

Let's Build Something—Second Generation Spinoff

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My co-author Ben, KK6FUT and I wrote the Let's Build Something (LBS) series of articles in the January and April issues of *QRP Quarterly* and it has received a wonderful response. We have received a very gratifying number of e-mails from individuals and clubs who have taken the articles to heart and are building the LBS individually and in quantity. I am happy to say that most efforts have been successful.

Along the way to finishing our own copies of LBS, Ben and I discovered that a real side benefit of the LBS project was the ability to use it as an experimental platform. My experiments included different crystal filters, both of the homebrew and commercial type, and changing the radio to operate on other bands. The DDS VFO used in the radio made band changes extremely easy to implement.

The next obvious step would be to use the LBS platform for the incorporation of surface mount devices (SMD) within the radio. There are very good reasons for using SMD including low part cost, availability and overall size reduction of the final project. The negative side of using SMD is that the pure "tack here and solder there," as is done with "Ugly Construction", is not appropriate here. SMD construction can be accomplished by hams but additional testing and circuit construction equipment is required. Otherwise, the soldering of parts you can hardly see onto tiny pads can appear to be more of a "black magic art" than a skill. Shop equipment consisting solely of an old beat-up hand drill won't be sufficient.

For that reason, let me caution you that this article does not fall into the same category of being a detailed construction article as was the case with the original LBS series. This article is more of a "think piece" designed to expose some ideas to experienced builders with construction and testing equipment beyond that available to those builders who are new to the art.

With the above thought in mind, I will discuss the building of what I call LBS-II. My LBS-II takes the extreme plunge and maximizes the use of surface mount. Later, a matrix will be provided of candidate boards for that transition. A photo pictorial

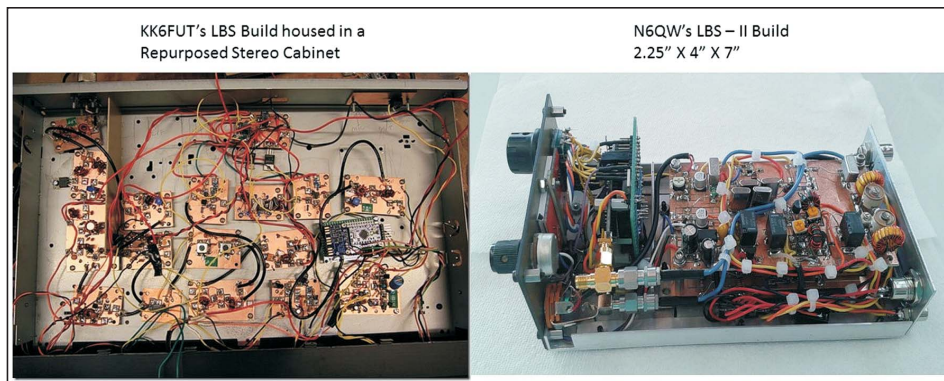


Figure 1—Size comparison: LBS to LBS-II.

Element	LBS	LBS-II
Components	Leaded	Extensive SMD
Mixers	Homebrew	TUF-1 (TUF-3, SBL-1)
Audio Amp	Discrete Components	2N3904/LM386-3
Display	LCD	128X128 Color TFT
Arduino	Nano V3	Pro-Mini
IDE	1.0.5	1.6.3
Band	40 Meters	20 Meters
IF Frequency	4.9152 MHz	5.185 or 9.0 MHz
Tune Up	Carrier Unbalance	Arduino Audio Tone
Size	Large	Small
Ability to make changes	Easily Done	More difficult
Booster Amps	Several	None

Figure 2—Feature comparison: LBS to LBS-II.

which documents the building of the complete transceiver is located at <http://www.n6qw.com/LBS2.html> and there is a YouTube video of the initial receiver testing that can be found at <https://www.youtube.com/watch?v=tiJQh01Hwzw>.

Figure 1 is a size comparison of the original LBS transceiver as built by Ben, KK6FUT and the LBS-II recently completed by me. For essentially the same overall circuit design, there is a dramatic size reduction achieved principally through the use of surface mount devices. My original LBS build was "open air" on a 2' x 2' chunk of plywood. Ben's version was a neater package, 2.5" x 10.5" x 17". The LBS-II is 2.5" x 4" x 7". Another way of viewing the two rigs comparably is to say that Ben's version of the LBS-I is 446

cubic inches and the LBS-II is 70 cubic inches, a reduction of 84%. Table 1 lists other comparisons between the two versions of this rig.

