

Building and Operating:

LF Converter  
An SA602 based LF up-converter  
from Jackson Harbor Press

Introduction:

The frequencies below the broadcast band are covered by few receivers on the market - those that do cover these frequencies are sometimes lacking in performance. This kit allows the owner of a ham band receiver ( or transceiver) to listen to this band at a minimal cost with acceptable performance. There are a number of different stations to listen to on LF, including:

Military	24-26 KHz	strong computer modulated carriers
WWVB	60	time / frequency standard station in Colorado
Lowfers	160-190	Part 15 stations operating at less than 1 watt
beacons	200 - 280	low power aeronautical beacons located at airports
DGPS	290 - 330	stations that send correction signals for GPS receivers

See the web site for short recordings of some of the above stations in WAV format made with an Elecraft K2 fed by the LF converter..

The LF converter takes the band of frequencies from approximately 10 KHz to 300 KHz up to the 75 or 30 meter ham bands (4 to 4.3, 10 to 10.3 MHz bands). The converter can be easily changed to another ham band (or another 300 KHz range) by changing the crystal. A socket is provided to make this easy to accomplish.

Please note that the LF Converter will output an image band below the ranges mentioned above. For example, with the 4 MHz crystal the user can tune the LF band backwards from 4 to 3.7 MHz in the 75/80 meter band of a ham receiver/transceiver. It is a little more confusing, but for example, WWVB at 60 kHz will appear on 75 meters at 4 MHz minus 60 kHz or 3.94 MHz.

General notes on building the LF Converter

One decision the builder should make before starting construction of the LF converter kit is how the project will be mounted in the case. The LF converter should be mounted in an all metal case - a Sucrets or Altoids tin will work fine. It is important to keep the converter output shielded to prevent false signals from the 75, 30 or 20 meter band being received.

Sockets are provided for both the mixer IC and the crystal - the use of these sockets is optional. The sockets may adversely affect performance, but I find that it is very useful to be able to change the crystal and IC easily.

The components should be inserted a few at a time, soldered in place and then clip the leads. The pads and traces are small and delicate - a small tipped, low power (25 watts or less) soldering iron should be used.

Building the LF Converter

Step 1) Get the parts together: All of the board mounted components have been supplied but you will still have to provide off-board items to fully implement the kit. These items include:

- + 12V power connector
- Antenna input connector
- Output connector to receiver / transceiver, BNC or RCA phono will work fine
- metal case, an Altoids or other candy tin will work fine
- shielded cable, audio is fine for the input, RG-174 may work better for the output
- 4 sets mounting hardware, 4-40 sized

Step 2) Identify and orient the components: Most of the components should be fairly easy to identify and place - see the parts list and the parts placement diagram for descriptions. The electrolytic cap is clearly marked for polarity - be sure to orient the negative stripe correctly per the parts placement diagram. The yellow trimmer cap should be oriented with the flat side towards the crystal. The round side of the trimmer is the "ground" side - connecting this side to ground will minimize any capacitance shifts when a screwdriver is used to adjust the trimmer.

The ferrite cores used for L1 and L2 will depend on the age of the kit. They may be either small, .375 inch diameter, black donuts or small balun cores (black rounded rectangular ferrites with 2 holes). Use the table in step 3 for instructions on how to form L1 and L2.

Step 3) Wind L1 & L2: There are two inductors used in this kit - they are identical, use the following table for winding info:

Core type:	design Ind.	turns	relevance	wire size	wire length
-----	-----	----	-----	-----	-----
balun: BN-61-2402	26.5 uH	9	Current	#30 magnet	8 inches
the following are no longer used:					
toroid: FT37-43	26.5 uH	8	original	#26 hookup	7 inches
balun: BN-43-2402	26.5 uH	prewound	second	wire wrap	prewound
toroid: FT37-61	26.5 uH	22	third	#26 magnet	15 inches

To wind balun cores: Start with a piece of wire with the length specified in the above table. Put one end of the wire through one hole of the balun core and leave about 1 inch of wire exposed. Then threading the other end of the wire through the other hole in the core of the balun. Each time the wire passes through BOTH of the holes in the core counts as 1 turn.

To wind toroids: Start with a piece of wire with the length specified in the above table. Put one end of the wire through the hole of the toroid core and leave about 1 inch of wire exposed. Then start threading the other end of the wire around and through the core of the toroid. Each time the wire passes through the core counts as 1 turn. Even out the turns on the core as shown on the parts placement diagram.

There are generally two ways to strip the insulation from magnet wire, the first way (which I use) is to scrape it off with a diagonal cutter or some other sharp tool. The second way (which most prefer) is to use heat from a blob of solder to burn the insulation off.

