

AAØZZ / WB9JPS IQPro LNA/LPF

Low Noise Amplifiers and Low Pass Filters with Automatic Selection with Frequency

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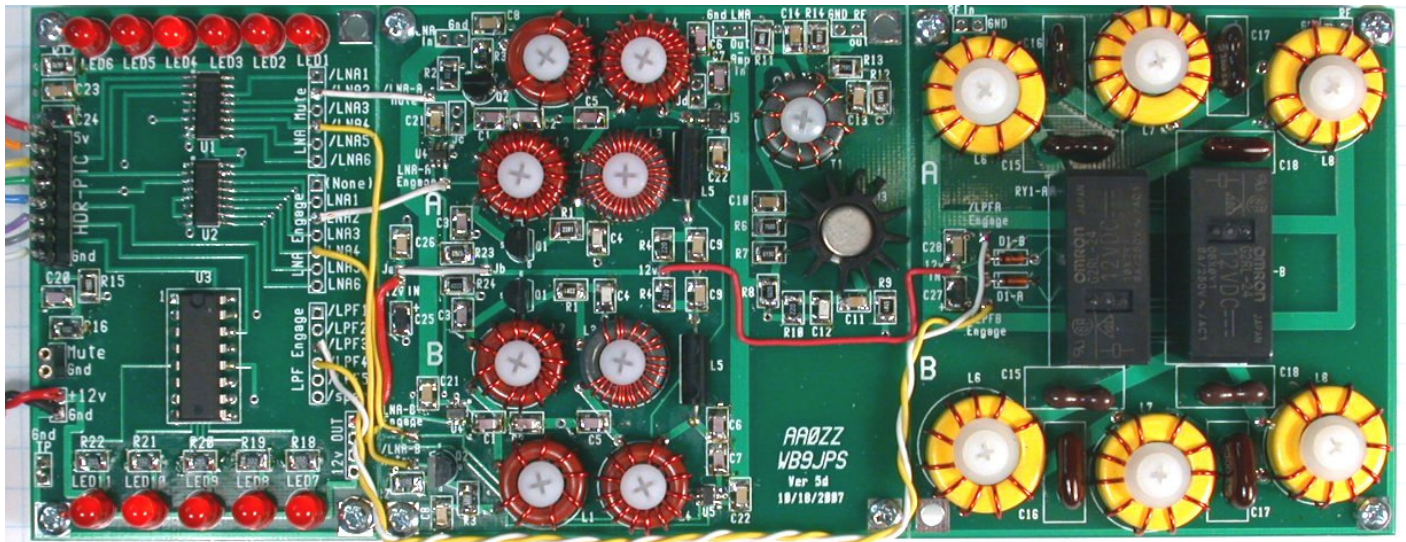


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1 Introduction

The IQPro is a DDS VFO with dual outputs (I and Q) that tunes continuously from 0 to 30 MHz. It is designed to work with direct conversion receivers (such as the R2Pro) as well as multi-band transmitters. However, most people have been using the R2Pro in single or dual band rigs because the R2Pro needs different Low Noise Amplifiers (LNAs) for different frequency ranges. These LNAs provide a couple of functions. They amplify the input signals coming from the antenna before going to the receiver mixer and they provide reverse isolation so that the receiver doesn't send signals back out to the antenna.

In addition to the need for band-specific LNAs, the multi-band transmitter also needs different Low Pass Filters (LPFs) for different frequency ranges to prevent harmonics from being transmitted.

As the IQPro frequency changes to the different frequency ranges, it generates control signals which go to an output header. The intent was to provide a way to activate external circuitry to automatically switch to the correct LNA and LPF as the frequency changes. This LNA / LPF board does just that.

2 Theory of Operation

2.1 Background

The IQPro was developed with the idea that the latching relays would engage the appropriate Low Pass Filter on the transmitter's output. The IQPro Driver PIC code has outputs for four data lines plus "set" and "reset" signals for latching relays. These signals are routed to header HDR5, along with 5 V power and ground. The intent was for the IQPro to operate with six filter bands with one LNA and one LPF paired for each band. Thus one dedicated line would be dedicated for each frequency band and that line would go active, along with a "set" or "reset" signal, to engage or disengage the LNA and LPF relays for that frequency band. (Note that these bands were not the same as the ham bands.) The IQPro Driver PIC sent relatively short pulses (8 ms) to set or reset the latching relays.

During implementation of this LNA/LPF board we discovered that the scheme to use six bands of paired LNAs and LPFs did not work because the frequency ranges for the LNAs were different from the ranges of the LPFs. This made it quite a bit more complicated. (See the Frequency Scheme section below.) We also decided to use non-latching RF switches and non-latching LPF relays. The pin assignments for the six data pins on header HDR 5 were changed to three binary bits for the LNA number and three binary bits for the LPF number. The LNAs and LPFs were no longer paired and could be changed independently as needed. Of course, there was no longer a line per band so logic decoder chips were implemented in the LNA/LPF board to decode the binary bits to RF switch and relay "engagement" lines. Additional logic decoder chips were used to operate the "mute" circuits in the LNAs.

A basic LNA/LPF PC board consists of a control section, an LNA section (containing two LNAs), a buffer-amplifier / pad section, and an LPF section (containing two LPFs). There are "snap-off" break lines between the sections. The builder will start off by selecting two bands for the "base" board and completely building all sections of this board. Then, to add two more LNAs and two LPFs, the builder gets another board, "snaps" off the control section, installs the LNA and LPF components, and attaches the board "sandwich style" with corner spacers above the previous board. Up to three sandwich layers are possible. The builder can chose whether he wants to leave the LPF sections attached or to split the LPFs off into a

stand-alone “sandwich”. With the frequency scheme outlined below, six LNAs (plus the “coax jumper” for the lowest frequency “no LNA” range) and five LPFs are used to cover the 0 - 30 MHz range.

There are "buses" at the edges of the sections. This means that any single LNA and LPF can be engaged by attaching its input and output to the buses. Vertical wires connect the various buses at the board edges. Two electronic switches (SPST) engage the proper LNA (input and output) as the IQPro frequency changes and a MOSFET controls the mute for each LNA. Then, since the LPFs are designed to be attached to the output of the transmitter, it must handle more power than the LNA. For this reason, electronic switching could not be used for the LPFs so heavy-duty non-latching relays are used instead. (How much power can the relays handle? I'm not quite sure but it's much more than QRP power.)

2.2 Control Section

The control section has three "decoder" ICs in it. The six band-switch control signals coming from the IQPro are attached to the input header via a wiring harness and the signals are interpreted by three decoders. One engages the appropriate LNA, one mutes all unused LNAs, and one engages the appropriate LPF. A second input header in the control section brings the mute signal from the builder's T/R switch to the second decoder. The third decoder is a different type, since it must handle more power — to engage and hold the selected relay. (In this case, the device port is low-active and "sinks" the current from the LPF 12 V source.)