Construction

When I first started considering the LBS-II, I spent a good deal of time "noodling," with good reason, over circuitry layouts. There is so much circuitry in such a small area that unwanted coupling and circuit interaction can be an accident waiting to happen. Eventually, I decided that the best approach would be to use two circuit boards stacked on top of each other. This afforded some natural shielding in critical places. The top board contains all of the low level stages and the bottom board has the transmit linear amplifier

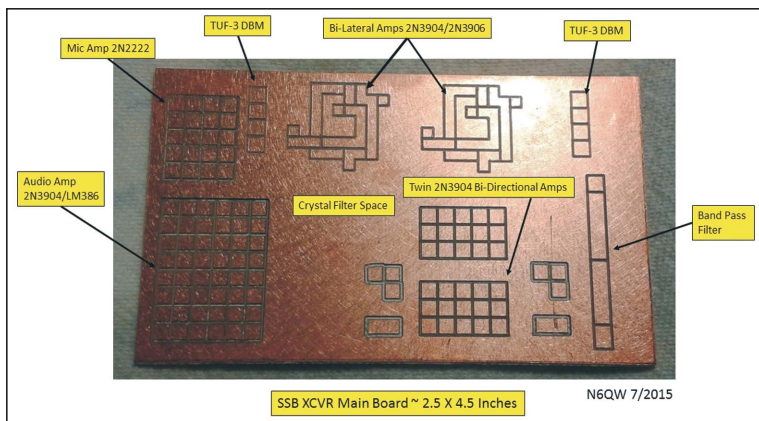


Figure 2—LBS-II Main Transceiver Board layout.

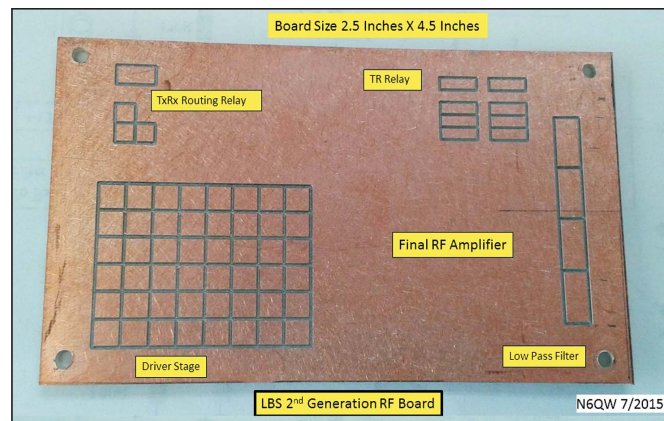


Figure 3—LBS-II RF Board layout.

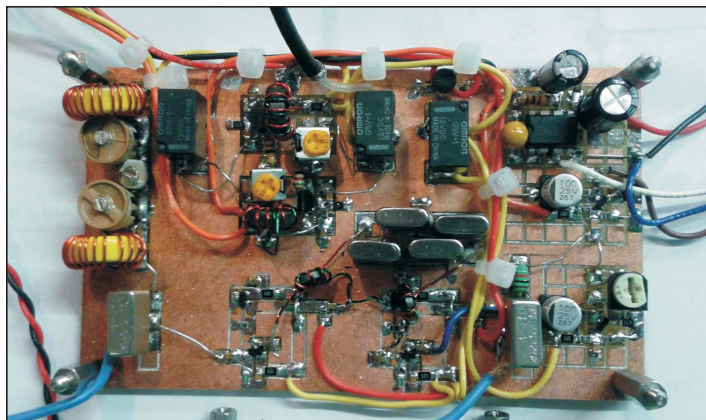


Figure 4—Main Transceiver Board filled with parts.