If you have an LC meter, you may wish to check the wound cores against the designed inductance. Because of the relatively poor tolerance of the ferrite material as far as inductance is concerned, rarely will the target inductance be hit exactly. But the half wave filter is pretty forgiving of this. Lower values of inductance will result in higher cutoff frequencies, higher values in lower frequencies. The values for the inductor of a half wave filter for a 50 ohm input/output impedance is derived from the inductive impedance calculation:

$$Xl = 2 * \pi * \text{cutoff frequency} * \text{inductance}$$

using a little algebra:

$$\text{inductance} = Xl / (2 * \pi * L)$$

for a 300 kHz frequency, 50 ohms: inductance = 50 ohms / (2 \* 3.14 \* .3 MHz) or 26.5 uH

similarly, the capacitors are calculated in the same way using the  $Xc = 1 / (2 * \pi * f * C)$  and using algebra to change that to

$$C = 1 / (2 * \pi * f * Xc)$$

The standard capacitor values closest to the calculated values are selected.

For this kit, the filter is replicated twice with the center capacitor approximately doubled in value.

The balun core values can be changed by either adding or subtracting half-turns (one hole at a time).

The toroid values can be changed by either adding or subtracting turns or to some extent, squeezing the windings.

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step 4) Place and solder the components on the main circuit board: Use the parts placement diagram for information on the placement and orientation of the parts. Clip the leads after soldering. I would recommend that the builder insert parts by their profile (or height) above the circuit board starting with the lowest and working up.

a) optional: DIP socket - should be inserted with the notch towards the left edge of the board

b) optional: crystal SIP socket (3 pin) - should be inserted above the DIP socket at the X1 position.

c) C7 and C8, the .1 uf caps (marked .1M or 104) near the DIP socket

d) U2 (78L08 8V regulator) with flat side toward the top edge of the board.

e) two .1 uf bypass caps (C1 and C2, marked .1M or 104) on either side of U2

f) the toroids L1 and L2 should have their leads stripped and inserted at the left of the board

g) .022 uf polyester cap (C5 marked 223J) between the two toroids

h) .01 uf polyester caps (C4 and C6, marked 103J) at either side of the two toroids

i) the yellow trimmer cap (C12) with the flat face towards the crystal socket

j) the 68 pf cap (C10 marked 68J) in parallel with the top +8V trace

k) the 270 pf cap (C11, marked 271J) next to the 8 pin DIP socket

l) vertical 10 uf electrolytic cap (C3) at top right of board with negative stripe to the left edge of board

m) C9 the .1 uf cap (marked .1M or 104)

n) R1 the 240 (red-yellow-brown-gold) ohm resistor

o) Q1 the PN2907 transistor - be sure to form the leads for the .1 inch lead spacing and also make sure to install the transistor with the flat face as shown on the parts placement diagram (away from C9).

Step 6) Check the board: Before proceeding, take the time to check the bottom of the board for solder bridges. Use the bottom view diagram as a guide to visually check for these shorts. It may help to clean the flux from the board and then use a strong light in conjunction with a magnifying glass to see these problems. Also, double check the orientation of the critical components such as the regulator (U2), the yellow trimmer cap, C12, and the 10 uf electrolytic cap, C3.. After you are convinced that the board is OK, connect 12V power to the top edge of the board as shown on the parts placement diagram. Now use a voltmeter to check that the regulated +8V is present on the top power trace. If it isn't, recheck your component orientation and soldering.

Now form the leads of IC U1 to fit in the socket, insert the IC and the crystal into their respective sockets, being sure to follow the parts placement diagram for proper orientation (pin 1 indicated by a notch or dimple should be to the top edge of the board. Finally, use shielded wire to connect the antenna input connector and receiver output connector as shown on the parts placement diagram. Install the board in the metal case.

Next, connect the antenna (a long wire is fine) and the receiver and power up the board. If you are using a transceiver, use the receive only antenna input if one is available. If you are using the normal transceiver antenna, realize that an accidental transmission with the LF converter connected in place of the normal transmitting antenna or dummy load will probably damage the LF converter and possibly your transceiver.

You should be now be able to hear LF stations - the military stations from 24-26 KHz are very loud. WWVB is not quite as loud at 60 KHz. See the web site for recorded LF transmissions.

Setup and operation: The LF converter requires one adjustment, tune in a station of known frequency, WWVB at 60 KHz is the best one since there are few other stations in the immediate "vicinity". Set your receiver frequency to 3.94 (image), 4.06, 9.94 (image) or 10.06 MHz, and then use a small screwdriver to adjust C12 until you hear the modulated tone of WWVB at the correct offset frequency for your receiver (consult the manual for the receiver for the offset information for your radio). The Son of Zerobeat kit can be used to easily set the trimmer to within +/- 10 Hz.

The LF converter may suffer in performance in the presence of strong AM broadcast signals. The user may need to install some additional LC filter circuitry to minimize this problem.