2.3 LNA Section

Two LNAs (with mutes) are on each board. They are common-gate JFET amplifiers with bandpass filters and 10 dB of gain, and are exactly the same as the R2Pro designs. Two Hittite HMC550 (SPST) switches are used for each LNA, one to connect the LNA to the input bus and one to connect it to the output bus. One control wire runs from the control section to each LNA to operate the two switches to engage the LNA. The Hittite switches were selected (by Gary) because of their small size and low loss switching characteristics. They are non-latching, normally open switches.

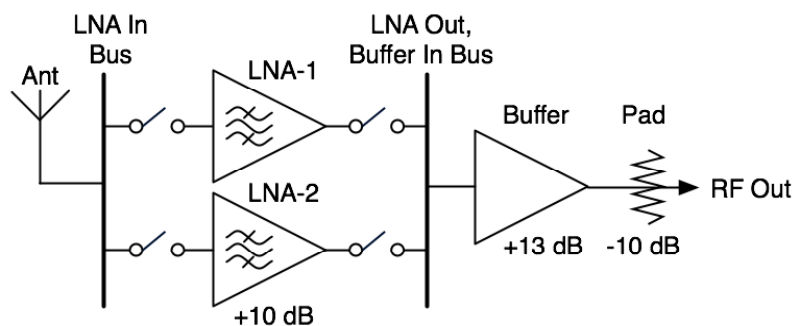


Figure 1

By the way, the builder has great flexibility regarding which LNAs and LPFs he will put in the various "sandwich" layers. He just has to connect the appropriate control section wires to the corresponding LNA and/or LPF input pads. If the builder just wants two bands, he can select them and connect the appropriate control section wires. Add two more bands later with LNA board shown in Figure 2, etc. Easy and flexible.

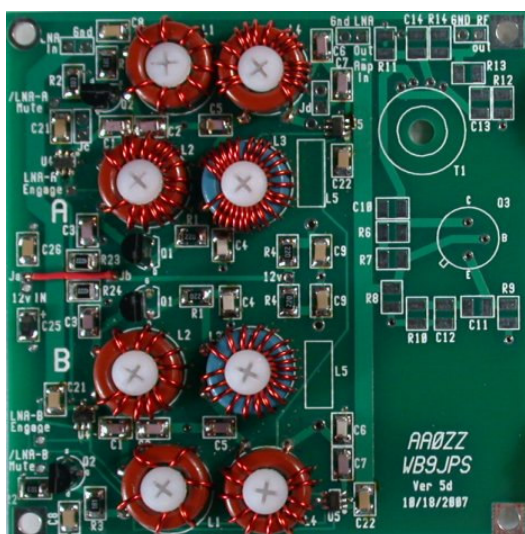


Figure 2
Add-on LNA Board (2 bands)

2.4 Buffer-Amplifier / Pad Section

One buffer-amplifier / pad is used for the entire project. It is always attached to the LNA output bus. The output of the buffer-amplifier / pad goes off-board to the receiver antenna input port. Note that the LNA output is being amplified and then padded back (by 10 dB) such that the receiver mixer always sees a 50 ohm drive. (Rick Campbell, KK7B, says the R2Pro will then "love it". Thanks to Rick and Wes Hayward, W7ZOI, for this basic buffer design and to Gary for his modifications.)

2.5 LPF Section

The LPF section has input and output buses, since its input is taken from the output of the transmitter. If the builder wants to move the LPF "sandwich" to another location (i.e, near the transmitter) he just has to "snap off" all the LPF sections and move the LPF "sandwich". He will still have to run control wires, of course, but it's only one wire per band, plus 12 V power. The filters are seventh-order Chebyshev designs when using the components in the parts list. This guarantees sufficient second- and third-harmonic rejection for all amateur bands regardless of whether your transmitter is class AB or C. The builder can of course modify these filters in any way he chooses, but make sure they stay compatible with the frequency scheme, below. Figure 3 shows an add-on LPF board for two additional bands.

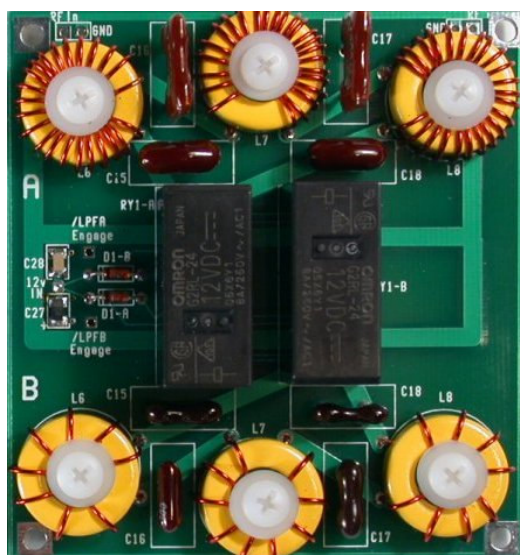


Figure 3
Add-on LPF Board (2 bands)

2.6 Frequency Scheme

The current scheme is not what I originally planned for the LNA/LPF project when I developed the IQPro. I changed it because the situation was more complicated than originally envisioned and the planned scheme was not sufficient. I originally planned to have one IQPro output pin per band and expected latching band relays to be driven directly from the IQPro's band-switch header. However, as it turns out, there are more bands than originally planned because the LNAs and LPFs don't always switch in tandem as the frequency changes.

This is the current scheme with 10 frequency ranges:

| Band | Low Frequency | Upper Frequency | LNA Number | LPF Number |
|---------------|---------------|-----------------|------------|------------|
| Below 160 MHz | 0 | 1.799 MHz | (none) | 1 |
| 160 meters | 1.8 MHz | 3.499 MHz | (none) | 1 |
| 80 meters | 3.5 MHz | 6.999 MHz | 1 | 2 |
| 40 meters | 7.0 MHz | 10.099 MHz | 2 | 3 |
| 30 meters | 10.1 MHz | 13.999 MHz | 3 | 3 |
| 20 meters | 14 MHz | 17.999 MHz | 4 | 4 |
| 17 meters | 18.0 MHz | 20.999 MHz | 5 | 4 |
| 15 meters | 21.0 MHz | 24.899 MHz | 5 | 5 |
| 12 meters | 24.9 MHz | 27.999 MHz | 6 | 5 |
| 10 meters | 28.0 MHz | 30 MHz | 6 | 5 |

This scheme uses the six LNAs designed by Rick Campbell for the R2Pro and it has five LPFs,

2.7 Input Header

Implementing this scheme means new IQPro Driver PIC code is required. Now, three band-switch header pins will be used to specify the LNA and the other three will be used to specify the LPF.