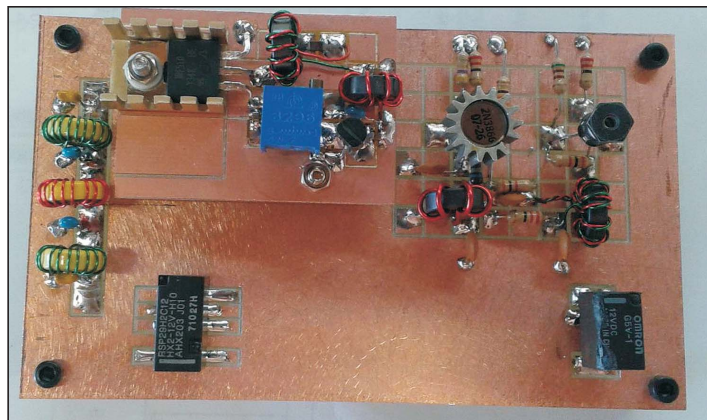


Figure 5—RF Board filled with parts.

stages, the low pass filter and some of the TR relay circuitry. The top board copper acts as a shield to keep RF out of the lower level stages. In addition, the IRF510 final amplifier is built on a small sub-board affixed to the lower of the stacked boards. This was done for two reasons. The IRF510 is NOT my favorite RF device and by having it on a removable board, I could replace the entire board with a real RF device. The second reason is the heat removal aspect. Having the board elevated and using metal pillars provides a heat conduit to the lower board.

Figures 2 and 3 shows the two boards used in the LBS-II. It is another way of showing the “real estate allocation” in the LBS-II and how I looked at the circuit blocks, how the signals would flow, how to reduce inter-block coupling, and finally how to minimize unwanted circuit coupling. Note that the boards were generated using a computer-controlled milling machine, a method I have used before in several of my projects. It is almost as efficient as a printed circuit board (PCB) and easier for me to generate than going

through the PCB process. All of this was done before I soldered a single component to a board. Again, “noodling” at the onset pays attention to the circuit interactions.

Figures 4 and 5 show the finished boards with parts stuffed on them.

A close look at the boards also brings out a second disadvantage of going the SMD route. As space is condensed through building on just two boards, the circuit module approach that enabled a significant amount of experimentation and circuit block evaluation in the original LBS is somewhat lost. The tight packaging and multiple purposes of each board makes individual circuit changes much more difficult at a later date. Making individual boards for each circuit defeats the idea of reducing space.

The obvious answer to achieve both worlds would be to make an intermediate LBS with SMD parts and individual boards for each circuit. Then once all experimentation was finished, a final version with multi-circuit boards could be constructed. Even then, some interaction effects might be experienced by the pro-

cess of bringing circuits closer together. This approach is again another reason for saying that LBS II is not a detailed construction article.

Now let’s look at some of the individual circuits. Figure 6 is the Microphone Amplifier Circuit as used in the original LBS. Figure 7 is that same circuit done in Surface Mount. The Microphone Amplifier in Figure 7 is also, with a slight modification, the audio Pre-Amp stage used on receive. Thus, the layout used in Figure 7 can be simply transferred over to the Audio Pre-Amp portion of Figure 8. Three surface mount devices are used in the LM386 portion of the new audio amplifier: the 100 nF capacitor, the 10 ohm and the 100 ohm resistors. I used 1208 sized devices as they are capable of higher heat dissipation. All other components in the final audio stage are leaded components. By the way, the new audio amplifier stage shown in Figure 8 can also be simply incorporated into the original LBS project if the reader so desires. However, we found the original circuit of LBS-I to be perfectly satisfactory.

