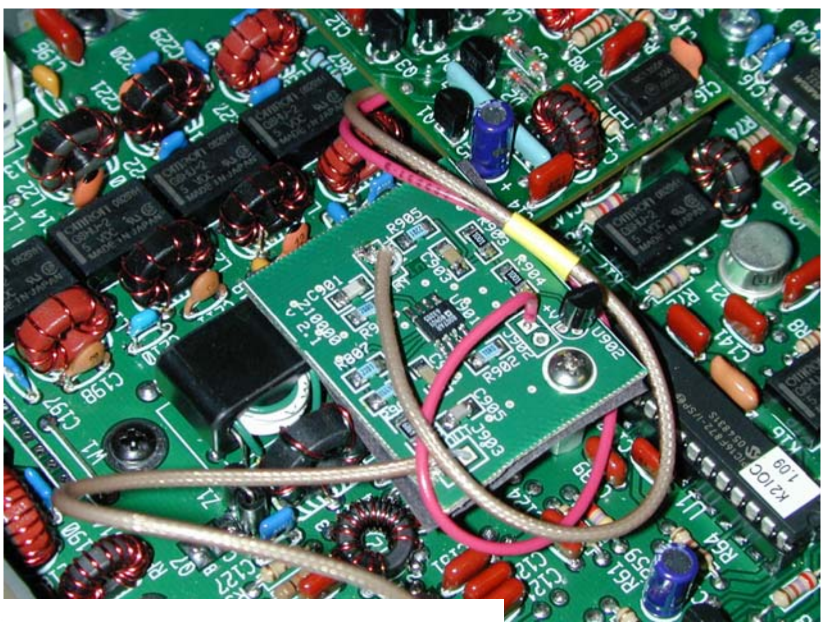
Assembly and Operations Manual

Z10000 Broadband Buffer Amplifier

Elecraft® K2 Version & Universal Version

Version 3.2.1 / 05 January 2009



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Assembly and Operations Manual
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Version 3.2.1 January 2009

Last Revised 05 January 2009

1.0 Introduction and Specifications

1.0 Introduction

Clifton Laboratories' Z10000 IF sampler buffer amplifier is available in two versions:

- Z10000-K2 model—A version optimized to be used with an Elecraft K2 transceiver, with bandpass response shaping for a 4915 KHz IF;
- Z10000-U or "Universal" model—The same PCB as the Z10000-K2, but without the frequency-dependent parts. The Z10000-U is broadband.

The Z10000 is intended to provide a high impedance interface to Clifton Laboratories' Z90 and Z91 SpectraScan Panadapter, but may also be used as a general purpose buffer amplifier.

1.2 Specifications

The Z10000-K2 and –U models share many specifications:

Parameter	**Common to Z10000-K2 and Z10000-U**
Physical size	Approx 1.4" (35 mm) x 1.25" (32 mm). Height approx 0.2" (5 mm) plus clearance for wiring. Mounting hole: clearance for 4-40 machine screw.
Power Requirements	+12V at approx 20 mA. On board regulator permits operation with 30V maximum supply voltage.
Connectors	None. Direct wire (coaxial cable) connection via solder pads. User may install headers (0.1") spacing if so desired.
Gain	User settable via programming resistor. Different maximum and minimum for –K2 and –U models.
Output Impedance	50 ohms; short circuit protected.
Active Devices	78L09 voltage regulator AD8007 amplifier
Reverse Isolation	Typically 80 dB at 4.915 MHz; depends on cable routing as stray coupling becomes important at this level of isolation. Less isolation at higher frequencies. See Section 1.3.3.
Harmonic Distortion (2nd and 3rd harmonic)	Typically 80 dB below carrier; depends on gain setting and input level
3rd order intermodulation distortion	Typically -70 dB below output for signal levels found in receiver input stages. IP3 depends on gain setting and frequency, typically +30 dBm.