The 8-pin header brings the signals from the IQPro into the LNA/LPF board. Here is the encoding scheme:

| Pin | Signal |
|-----|-----------------------------|
| 1 | +5V |
| 2 | LNA Least Significant Digit |
| 3 | LNA Middle digit |
| 4 | LNA Most Significant Digit |
| 5 | LPF Least Significant Digit |
| 6 | LPF Middle digit |
| 7 | LPF Most Significant Digit |
| 8 | Ground |

When all LNA/LPF signals are LOW there will be NO LNA LED lit but the right-most LPF LED will be on. LNA-0 is used for the "bypass LNA" and it does activate the LNA - (None) pin. There is no MUTE signal for LNA-0 since the bypass LNA is simply a coax jumper between the input and output RF switches. This LNA-(None) pin can be connected to an LNA side "A" section and a piece of coax can be connected between the input pads (Jc plus it's ground pad) and output pads (Jd plus it's ground pad). The IQPro Driver PIC code will select the "bypass LNA" when the frequency is below 3.5 MHz. You can test the pin with a voltmeter and see this pin has +5 V when all three LNA inputs are zero.

On the other hand, when all three LPF inputs are zero, the first LPF is selected and the first (right-most) debug LED is lit. There is never a bypass LPF condition.

2.8 Non-latching RF Switches and Relays

The signals on the IQPro band-switch header are held constant for the frequency it is in. The decoder logic of the control section of the LNA/LPF board then holds the engage and mute signals constant to engage the RF switches of the selected LNA, engage the signal which "un-mutes" the selected LNA, and activate the non-latching relay for the selected LPF.

Appendix A – Assembly Notes

Note: THIS IS NOT INTENDED TO BE AN ALL-INCLUSIVE SET OF ASSEMBLY STEPS!

- 1) The silk-screen polarity marking for capacitor C27 is incorrect. The positive side of this capacitor should be toward the middle of the board.
- 2) You need to install a jumper in the center of the board, between the two LNAs, from pad Ja to pad Jb. There is a silk-screened line there.
- 3) You need to install the heat sink (included) on the 2N5109 transistor. It gets pretty warm.
- 4) The silk-screen outline for L6 on the LPF-A side is missing. The mounting holes are there and the L6 label is there but no concentric circles. Make it just like L6 on LPF-B.
- 5) When installing the 2N5107 “metal can” transistor, lift it a little off the board to make sure it doesn’t short out the pins. You can install a spacer under it if you want to. It should be OK as is but make sure.
- 6) You need to connect the grounds of the control section and the LNA section. One way is to put a wire under the heads of the two mounting screws in lower right corner of the control section and the bottom left edge of the LNA section. One ground connection is necessary per “layer”.
- 7) You may configure and connect the components for any band in any position on any board. It’s just a matter of you keeping track. Just remember that the LNA and LPF numbers described in the chart above determine which enable and mute signals will be activated as the IQPro frequency changes.
- 8) Examine the tiny Hittite HMC550 switches carefully before installing. There is a tiny dot by pin 1, and also the label is right-side-up when pin one is at the lower left, when looking at the top of the package.

Appendix B – Schematic

Multi-band LNA/LPF v5e

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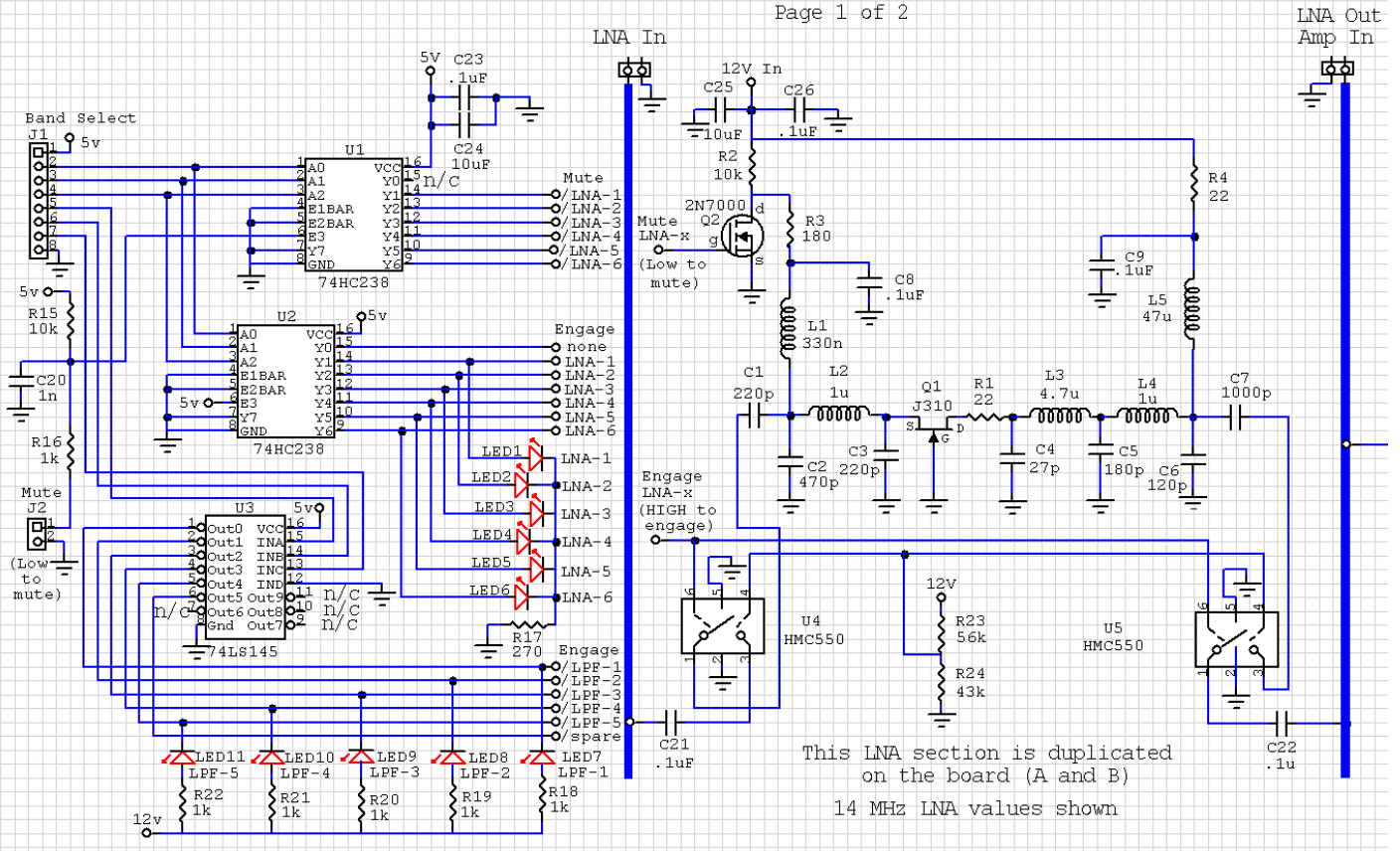