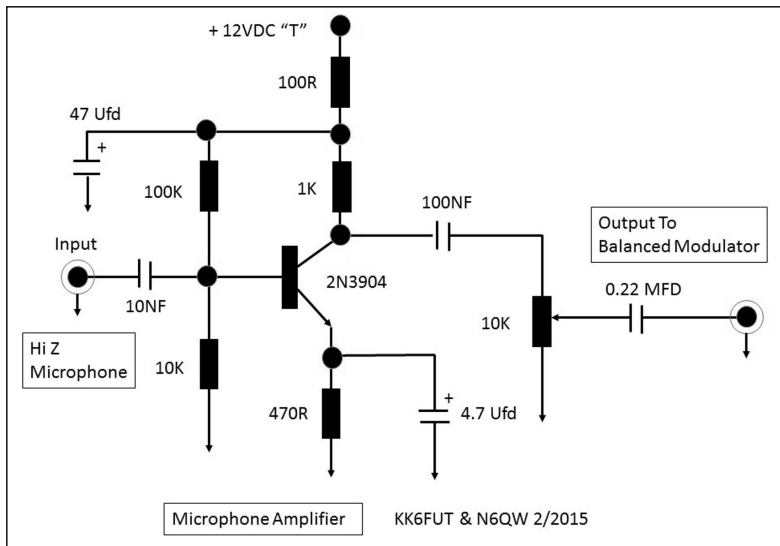


Figure 6—The Microphone Amplifier circuit.

Also, I note that many readers will look at Figure 7 and see a 100 uF bypass cap in the 2N3904 stage and Figure 8 shows a 47 uF in the 2N3904 stage. There is a simple answer—I only had 100 uF surface mount devices. Both values will work equally well in both circuits, so I used what I had available. This means that the microphone amplifier can be replicated and used as the Audio Pre-Amplifier.

My initial build used a homebrew 5.185 MHz four pole crystal filter. It worked great on USB (actually because of the frequency inversion of the mixing process it was a LSB filter) but not so good on LSB. It was a quick and dirty selection of the crystals and no real rigorous effort to measure the various parameters and on and on. It was as I frequently say “Good Enough”! But I did consider other frequencies and subsequently purchased a four pole 9.0 MHz filter from INRAD which is now in the circuit. This 4 pole filter is easy to incorporate and the builder is supplied both SMD and leaded capacitors so the choice is yours. I built the filter on a small circuit board, using the pattern in Figure 9 and incorporating the SMD capacitors. It now is soldered into the LBS-II. I strongly recommend this filter and think it is a good buy. With the Si5351, a few lines of code change and you have a new IF frequency.

The Color Display is another cool “add on” and the wiring of that unit using the Pro-Mini is shown in Figure 10. The Arduino sketch code for the color display can be found on the link provided earlier.

The Pro-Mini is a stripped down version of the Nano. In retrospect, the Nano would have perhaps been a better choice as it has a built in Serial Interface and 3.3 VDC on board regulator needed for the TFT Color Display. In any event, you will need the display libraries in the file folder. Simply cut and paste the text in an Arduino IDE 1.6.3 blank sketch. So, I guess what I said about this not being a construction project is not entirely true. The source code for the 128 x 128 Color TFT Display can be found on my website link provided earlier and contains the 9.0 MHz values. If the Pro-Mini is used, you will also need the USB to serial convertor to load or make any changes to the code. A front panel

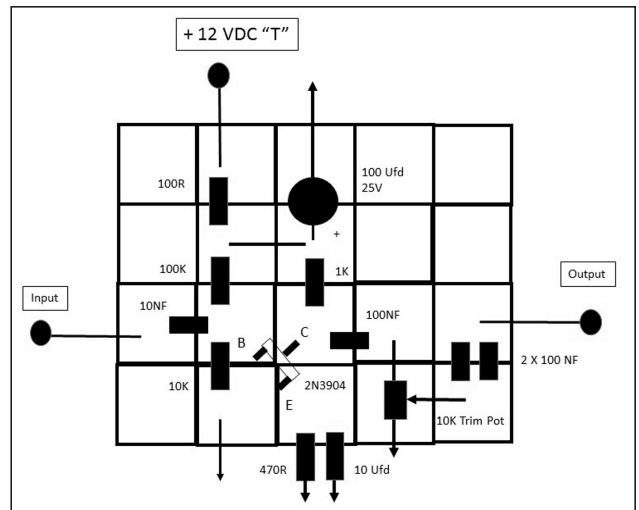


Figure 7—SMD layout for the Microphone Amplifier circuit. The 10 uF capacitor is non-polarized.

view of the completed LBS-II is shown in Figure 11.

There are some subtleties using this new code including the TUNE function, auto tripping of the PTT and a pulsed plus shaped audio tone which is introduced into the balanced modulator. A press of the Tune button shows up on the display in red as “TUNE”, the PTT is tripped and a 7 second pulsed (and shaped) 988 Hertz audio tone is pumped through the radio.

