low pass filters calculated from a series of figures produced by Ed Wetherhold, W3NQN, (a G QRP Club member) and published in two articles in the UK Short Wave Magazine in December 1983 and January 1984.

Ed Wetherhold has been the ARRL adviser on passive filters for several years and published many fine articles on audio and radio frequency passive filtering. I believe that the two articles in Short Wave Magazine still represent the best source of information for the design of good low pass filters for RF amplifiers.

The articles are comprehensive but here I just want to share enough of the information to enable readers to build useful filters to add to their home made transmitters. There is very little mathematics - about 4 pushes of a calculator is the most required to produce information for a buildable filter. I will also give a chart for "off the shelf" low pass filters, which can handle up to 10 watts or RF power, suitable for every HF amateur band.

The W3NQN designs are based upon a seven elements : four capacitors and three inductors. They are designed for 50 ohms input and output impedance and use standard capacitor values. This is very useful because many calculations and computer programs for filter design give very odd values of capacitance which have to be made up from series and parallel values. Figure 1 shows a Seven Element Low Pass Filter. Now lets look at some numbers.

Recommended Values

Table 1 is a very short extract from a large list of filter parameters in the original W3NQN articles. I have taken the practical values for the nine HF amateur bands which have given me the best results over the years. Alongside each band are values for the seven elements in the filters with values on pF for capacitors and uH for inductors. The characteristics of each filter are described in terms of the ripple cut-off frequency (F-co) and the frequencies of the 3dB (F - 3dB) and 30dB (F - 30dB) attenuation levels. The capacitors are all easy values. I generally use polystyrene capacitors for my filter building.

The Inductors

The inductors are all wound on toroidal cores in the popular Micrometals range. Translating the inductance value to practical inductors is very simple. The formula

is given to calculate the number of turns. It does require knowledge of the inductance at 10 turns for the required core. These values are given in Table 2. Again I have reduced the W3NQN information to the 2 mix and 6 mix toroids, the ones that are of most use for this application. The formula is easily executed with a pocket calculator and the resultant figure is rounded to the nearest complete number of turns. The wire gauge is not critical. Simply use the gauge that will fit well on the core. The target is to wind an even coil on the core to occupy about three-quarters of the available space. If the opposite ends of the winding are too close this will introduce extra capacitance.

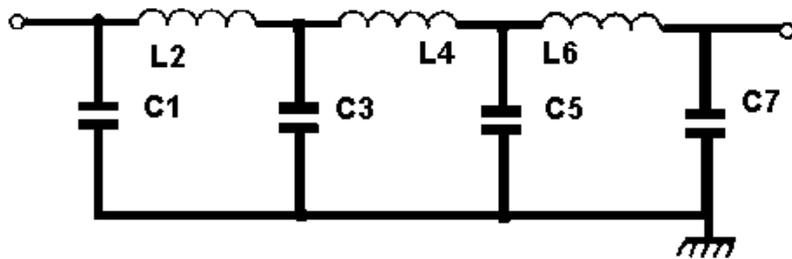
Power Levels

Table 3 shows the smallest core that may be used for particular RF power levels. It is interesting because for transmitters of 10 watts or less, T37 cores are suitable, making the filters very compact. Also notice that larger cores are required for the lower frequency bands. This again is an extract from the W3NQN data which used a very conservative maximum AC flux density to determine the minimum core size. So use this table to choose a core suitable for the required power handling of the filter.

Practical Examples

Table 4 gives practical designs for a series of low pass filters over the 9 HF amateur bands for transmitters of 10 watts power output and less. The constructor simply has to read off the values and make up the filters. All of these are filters that I have used to good effect in the past. Should you require filters for use with higher powers, take the information from the tables to choose a suitable core and work out the appropriate number of turns for that core. A complete Do-It-Yourself filter design kit !

I keep a range of low pass filters in the shack, each one mounted in a small tin, for testing purposes. So when playing with transmitter circuits, I have a low pass filter I can put into use for testing the output. The more frugal constructor could use such a set of filters for several transmitters and not build filters into each of them.



W3NQN 7 ELEMENT
STANDARD VALUE
CAPACITOR LOW
PASS FILTERS

TABLE 1 :
Recommended Values

Band MHz	F-co MHz	F - 3dB	F- 30dB	C1,7 pF	C3,5 pF	L2,6 uH	L4 uH
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MHz MHz

1.8	2.16	2.76	4.0	820	2200	4.442	5.608
3.5	4.125	5.11	7.3	470	1200	2.434	3.012
7.0	7.36	9.04	12.9	270	680	1.380	1.698
10.1	10.37	11.62	15.8	270	560	1.090	1.257
14.0	14.40	16.41	22.5	180	390	.773	.904
18.068	18.93	22.89	32.3	110	270	.548	.668
21.0	21.55	27.62	39.9	82	220	.444	.561
24.98	25.24	28.94	39.8	100	220	.438	.515
28 - 30	31.66	40.52	58.5	56	150	.303	.382

CALCULATING NUMBER OF TURNS REQUIRED ON A TOROID FOR A GIVEN INDUCTANCE

$N = 10 \times \text{SQUARE-ROOT} (L / L10)$

N = Number turns

L = Required inductance

L10 = Inductance at 10 Turns

TABLE 2 : INDUCTANCE AT 10 TURNS FOR MICROMETALS TOROIDS

Core Mix	Inductance (uH) at 10 turns						Range MHz
	Colour	T37	T44	T50	T68	T80	
- 2	Red	.40	.52	.49	.57	.55	1-7
- 6	Yellow	.30	.42	.40	.47	.45	7 +

Note:

1] Inductance values have a tolerance of 5% and are based upon a single layer winding.

- 2] The core prefix gives the nominal outside core diameter in hundredth of an inch
 3] For example : a T37-2 core has a nominal outside diameter of 0.37 inches and an inductance of 0.40uH at 10 turns.

TABLE 3 : SMALLEST USABLE
 TOROIDAL CORE FOR OUTPUT
 POWERS

Core	Designation of Smallest Usable Toroidal Core				
	Colour	<10 25	10- 50	25- 100	50- 200
- 2	Red	T37	T44	T68	T80
- 6	Yellow	T37	T37	T37	T44 T50

TABLE 4 : Practical Examples
 for Transmitters Under 10
 watts RF Output

Band MHz	C1,7 pF	C3,5 pF	L2,6 turns	L4 turns	Core	Wire swg
1.8	820	2200	30	34	T50-	30 2
3.5	470	1200	25	27	T37-	28 2
7.0	270	680	19	21	T37-	26 6
10.1	270	560	19	20	T37-	26 6
14.0	180	390	16	17	T37-	24 6
18.068	110	270	13	15	T37-	24 6

21.0	82	220	12	14	T37-	24
					6	
24.98	100	220	12	13	T37-	22
					6	
28 - 30	56	150	10	11	T37-	22
					6	

Note :

Wire gauge is not critical.

Use size to comfortably fill the core about three-quarters of full circumference.

The number of turns has be rounded to the nearest whole number from the calculated value.



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