Figure 4
LNA/LPF Board Schematic Page 1 of 2

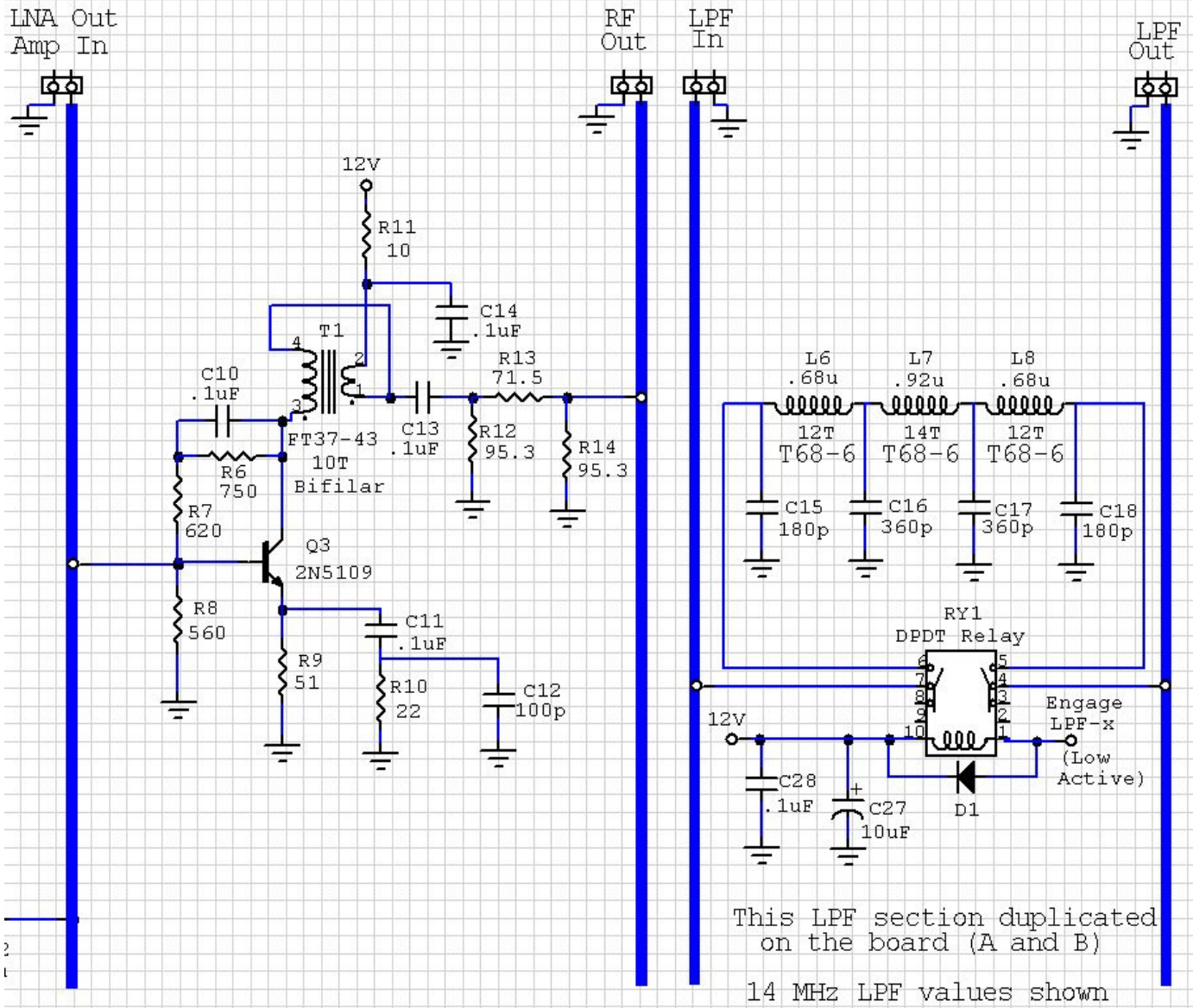


Figure 5
LNA/LPF Board Schematic Page 2 of 2

Appendix C - Parts List

LNA-LPF Board Parts

V9c

2/19/2008

Base Board (Control Section, 2 LNAs, buffer-amp/pad, 2 LPFs)

| Quantity | Designator | Description | (D) DigiKey (M) Mouser or Other | Small Quantity Price | Total at Small Quantity Price |
|------------------------------------|---|-----------------------|---------------------------------------|----------------------------|--|
| Resistors SMT 1210, 1/4w 1% | | | | | |
| 1 | R13 | 71.5 ERJ-14NF71R5U | (D) P71.5AACT-ND | \$0.38 | \$0.38 |
| 2 | R12, R14 | 95.3 ERJ-14NF95R3U | (D) P95.3AACT-ND | \$0.38 | \$0.76 |
| Resistors SMT 1206, 1/4w 5% | | | | | |
| 1 | R11 | 10 CRCW120610R0JNEA | (D) 541-10ECT-ND | \$0.04 | \$0.04 |
| 5 | R1(x2), R4(x2). R10 | 22 CRCW120622R0JNEA | (D) 541-22ECT-ND | \$0.04 | \$0.20 |
| 1 | R9 | 51 CRCW120651R0JNEA | (D) 541-51ECT-ND | \$0.04 | \$0.04 |
| 2 | R3(x2) | 180 CRCW1206180RJNEA | (D) 541-180ECT-ND | \$0.04 | \$0.08 |
| 1 | R17 | 270 CRCW1206270RJNEA | (D) 541-270ECT-ND | \$0.04 | \$0.04 |
| 1 | R8 | 560 CRCW1206560RJNEA | (D) 541-560ECT-ND | \$0.04 | \$0.04 |
| 1 | R7 | 620 CRCW1206620RJNEA | (D) 541-620ECT-ND | \$0.04 | \$0.04 |
| 1 | R6 | 750 CRCW1206750RJNEA | (D) 541-750ECT-ND | \$0.04 | \$0.04 |
| 6 | R16, R18-R22 | 1.0K CRCW12061K00JNEA | (D) 541-1.0KECT-ND | \$0.04 | \$0.24 |
| 3 | R2(x2), R15 | 10K CRCW120610K0JNEA | (D) 541-10KECT-ND | \$0.04 | \$0.12 |
| 1 | R24 | 43K CRCW120643K0JNEA | (D) 541-43KECT-ND | \$0.04 | \$0.04 |
| 1 | R23 | 56K CRCW120656K0JNEA | (D) 541-56KECT-ND | \$0.04 | \$0.04 |
| Capacitors | | | | | |
| Capacitors SMT 1206, 5% | | | | | |
| 2 | C1(x2) | (See LNA data) | (See LNA data) | \$0.51 | \$1.02 |
| 2 | C2(x2) | (See LNA data) | (See LNA data) | \$0.51 | \$1.02 |
| 2 | C3(x2) | (See LNA data) | (See LNA data) | \$0.51 | \$1.02 |
| 2 | C4(x2) | (See LNA data) | (See LNA data) | \$0.51 | \$1.02 |
| 2 | C5(x2) | (See LNA data) | (See LNA data) | \$0.51 | \$1.02 |
| 2 | C6(x2) | (See LNA data) | (See LNA data) | \$0.51 | \$1.02 |
| 2 | C7(x2) | (See LNA data) | (See LNA data) | \$0.51 | \$1.02 |
| 15 | C8(x2), C9(x2), C10, C11, C13, C14, C21(x2), C22(x2), C23, C26, C28 | .1u X7R 10% 1206 | (D) 311-1179-1-ND | \$0.10 | \$1.47 |
| 1 | C12 | 100p NP0 5% 1206 | (D) 478-1480-1-ND | \$2.00 | \$2.00 |
| 2 | C15(x2) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$3.50 |
| 2 | C16(x2) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$3.50 |
| 2 | C17(x2) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$3.50 |
| 2 | C18(x2) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$3.50 |
| 1 | C20 | 1000p NP0 5% 1206 | (D) 478-1492-1-ND | \$0.51 | \$0.51 |
| 3 | C24, C25, C27 | 10u Tantalum 16v | (D) 511-1473-1-ND | \$0.33 | \$0.99 |
| Diodes | | | | | |