Considerations Associated with Surface Mount Building

- Circuit Layout is critical as there simply are no extra lead lengths to bend around parts to connect wires such as you might

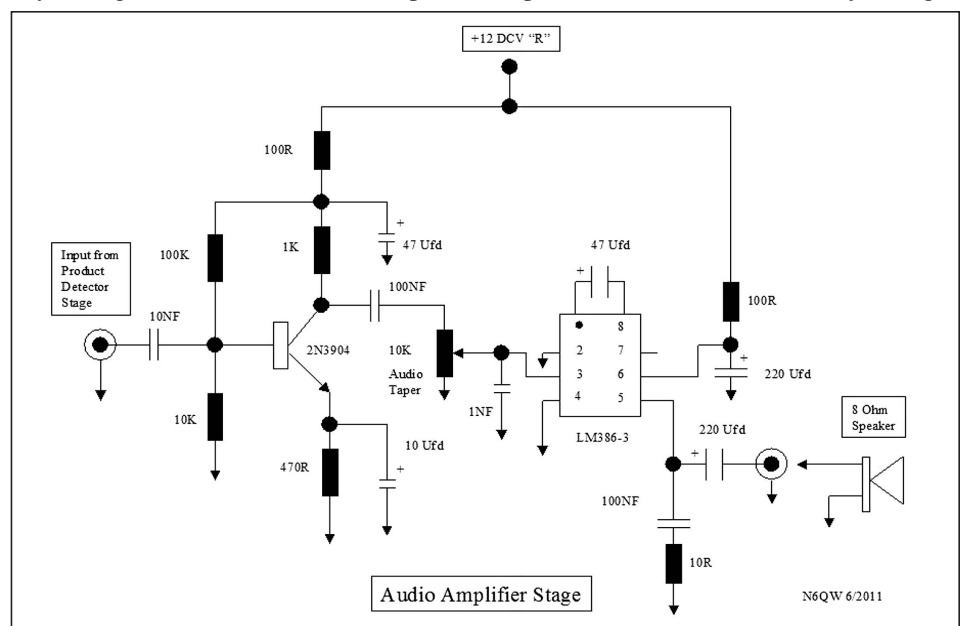


Figure 8—Audio Amplifier stage for LBS-II.

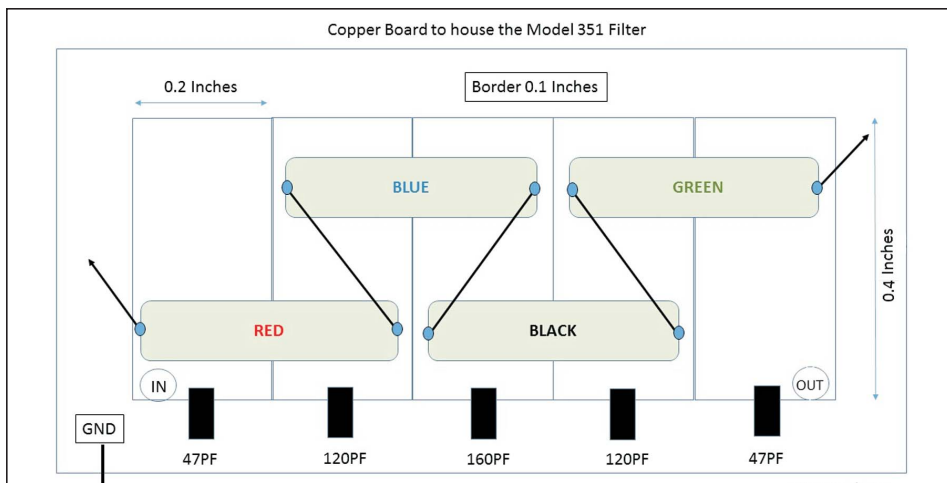


Figure 9—Circuit Layout for Inrad 9 MHz filter.