Input Signal Level	DC not to exceed 25 volts; AC input level depends on gain setting; typically used with a less than 100 mV PP input.

Parameter	Z10000-K2	Z10000-U
Bandwidth	Flat within ±1 dB over 200 KHz range centered on 4915 KHz. Rolled off above 6 MHz and below 4 MHz.	Depends on gain. If set for +6 dB net gain, usable bandwidth > 100 MHz. (See typical performance plot) Low frequency response extends to below 50 KHz.[1]
Input Impedance	Depends on bias isolation resistor setting; used to provide extra roll off and loss; recommended values range from 1 K to 4.7K ohm	Depends on frequency and attachment technique. Greater than 1.5 K ohm to 10 MHz, (See typical performance plot)
Gain	Depends on R905 & R907 values. Typical maximum gain at 4915 KHz is +9 dB, typical minimum gain is -18 dB	Depends on R907 value. Typical maximum gain at 5 MHz is +14 dB, typical minimum gain is -4 dB

1.3 Typical Performance Measurements

The data presented was taken with several Z10000 amplifiers.

- Unit 1—A production model Z10000-U buffer amplifier equipped with connectors for easier testing, set for net 10 dB gain (nominal[2]). R905 = 4.7K and R907 = 95.3 ohms. A 49.9 ohm surface mount resistor was installed across the test amplifier's input to provide for 50 ohm nominal input impedance.
- Unit 2—A production model Z10000-K2 buffer amplifier, set for a nominal loss of 9.5 dB. (The K2 has significant gain ahead of the recommended Z10000 connection point; hence to provide net 0 dB from K2 antenna port to Z10000 output requires the buffer amplifier to operate with signifcant negative gain (loss).
- Unit 3—A prototype Z10000-U ampllifier, set for 6.7 dB nominal net gain.

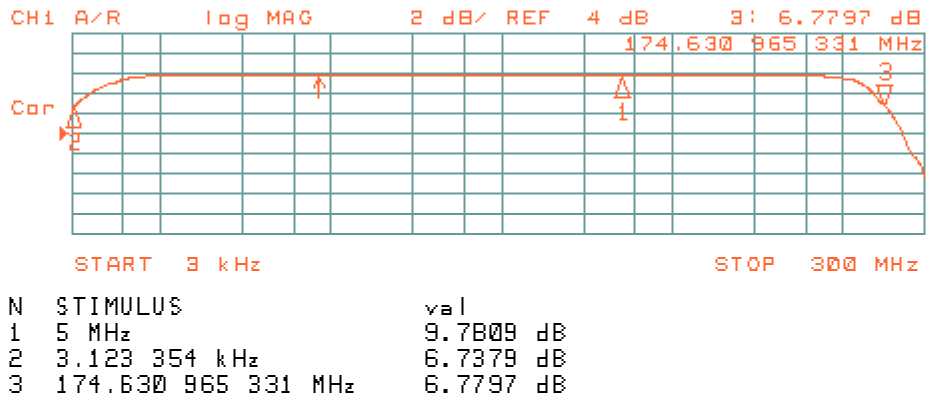
1.3.1 Frequency Response and Gain

[1] It is possible to extend the Z10000's low frequency response to 3 KHz by replacing all 0.22µF capacitors with 1.0µF. The Z10000-U used in the test data presented has this modification.

[2] The theoretical gain for the tested configuration is 9.9 dB, representing 15.9 dB amplifier gain, followed by 6 dB loss resulting from the series 49.9 ohm output series resistance.

The data presented in this manual was taken with two vector network analyzers; a Hewlett Packard model 8752B and an HP model 87510A. Both VNAs assume the device under test is terminated with the network analyzer's impedance, 50 ohms (The 8752B is a 75 ohm test set and is used with minimum loss 75:50 ohm matching pads for all measurements presented.) Since the buffer amplifier's impedance significantly exceeds 50 ohms, a false gain will be observed due to the network analyzer's output voltage nearly doubling (+6 dB gain) into a high impedance load. To prevent this effect from distorting the gain results, all amplifiers under test have their input is terminated with a 49.9 ohm shunt resistor.