| | | | | | |
|--------------------------------|---------------------------|--|--|-------------------------------------|--|
| 2 | D1(x2) | 1N4148 DO-35 | (D) 1N4148-TPMSCT-ND | \$0.05 | \$0.11 |
| Transistors | | | | | |
| 2 | Q1(x2) | J310 TO-92 | (D) J310GOS-ND | \$0.46 | \$0.92 |
| 2 | Q2(x2) | 2N7000 TO-92 | (D) 2N7000FS-ND | \$0.26 | \$0.52 |
| 1 | Q3 | 2N5109 TO-39 | (M) 610-2N5109 | \$1.87 | \$1.87 |
| Other | | | | | |
| 2 | U1, U2 | 74HC238 SMD | (D) 296-9188-5-ND | \$0.48 | \$0.96 |
| 1 | U3 | 74LS145 16-DIP | (D) 296-1641-5-ND | \$0.81 | \$0.81 |
| 4 | U4(x2), U5(x2) | HMC550 SOT26 | (www.hittite.com) | \$0.80 | \$3.20 |
| 2 | RY1(x2) | Omron G2RL-24-DC12 | (D) Z147-ND | \$4.03 | \$8.06 |
| 11 | LED1-11 | LED, T1-3/4 (red) | (D) P374-ND | \$0.17 | \$1.85 |
| 1 | Heatsink | TO5 (TO39) for 2N5109 | (D) HS101-ND | \$1.14 | \$1.14 |
| 1 | T1 | FT50-43 toroid 10T bifilar | | \$0.25 | \$0.25 |
| 2 | L1(x2) | (See LNA data) | (See LNA data) | \$0.25 | \$0.50 |
| 2 | L2(x2) | (See LNA data) | (See LNA data) | \$0.25 | \$0.50 |
| 2 | L3(x2) | (See LNA data) | (See LNA data) | \$0.25 | \$0.50 |
| 2 | L4(x2) | (See LNA data) | (See LNA data) | \$0.25 | \$0.50 |
| 2 | L5(x2) | 47uH shielded | (D) DN42101-ND | \$1.68 | \$3.36 |
| 2 | L6(x2) | (See LPF data) | (See LPF data) | \$0.25 | \$0.50 |
| 2 | L7(x2) | (See LPF data) | (See LPF data) | \$0.25 | \$0.50 |
| 2 | L8(x2) | (See LPF data) | (See LPF data) | \$0.25 | \$0.50 |
| 1 | Header J1 | SIP Socket (.100" spacing) (8-pins) | (M) 517-974-01-10 | \$1.29 | \$1.29 |
| 1 | Header J2 | SIP Socket (.100" spacing) (2-pins) | (M) 517-974-01-02 | \$0.92 | \$0.92 |
| 1 | Replacement PIC for IQPro | 16F877A | (Kanga) | \$8.00 | \$8.00 |
| 1 | LNA/LPF Base PCB | PC Board | (Kanga) | \$20.00 | \$20.00 |
| | | | | | ===== |
| | | | Base, Amp, 2 LNA, 2 LPF | | \$84.96 |
| Add-on Dual LNA Board | | | | | |
| Quantity | Designator | Description | (D) DigiKey (M) Mouser or Other | Small Quantity Price | Total at Small Quantity Price |
| Resistors SMT 1206, 5% | | | | | |
| 4 | R1(x2), R4(x2) | 22 CRCW120622R0JNEA | (D) 541-22ECT-ND | \$0.04 | \$0.16 |
| 2 | R3(x2) | 180 CRCW1206180RJNEA | (D) 541-180ECT-ND | \$0.04 | \$0.08 |
| 2 | R2(x2) | 10K CRCW120610K0JNEA | (D) 541-10KECT-ND | \$0.04 | \$0.08 |
| 1 | R23 | 56K CRCW120656K0JNEA | (D) 541-56KECT-ND | \$0.04 | \$0.04 |
| 1 | R24 | 43K CRCW120643K0JNEA | (D) 541-43KECT-ND | \$0.04 | \$0.04 |
| Capacitors SMT 1206, 5% | | | | | |

| | | | | | |
|---|---------------------------------------|------------------|-------------------|--------|--------|
| 2 | C1(x2) | (See LNA Data) | (See LNA Data) | \$0.51 | \$1.02 |
| 2 | C2(x2) | (See LNA Data) | (See LNA Data) | \$0.51 | \$1.02 |
| 2 | C3(x2) | (See LNA Data) | (See LNA Data) | \$0.51 | \$1.02 |
| 2 | C4(x2) | (See LNA Data) | (See LNA Data) | \$0.51 | \$1.02 |
| 2 | C5(x2) | (See LNA Data) | (See LNA Data) | \$0.51 | \$1.02 |
| 2 | C6(x2) | (See LNA Data) | (See LNA Data) | \$0.51 | \$1.02 |
| 2 | C7(x2) | (See LNA Data) | (See LNA Data) | \$0.51 | \$1.02 |
| 9 | C8(x2), C9(x2), C21(x2), C22(x2), C26 | .1u X7R 10% 1206 | 311-1179-1-ND | \$0.10 | \$0.88 |
| 1 | C25 | 10u Tantalum 16v | (D) 478-14xx-1-ND | \$0.33 | \$0.33 |

Transistors

| | | | | | |
|---|--------|--------------|-----------------|--------|--------|
| 2 | Q1(x2) | J310 TO-92 | (D) J310GOS-ND | \$0.46 | \$0.92 |
| 2 | Q2(x2) | 2N7000 TO-92 | (D) 2N7000FS-ND | \$0.26 | \$0.52 |