Sometimes strong signals in the ham band (to which the LF signals are converted) may appear - this generally indicates that the shielding is poor between the LF converter and the receiver. Good quality BNC or RCA phono connectors and high quality coaxial cable should minimize this problem.

LF Antenna: Much information is available on the internet concerning LF antennas. There are many different types which should all work fine with the LF converter. Loop antennas including shielded loops and ferrite bar antennas are very popular. Active "whip" antennas also work well. Personally, I often just use my HF long wire antennas. Noise is a big problem on LF, especially in the spring-summer season. Directional antennas help to minimize noise pickup. Man made noise, especially from light dimming equipment can be a severe problem on LF.

Circuit description: The LF Converter circuit has the following major circuit blocks:

- 1) power supply: a 78L08 regulator is used along with bypass capacitors to convert a +12 to +13.8 volt (12 volts nominal) input voltage to 8 volts.
- 2) low pass filter: C4, C5 and C6 along with L1 and L2 form a simple 300 KHz low pass filter. Ferrite cores were used to minimize the number of turns required compared to powdered iron cores.
- 3) converter: The remaining components convert the band of frequencies from 0 to 300 KHz up to the receiver input frequency range of 4.0 to 4.3 (4.0 to 3.7 image) or 10.0 to 10.3 (10 to 9.7 image) MHz.

Modification ideas:

- 1) extra front end filtering: One of the kit testers lives in the Chicago area, when he tried to listen to WWVB at 60 KHz, he encountered some heterodyne interference from two 50,000 watt AM stations in the Chicago area (WGN at 720 KHz and WBBM at 780 KHz). Unfortunately,  $780 - 720 = 60$  KHz. One mod which helped him was an extra two sections of low pass filtering on the input with the same values and layout as the one in the kit. This was housed in the separate tin box but probably could also be fitted into the same box as the converter.
- 2) One kit tester noted that the input low pass filter is setup for 50 ohm termination but the NE602 input is more on the order of 1500 ohms. I tried putting a 51 ohm resistor in parallel with C6 - the results weren't startling, really didn't notice much difference between having the resistor in or out of the circuit. Perhaps a better approach would be an input filter designed for more realistic input and output impedances ?
- 3) The 8V regulator specified may be a little bit of overkill, a 78L06 6V regulator may work just as well and allow the use of a 9V battery to power the kit. 5V regulators are also a possibility, such as the 78L05. Note that the lower voltages may result in lower sensitivity.
- 4) One item often used by LF experimenters is a pre-amp. The extra gain may not be needed, but a simple JFET pre-amp with a PNP buffer transistor on the output will allow the user to drive the 50 ohm input impedance of the converter with better results. The

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preamp can also be easily remoted, driving a long 50 ohm shielded cable - this allows the antenna (usually a loop) to be located away from man-made sources of noise. The loop antennas usually employed by serious LF enthusiasts (particularly the shielded variety) will probably require the use of a pre-amp.

5) Changes for the toroids - most people familiar with toroids use insulated magnet wire to make the windings - personally I'd rather use hookup wire since it's much easier to remove the insulation. Also, ferrite cores were used in this kit, powdered iron are normally used but they have two disadvantages, they'll require a lot more turns to get the inductance required and the LF powdered iron toroids (usually the gray T50-3 toroids) are harder to find than ferrite toroids.

6) Other frequency bands: Other crystals can be used at X1 - those with receivers which have provision for external converters can try non even megahertz crystals such as 3.579 MHz - these crystals can be the inexpensive "computer" type.

7) 530 kHz Chebyshev 3 dB filter parts: Capacitors and a 50 ohm resistor are now included with the base kit for an optional 530 kHz cutoff Chebyshev filter. No extra inductors or wire are included. This filter would normally replace the stock filter if the builder wants to listen to stations above 300 kHz.

included parts:

2 x .022 uF polyester caps

1 x .027 uF polyester cap

1 x 49.9 ohm resistor

(no extra toroids or wire are included - use the BN-61-2402 cores and magnet wire from the kit for L1 and L2)

to change the stock 300 kHz lowpass filter to a higher cutoff filter make the following changes:

L1, L2 => 6 turns on BN-61-2402 11.4 uH (wire passes through both holes for a turn)

C4, C6 => .022 uF (marked 223)

C5 => .027 uF (marked 273)

the 49.9 ohm resistor can be used to terminate the filter (connect across C6)

8) 400 kHz Chebyshev 3 dB filter parts, design by Jack Smith: This is an optional, extra cost item.