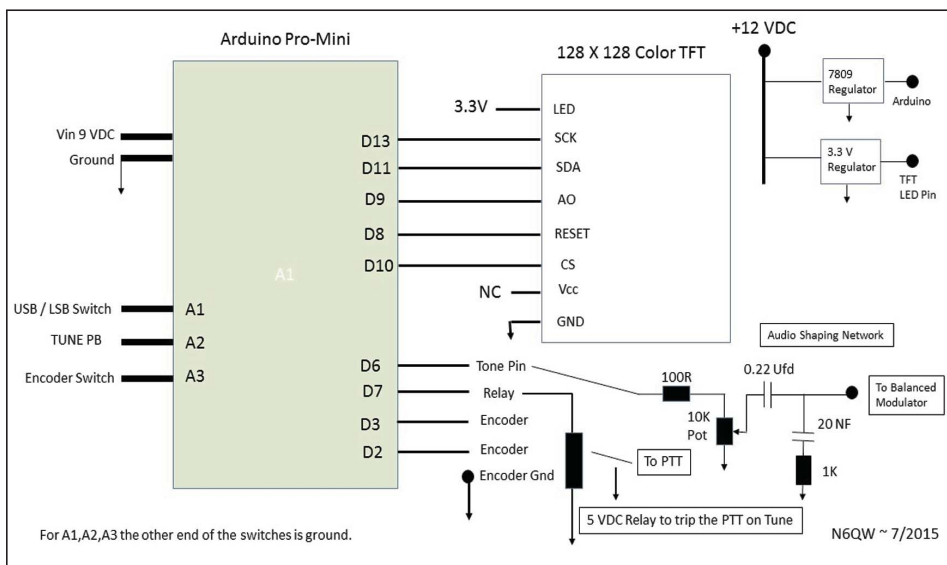


Figure 10—Circuit for Arduino Pro Mini and new TFT display.

	Circuit Element	Comments
1	Microphone Amplifier	Few components and easy layout (Figure 8)
2	Audio Amplifier	The pre-amp stage (2N3904) is the same circuit as built for the Microphone Amp. A leaded LM-386-3 is used for the output device. The final audio amplifier stage uses both SMD and leaded parts. (Figure 8 partially repeated)
3	Bi-Directional Stage	Uses mostly SMD but the 2N3904 is a TO-92 device that is capable of a higher collector dissipation. The trim pot and the matching transformers are not SMD.
4	Bilateral Amplifiers	Probably difficult without having a specific layout
5	Relays	MeSquares (from W1REX) work very well

Table 2—Candidate Boards for SMD transition.

have in Ugly Construction. Using graph paper for the circuit layout can be very helpful in the successful use of surface

mount parts. Soldering hardware is the very last thing you do! Care must be exercised in the purchase of surface

mount parts as they come in varying sizes. The 1206 sized parts are by far the easiest to use as they can actually be seen and reasonably pushed into place for soldering. For the 0402 sized parts you need a microscope and automated soldering.

- Wattage rating is critical as I found out! The 1206 sized parts have a much higher wattage rating than the 0402 size. The 1206 parts are typically 1/8 watt which makes them OK for anything that is not handling any sort of power such as you would have in bias and/or circuits that carry RF. In the LBS-II, I am now observing what I call a power drift. On transmit, the initial power level readings are somewhat higher than after a few minutes of talking away. I attribute that to various resistors getting very warm and shifting values. I used what parts I had in stock and many of those were not 1206 and thus have the results I am seeing. Watts count whether leaded or surface mount.
- Transistors are another area of consideration relative to heat and collector dissipation. The 2N3904 surface mount transistors work exceptionally well in the microphone amp, audio preamp and as a part of the bilateral amps. They have a device rating of about 200 mW. But in the bidirectional stages that rating is marginal. So while the bi-directional amps used surface mount resistors and capacitors, the 2N3904's were leaded since they have a device dissipation of 600 mW.
- The close spacing created in part by the small size of the parts can cause unwanted coupling. This is where looking at the real estate allocation becomes critical—you DON'T want the output to be near the input or you are setting up ripe conditions for self-oscillation.
- Trouble shooting after the circuit is built is very difficult—there is hardly any location/or room to place a scope probe. Solder splashes are a killer. So examine well the particular circuit element before applying any power. Consideration should be made to providing test pads within the circuit area. Unfortunately, this was an afterthought on my part.
- Surface mount requires some “fixtures and shop aids” for parts placement and holding parts in place during the soldering process. There have been descrip-

tions of such devices in *QQ* and other ham publications. I keep things simple by using masking tape to hold the board to the work bench and a 0.5 mm mechanical pencil with soft lead to hold the part down while I solder. An 80 watt Radio Shack soldering iron is not the iron of choice. And finally, a bench vise is useless to hold the SMD parts in place for this application!