Other

| | | | | | |
|---|----------------|----------------|-------------------|--------|--------|
| 4 | U4(x2), U5(x2) | HMC550 SOT26 | (www.hittite.com) | \$0.80 | \$3.20 |
| 2 | L1(x2) | (See LNA Data) | (See LNA Data) | \$0.25 | \$0.50 |
| 2 | L2(x2) | (See LNA Data) | (See LNA Data) | \$0.25 | \$0.50 |
| 2 | L3(x2) | (See LNA Data) | (See LNA Data) | \$0.25 | \$0.50 |
| 2 | L4(x2) | (See LNA Data) | (See LNA Data) | \$0.25 | \$0.50 |
| 2 | L5(x2) | 47uH shielded | (D) DN42101-ND | \$1.68 | \$3.36 |

| | | | | | |
|---|----------------|----------|---------|--------|--------|
| 1 | Add-on LNA PCB | PC Board | (Kanga) | \$8.00 | \$8.00 |
|---|----------------|----------|---------|--------|--------|

=====
2 additional LNAs \$26.75

160 Meter add-on Board (Bypass LNA)

| Quantity | Designator | Description | (D) DigiKey (M) Mouser or Other | Small Quantity Price | Total at Small Quantity Price |
|--------------|----------------|----------------------|---------------------------------------|----------------------------|--|
| Other | | | | | |
| 2 | U4(x1), U5(x1) | HMC550 SOT26 | (www.hittite.com) | \$0.80 | \$1.60 |
| 1 | Add-on LNA PCB | PC Board | (Kanga) | \$8.00 | \$8.00 |
| 1 | Coax jumper | RG-188 | (www.thewireman.com) | \$0.49 | \$0.49 |
| 1 | R24 | 43K CRCW120643K0JNEA | (D) 541-43KECT-ND | \$0.04 | \$0.04 |
| 1 | R23 | 56K CRCW120656K0JNEA | (D) 541-56KECT-ND | \$0.04 | \$0.04 |
| 2 | C21, C22 | .1u X7R 10% 1206 | (D) 311-1179-1-ND | \$0.10 | \$0.20 |

=====
"Bypass" LNA \$10.37

Add-on Dual LPF Board

| | | | | | |
|--|--|--|--|--|--|
| | | | | | |
|--|--|--|--|--|--|

| Quantity | Designator | Description | (D) DigiKey (M) Mouser or Other | Small Quantity Price | Total at Small Quantity Price |
|--------------------------------|----------------|--------------------|---------------------------------------|----------------------------|--|
| Capacitors SMT 1206, 5% | | | | | |
| 1 | C28 | .1u X7R 10% 1206 | 311-1179-1-ND | \$0.10 | \$0.10 |
| 2 | C15(x2) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$3.50 |
| 2 | C16(x2) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$3.50 |
| 2 | C17(x2) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$3.50 |
| 2 | C18(x2) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$3.50 |
| 1 | C27 | 10u Tantalum 16v | (D) 478-14xx-1-ND | \$0.33 | \$0.33 |
| Diodes | | | | | |
| 2 | D1(x1) | 1N4148 DO-35 | (D) 1N4148-TPMSCT-ND | \$0.05 | \$0.11 |
| Other | | | | | |
| 2 | RY1(x2) | Omron G2RL-24-DC12 | (D) Z147-ND | \$4.03 | \$8.06 |
| 2 | L6(x2) | (See LPF Data) | (See LPF Data) | \$0.50 | \$1.00 |
| 2 | L7(x2) | (See LPF Data) | (See LPF Data) | \$0.50 | \$1.00 |
| 2 | L8(x2) | (See LPF Data) | (See LPF Data) | \$0.50 | \$1.00 |
| 1 | Add-on LNA PCB | PC Board | (Kanga) | \$8.00 | \$8.00 |
| | | | | | ===== |
| | | | 2 additional LPFs | | \$33.59 |

Add-on Single LPF Board

| Quantity | Designator | Description | (D) DigiKey (M) Mouser or Other | Small Quantity Price | Total at Small Quantity Price |
|--------------------------------|------------|--------------------|---------------------------------------|----------------------------|--|
| Capacitors SMT 1206, 5% | | | | | |
| 1 | C28 | .1u X7R 10% 1206 | 311-1179-1-ND | \$0.10 | \$0.10 |
| 1 | C15(x1) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$1.75 |
| 1 | C16(x1) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$1.75 |
| 1 | C17(x1) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$1.75 |
| 1 | C18(x1) | (See LPF Data) | (Avg price. See LPF Data) | \$1.75 | \$1.75 |
| 1 | C27 | 10u Tantalum 16v | (D) 478-14xx-1-ND | \$0.33 | \$0.33 |
| Diodes | | | | | |
| 1 | D1(x1) | 1N4148 DO-35 | (D) 1N4148-TPMSCT-ND | \$0.05 | \$0.05 |
| Other | | | | | |
| 1 | RY1(x1) | Omron G2RL-24-DC12 | (D) Z147-ND | \$4.03 | \$4.03 |
| 1 | L6(x1) | (See LPF Data) | (See LPF Data) | \$0.50 | \$0.50 |
| 1 | L7(x1) | (See LPF Data) | (See LPF Data) | \$0.50 | \$0.50 |

| | | | | | |
|---|----------------|----------------|-------------------------|--------|----------------|
| 1 | L8(x1) | (See LPF Data) | (See LPF Data) | \$0.50 | \$0.50 |
| 1 | Add-on LPF PCB | PC Board | (Kanga) | \$8.00 | \$8.00 |
| | | | | | ===== |
| | | | 1 additional LPF | | \$21.01 |

All Parts (Base, Amp, 6 LNAs, 5 LPFs)

| | | | | Each | Total |
|---|--|--|----------------------------|---------|-----------------|
| 1 | | | Base, Amp, 2 LNA, 2 LPF | \$84.96 | \$84.96 |
| 2 | | | Add-on Dual LNA board | \$26.75 | \$53.50 |
| 1 | | | Add-on Dual LPF board | \$33.59 | \$33.59 |
| 1 | | | Add-on Single LPF board | \$21.01 | \$21.01 |
| 1 | | | "Bypass" LNA | \$10.37 | \$10.37 |
| | | | | | ===== |
| | | | Total for all bands | | \$203.43 |