2 BN-61-2402 cores 15.2 uH

#30 magnet wire (wind 7 turns of wire on each core - wire passes through both holes for a turn)

2 .027 uF polyester capacitors (the end caps)

connected in parallel the following two caps

form a .0363 uF capacitor (the "middle" one):

.033 uF polyester capacitor

.0033 uF polyester capacitor

49.9 ohm 1% terminating resistor can be used to terminate the filter (connect across C6)

9) The voltage regulator is rather "tender" - if the polarity of the applied power is reversed, it will be damaged very easily. To prevent this I'd suggest either using a different regulator (Low Dropout regulators like the LM2936 can shrug off polarity reversals without damage) or a less expensive, easier mod is to use a diode such as the 1n5817, 1n5818 or 1n5819 Schottky diodes in series

with the positive input lead. Conventional rectifier diodes like the 1n4000 series can also be used at the cost of a higher dropout voltage than the Schottky diodes.

10) Some builders have complained about the LF Converter being noisy. Although I'm not sure that these represent any huge improvement, here are some ideas that a builder may want to try.

First, the easiest mod to try would be to add more resistance in series with the 240 ohm resistor. I used a 1k ohm trim pot, lifted one end of the 240 ohm resistor and then soldered the trim pot wiper to the "flying" lead of the 240 ohm resistor and finally solder one of the other leads of the trim pot to the pad where the lifted 1k ohm resistor lead was. The pot can then be adjusted to vary the apparent noise (and gain) of the converter.

Second, if the 10 MHz crystal is being used, a 10.7 MHz IF transformer like the 42IF123 from Mouser can be used in place of the PN2907 PNP output transistor. This requires that the PNP transistor be removed – to save the board I would advise the builder to just clip the transistor off the board and then unsolder the three leads individually rather than trying to save/remove the transistor as a whole. Then what I did was to solder 3 pin sockets where the transistor was – this allows the user to reverse the mod (if desired) by inserting a new PNP transistor in the socket. The middle pad (of the transistor) is connected to one of the end pins of the IF transformer (primary is on the side with the three pins). The other end pin of the IF transformer is connected to pin 4 of the SA602 socket, leave the middle pin of the IF transformer unconnected. Connect one pin of the secondary of the IF transformer to ground and the other pin of the secondary is connected to the output connector. The slug of the IF transformer can then be adjusted to provide the greatest volume at the frequency of interest, not that it will be lower than the transistor output. The 42IF123 provides a 7:1 turns ratio which is pretty close to the 7.7:1 ratio called for by a 3000 ohm to 50 ohm transformation of the LF Converter output. If the user wants to use the 4 MHz or other crystal, the 10.7 MHz transformer would have to be "padded" with an external capacitor. One way around this would be to use an untuned transformer, either a ferrite transformer with an 8:1 turns ratio or just clip out the internal cap in the 42IF123 (which is easier said than done).

Supplemental information: For more information on the LF converter including the .WAV sound samples, please consult the Jackson Harbor Press web site:

<http://wb9kzy.com/lfconv.htm>

Please feel free to email with any questions, comments, suggestion or problems with this kit. My email address is:

[wb9kzy@wb9kzy.com](mailto:wb9kzy@wb9kzy.com)

Thanks for choosing the LF converter kit and  
Best Regards,

Chuck Olson, WB9KZY

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### List of parts included with the LF Converter kit

Ref	marking	Description
C1	.1M or 104	.1 uf multilayer ceramic .1" lead space cap
C2	.1M or 104	.1 uf multilayer ceramic .1" lead space cap
C3	10 uF 25 V	10 uf radial (upright) electrolytic capacitor
C4	103J	.01 uf polyester (dark red), .2" lead space cap
C5	223J	.022 uf polyester (dark red), .2" LS cap
C6	103J	.01 uf polyester (dark red), .2" lead space cap
C7	.1M or 104	.1 uf multilayer ceramic .1" lead space cap
C8	.1M or 104	.1 uf multilayer ceramic .1" lead space cap
C9	.1M or 104	.1 uf multilayer ceramic .1" lead space cap
C10	68	68 pf NPO ceramic disc capacitor, .2" lead space
C11	271J	270 pf NPO ceramic disc capacitor, .2" lead space
C12		yellow 7 to 40 pf ceramic trimmer capacitor
L1		9 turns on BN-61-2402 ferrite balun core
L2		9 turns on BN-61-2402 ferrite balun core
R1	240 ohms	red-yellow-brown-gold 1/4 watt resistor
Q1	PN2907	general purpose PNP bipolar transistor
U1	SA602	8 pin DIP, Philips mixer / oscillator IC
U2	78L08	8V, 100 ma regulator in TO-92 case
X1	10.000	10 MHz crystal (optionally 4 MHz)
		8 pin machined pin socket (for mixer, U1)
		3 pin machined pin socket (for X1)
		square main circuit board

### Items you'll need to provide to complete the LF converter kit

- Metal case (an Altoids tin is fine)
- input antenna jack
- output jack
- +12V power jack
- solder