- For those who would like to use the WIREX MeSquares for the surface mount build of the microphone amplifier, unfortunately the gap spacing between the squares is too large for straddling the SMD 2N3904 across three squares. Using the 1206 parts, these will straddle the gap OK and you could use a leaded part for the 2N3904. The MeSquares will also work for the Relays as shown in the table. So this would be a viable approach for gaining experience with SMD. I have contacted Rex, WIREX and there currently are no plans to manufacture smaller squares with a lesser gap.
- In learning a new technique, it is always best to take small step and learn from that experience before “taking on the whole enchilada”. Below is a matrix of suggested builds where the necessary skills can be learned so that more complex builds are built with confidence. This is just another way of introducing an intermediate build between LBS-I and LBS-II. We start with the microphone amplifier Figure 8, as it has but few components and can be built in a relatively short period of time. Once built, this module can be substituted directly into the LBS transceiver. The first three circuit candidates can be built on island squares. The RF stages (2N3904/2N3866 and the IRF510) were kept as leaded circuits given the required wattage level of the various resistors. But these circuits were not evaluated beyond just that initial consideration. There are surface mount RF devices that could easily produce the same power level but that introduces a whole range of additional concerns/problems. The LBS-II is not the smallest SSB



Figure 11—The completed LBS-II SSB transceiver.

transceiver I have built! The 20M Shirt Pocket Transceiver which appeared in the summer 2011 Edition of *QRP Quarterly* is indeed smaller. But the same issues apply such as power dissipation, shielding and circuit layout. Basically, the LBS and LBS-II have many of the same circuit elements as that 2011 Shirt Pocket project and I even commented in that article that the use of surface mount would shrink the size even further. I would like to amend that comment by saying that the smaller size would have to be driven by a commercial circuit board. Even though the two boards are a mere 2.5 x 4.5 inches—there is much wasted space. There are no commercial boards or kits available. I will leave that to others. I ask that you not contact me regarding supplying boards as I am not set up to do printed circuit boards. However, I would be happy to supply the .dxf files that could be converted to G Code for CNC milling.

Some Final Comments

My earlier caution about not building this project is aimed squarely at not attempting to duplicate an LBS-II. But, I am encouraging the readers to take some of the suggested circuit elements and convert them to surface mount and incorporate them into their LBS. This approach enables the development of SMD application skills and while giving hands on expe-

rience. The LBS provides the test bed for evaluating the converted SMD boards.

Things you would never expect frequently show up in a project where you have close quarters! Most of the testing and quite a few QSOs were made with the cover removed. I noted that when I installed the cover there seemed to be a power reduction and the receiver seemed less sensitive. The old wives tale that toroids are self-shielding may not be entirely true. During the course of beta besting the LBS-I, the Band Pass Filter was changed to T-68-2 cores (18 Turns #20 and the link now 3 Turns). What I had installed in there initially had somewhat of a reduced bandwidth. (The photos show a T-50-6). That change improved the bandwidth of the Band Pass Filter. But the cores are larger and when the galvanized sheet metal case was put in place, there was a de-tuning of the BPF with the cover installed because of the close proximity of the cores to the case. So the final configuration now contains a shield of the same material which is soldered to the top board and has tuning access holes. Once tuned with the shield in place, putting the cover back on does not change the tuning of the network.

Finally, a few words about thermal heat generation. Appreciable heat is generated in the LBS-II with the circuits so closely packed. Initially, my plan was to have a solid top on the radio. After installing the solid top cover, I noticed that after a few hours of operation it was warm to the touch. This necessitated cutting a rectangular hole in the top cover and installing some grill work. Thinking back, I had the same issue with the larger version of the shirt pocket transceiver and that issue was resolved in the same manner. If I could find one of the small clip on fans used with the early Pentium 4 CPUs this would be an ideal solution. Yes, there are even pins available on the Pro-Mini which would allow this fan to be controlled with a thermal switch for activating the fan. It's there; why not use it!

—73, Pete N6QW