LNA Components

| Quantity | Designator | Description | (D) DigiKey (M) Mouser or as specified | Small Quantity Price | Total at Small Quantity Price |
|--|------------|--------------------------|--|----------------------------|--|
| ("Bypass" LNA) 0 - 3 MHz (IQPro uses from 0 to 3.5 MHz) | | | | | |
| LNA 1 3 - 4 MHz (IQPro uses from 3.5 to 7.0 MHz) | | | | | |
| 1 | C1 | 820p NP0 5% 1206 | (D) 478-1491-1-ND | \$0.51 | \$0.51 |
| 1 | C2 | 1800p NP0 5% 1206 | (D) 478-1495-1-ND | \$0.51 | \$0.51 |
| 1 | C3 | 820p NP0 5% 1206 | (D) 478-1491-1-ND | \$0.51 | \$0.51 |
| 1 | C4 | 100p NP0 5% 1206 | (D) 478-1480-1-ND | \$0.51 | \$0.51 |
| 1 | C5 | 680p NP0 5% 1206 | (D) 478-1490-1-ND | \$0.51 | \$0.51 |
| 1 | C6 | 470p NP0 5% 1206 | (D) 478-1488-1-ND | \$0.51 | \$0.51 |
| 1 | C7 | 2200p NP0 5% 1206 | (D) 478-1496-1-ND | \$0.51 | \$0.51 |
| 1 | L1 | 1.25uH T50-2 (16T=1.3uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L2 | 4.12uH T50-2 (29T=4.0uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L3 | 20.25uH T50-1 (45T=20uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L4 | 3.84uH T50-2 (28T=3.8u) | www.kitsandparts.com | \$0.25 | \$0.25 |
| LNA 2 6 - 8 MHz (IQPro uses from 7.0 to 10.1 MHz) | | | | | |
| 1 | C1 | 470p NP0 5% 1206 | (D) 478-1488-1-ND | \$0.51 | \$0.51 |
| 1 | C2 | 820p NP0 5% 1206 | (D) 478-1491-1-ND | \$0.51 | \$0.51 |
| 1 | C3 | 470p NP0 5% 1206 | (D) 478-1488-1-ND | \$0.51 | \$0.51 |
| 1 | C4 | 56p NP0 5% 1206 | (D) 478-1477-1-ND | \$0.51 | \$0.51 |
| 1 | C5 | 390p NP0 5% 1206 | (D) 478-1487-1-ND | \$0.51 | \$0.51 |
| 1 | C6 | 220p NP0 5% 1206 | (D) 478-1484-1-ND | \$0.51 | \$0.51 |
| 1 | C7 | 1000p NP0 5% 1206 | (D) 478-1492-1-ND | \$0.51 | \$0.51 |

| | | | | | |
|---|----|---------------------------|----------------------|--------|--------|
| 1 | L1 | 0.71uH T50-2 (12T=0.68uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L2 | 1.96uH T50-2 (20T=2.0uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L3 | 10.24uH T50-1 (32T=10uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L4 | 1.96uH T50-2 (20T=1.9uH) | www.kitsandparts.com | \$0.25 | \$0.25 |

LNA 3 9 - 11 MHz (IQPro uses from 10.1 to 14 MHz)

| | | | | | |
|---|----|---------------------------|----------------------|--------|--------|
| 1 | C1 | 330p NP0 5% 1206 | (D) 478-1486-1-ND | \$0.51 | \$0.51 |
| 1 | C2 | 680p NP0 5% 1206 | (D) 478-1490-1-ND | \$0.51 | \$0.51 |
| 1 | C3 | 330p NP0 5% 1206 | (D) 478-1486-1-ND | \$0.51 | \$0.51 |
| 1 | C4 | 39p NP0 5% 1206 | (D) 478-1475-1-ND | \$0.51 | \$0.51 |
| 1 | C5 | 270p NP0 5% 1206 | (D) 478-1485-1-ND | \$0.51 | \$0.51 |
| 1 | C6 | 180p NP0 5% 1206 | (D) 478-1483-1-ND | \$0.51 | \$0.51 |
| 1 | C7 | 1000p NP0 5% 1206 | (D) 478-1492-1-ND | \$0.51 | \$0.51 |
| 1 | L1 | 0.49uH T50-2 (10T=0.45uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L2 | 1.42uH T50-2 (17T=1.4uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L3 | 6.76uH T50-1 (26T=6.8uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L4 | 1.42uH T50-2 (17T=1.4uH) | www.kitsandparts.com | \$0.25 | \$0.25 |

LNA 4 13 - 15 MHz (IQPro uses from 14 to 18.1 MHz)

| | | | | | |
|---|----|--------------------------|----------------------|--------|--------|
| 1 | C1 | 220p NP0 5% 1206 | (D) 478-1484-1-ND | \$0.51 | \$0.51 |
| 1 | C2 | 470p NP0 5% 1206 | (D) 478-1488-1-ND | \$0.51 | \$0.51 |
| 1 | C3 | 220p NP0 5% 1206 | (D) 478-1484-1-ND | \$0.51 | \$0.51 |
| 1 | C4 | 27p NP0 5% 1206 | (D) 478-1473-1-ND | \$0.51 | \$0.51 |
| 1 | C5 | 180p NP0 5% 1206 | (D) 478-1483-1-ND | \$0.51 | \$0.51 |
| 1 | C6 | 120p NP0 5% 1206 | (D) 478-1481-1-ND | \$0.51 | \$0.51 |
| 1 | C7 | 1000p NP0 5% 1206 | (D) 478-1492-1-ND | \$0.51 | \$0.51 |
| 1 | L1 | 0.31uH T50-2 (8T=0.33uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L2 | 0.96uH T50-2 (14T=1.0uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L3 | 4.84uH T50-1 (22T=4.7uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L4 | 0.96uH T50-2 (14T=1.0uH) | www.kitsandparts.com | \$0.25 | \$0.25 |

LNA 5 18 - 22 MHz (IQPro uses from 18.1 - 24.9 MHz)

| | | | | | |
|---|----|---------------------------|----------------------|--------|--------|
| 1 | C1 | 180p NP0 5% 1206 | (D) 478-1483-1-ND | \$0.51 | \$0.51 |
| 1 | C2 | 270p NP0 5% 1206 | (D) 478-1485-1-ND | \$0.51 | \$0.51 |
| 1 | C3 | 120p NP0 5% 1206 | (D) 478-1481-1-ND | \$0.51 | \$0.51 |
| 1 | C4 | 18p NP0 5% 1206 | (D) 478-1471-1-ND | \$0.51 | \$0.51 |
| 1 | C5 | 120p NP0 5% 1206 | (D) 478-1481-1-ND | \$0.51 | \$0.51 |
| 1 | C6 | 100p NP0 5% 1206 | (D) 478-1480-1-ND | \$0.51 | \$0.51 |
| 1 | C7 | 1000p NP0 5% 1206 | (D) 478-1492-1-ND | \$0.51 | \$0.51 |
| 1 | L1 | 0.24uH T50-2 (7T=0.24uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L2 | 0.71uH T50-2 (12T=0.76uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L3 | 3.61uH T50-1 (19T=3.5uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L4 | 0.71uH T50-2 (12T=0.76uH) | www.kitsandparts.com | \$0.25 | \$0.25 |

LNA 6 24 - 30 MHz (IQPro uses from 24.9 - 30 MHz)

| | | | | | |
|---|----|------------------|-------------------|--------|--------|
| 1 | C1 | 150p NP0 5% 1206 | (D) 478-1482-1-ND | \$0.51 | \$0.51 |
| 1 | C2 | 220p NP0 5% 1206 | (D) 478-1484-1-ND | \$0.51 | \$0.51 |
| 1 | C3 | 100p NP0 5% 1206 | (D) 478-1480-1-ND | \$0.51 | \$0.51 |
| 1 | C4 | 12p NP0 5% 1206 | (D) 478-1469-1-ND | \$0.51 | \$0.51 |

| | | | | | |
|---|----|---------------------------|----------------------|--------|--------|
| 1 | C5 | 82p NP0 5% 1206 | (D) 478-1479-1-ND | \$0.51 | \$0.51 |
| 1 | C6 | 56p NP0 5% 1206 | (D) 478-1477-1-ND | \$0.51 | \$0.51 |
| 1 | C7 | 680p NP0 5% 1206 | (D) 478-1490-1-ND | \$0.51 | \$0.51 |
| 1 | L1 | 0.18uH T50-2 (6T= 0.16uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L2 | 0.59uH T50-2 (11T=0.56uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L3 | 2.56uH T50-1 (16T=2.7uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| 1 | L4 | 0.49uH T50-2 (10T=0.54uH) | www.kitsandparts.com | \$0.25 | \$0.25 |
| | | | | | |
| | | | | | |

LPF Components

| Quantity | Designator | Description | (D) DigiKey (M) Mouser or www.tedss.com | Small Quantity Price | Total at Small Quantity Price |
|--|------------|------------------------|---|----------------------------|--|
| LPF 1 160 Meters (2.1 MHz cutoff) IQPro activates from 0 to 3.499999 MHz | | | | | |
| 1 | C15 | 1200p Silver Mica 500v | 2020000945 (x2) | \$1.00 | \$2.00 |
| 1 | C16 | 2600p Silver Mica 500v | DM19FD132JO3 (x2) | \$3.00 | \$6.00 |
| 1 | C17 | 2600p Silver Mica 500v | DM19FD132JO3 (x2) | \$3.00 | \$6.00 |
| 1 | C18 | 1200p Silver Mica 500v | 2020000945 (x2) | \$1.00 | \$2.00 |
| 1 | L6 | 5.12 uH T68-6 (33T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| 1 | L7 | 6.09uH T68-6 (36T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| 1 | L7 | 5.12 uH T68-6 (33T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| | | | | \$8.00 | |
| LPF 2 80 Meters (4.1 MHz cutoff) IQPro activates from 3.5 to 6.999999 MHz | | | | | |
| 1 | C15 | 620p Silver Mica 500v | DM15FD621JO3 | \$2.00 | \$2.00 |
| 1 | C16 | 1300p Silver Mica 500v | DM19FD132JO3 | \$3.00 | \$3.00 |
| 1 | C17 | 1300p Silver Mica 500v | DM19FD132JO3 | \$3.00 | \$3.00 |
| 1 | C18 | 620p Silver Mica 500v | DM15FD621JO3 | \$2.00 | \$2.00 |
| 1 | L6 | 2.71uH T68-6(24T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| 1 | L7 | 3.18uH T68-6 (26T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| 1 | L8 | 2.71uH T68-6(24T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| | | | | | |
| LPF 3 40, 30 Meters (10.7 MHz cutoff) IQPro activates from 7.0 to 13.999999 MHz | | | | | |
| 1 | C15 | 360p Silver Mica 500v | DM15FD361JO3 | \$1.50 | \$1.50 |
| 1 | C16 | 620p Silver Mica 500v | DM15FD621JO3 | \$2.00 | \$2.00 |
| 1 | C17 | 620p Silver Mica 500v | DM15FD621JO3 | \$2.00 | \$2.00 |
| 1 | C18 | 360p Silver Mica 500v | DM15FD361JO3 | \$1.50 | \$1.50 |
| 1 | L6 | 1.06uH T68-6 (15T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| 1 | L7 | 1.17uH T68-6 (16T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| 1 | L8 | 1.06uH T68-6 (15T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| | | | | | |
| LPF 4 20, 17 Meters (19 MHz cutoff) IQPro activates from 14.0 to 20.999999 MHz | | | | | |
| 1 | C15 | 130p Silver Mica 500v | DM15FD131JO3 | \$1.00 | \$1.00 |
| 1 | C16 | 300p Silver Mica 500v | DM15FD301JO3 | \$1.25 | \$1.25 |
| 1 | C17 | 300p Silver Mica 500v | DM15FD301JO3 | \$1.25 | \$1.25 |
| 1 | C18 | 130p Silver Mica 500v | DM15FD131JO3 | \$1.00 | \$1.00 |
| 1 | L6 | 0.57uH T68-6 (11T =) | www.kitsandparts.com | \$0.50 | \$0.50 |
| 1 | L7 | 0.68uH T68-6 (12T =) | www.kitsandparts.com | \$0.50 | \$0.50 |

| | | | | | |
|--|-----|-----------------------|----------------------|--------|--------|
| 1 | L8 | 0.57uH T68-6 (11T =) | www.kitsandparts.com | \$0.50 | \$0.50 |
| LPF 5 15, 12, 10 Meters (30.0 MHz cutoff) IQPro activates from 21 to 30 MHz | | | | | |
| 1 | C15 | 82p Silver Mica 500v | DM10ED820JO3 | \$1.00 | \$1.00 |
| 1 | C16 | 180p Silver Mica 500v | DM15FD181JO3 | \$1.00 | \$1.00 |
| 1 | C17 | 180p Silver Mica 500v | DM15FD181JO3 | \$1.00 | \$1.00 |
| 1 | C18 | 82p Silver Mica 500v | DM10ED820JO3 | \$1.00 | \$1.00 |
| 1 | L6 | 0.38uH T68-6 (9T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| 1 | L7 | 0.47uH T68-6(10T) | www.kitsandparts.com | \$0.50 | \$0.50 |
| 1 | L8 | 0.38uH T68-6 (9T) | www.kitsandparts.com | \$0.50 | \$0.50 |

Appendix D – Typical Performance Specifications

Power Consumption for Base Section with 2 LNAs and 2 LPFs

+12 V at 68 mA without an LPF relay engaged, 115ma with one LPF relay engaged

+5 V at 15.6 mA

LNA/Buffer Section

LNA gain: 10±1 dB

Buffer amplifier gain: 13 dB

Pad loss: 10 dB

Net gain, all stages: 3 dB

Noise figure: 5 dB at 14 MHz

Input third-order intercept (IIP₃): +17.5 dBm at 14 MHz

Input return loss within passband: >8 dB

Output return loss: >20 dB, 1-50 MHz

Gain when muted: -37 dB in passband at 14 MHz

Reverse isolation within passband: 65 dB in passband at 14 MHz

System performance with standard R2Pro receiver

Noise figure: 7.7 dB

Minimum detectable signal: -129 dBm

Input third-order intercept (IIP₃): +5.3 dBm

A detailed discussion of design tradeoffs, amplifier choices, and measurements is available in a pair of documents that Gary wrote prior to Craig's final design. You can download these from:

http://web.mac.com/gwj/iWeb/Site/Amateur_Radio_files/R2Pro_LNA_Performance_1.pdf

http://web.mac.com/gwj/iWeb/Site/Amateur_Radio_files/R2Pro_LNA_Performance_2.pdf

Lowpass Filter Section

Power handling: Components should be adequate at the 100 W level.