At 5 MHz, Unit 1's measured gain is 9.78 dB, only 0.12 dB less than theoretically predicted. The 3 dB bandwidth extends from 3 KHz to 174 MHz.

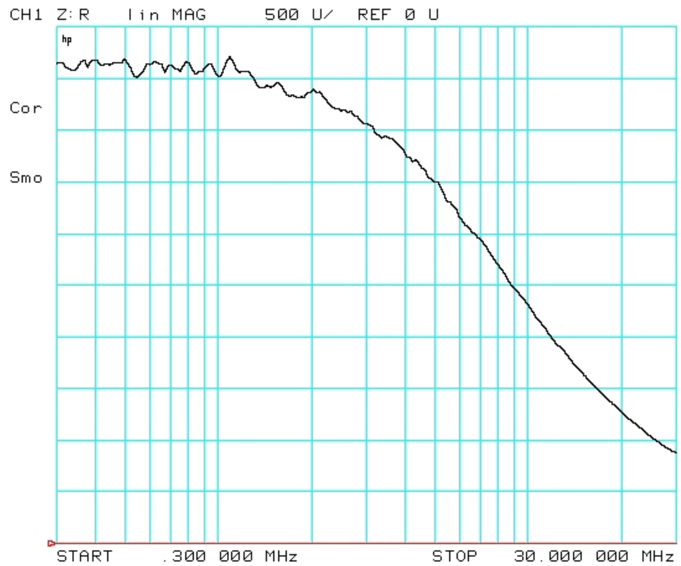


Unit 2, presented below, shows the effect of the K2-specific frequency shaping components. Both above and below the K2 IF frequency (4.9 MHz), the Z10000-K2's gain rolls off. At the desired 4.9 MHz, the net gain is -9.6 dB, necessary to offset the K2's post-mixer ampllifier gain when a net 0 db transfer gain is desired.

1.3.2 Input Impedance

The buffer amplifier's input impedance is dominated by two elements; the bias isolation resistor (4.7 KΩ in the test amplifier) and shunt capacitance (the shunt capacitance of the PCB traces, connecting wires to the amplifier and the amplifier's input capacitance.)

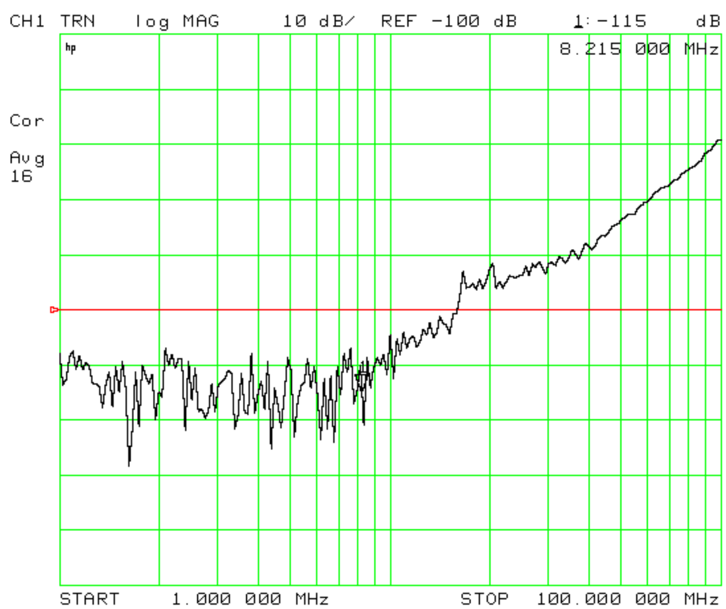
The measured data presented at the right (from Unit 3) should be considered as representative of an amplifier with short (a few inches) coaxial cable input leads.



1.3.3 Reverse Isolation

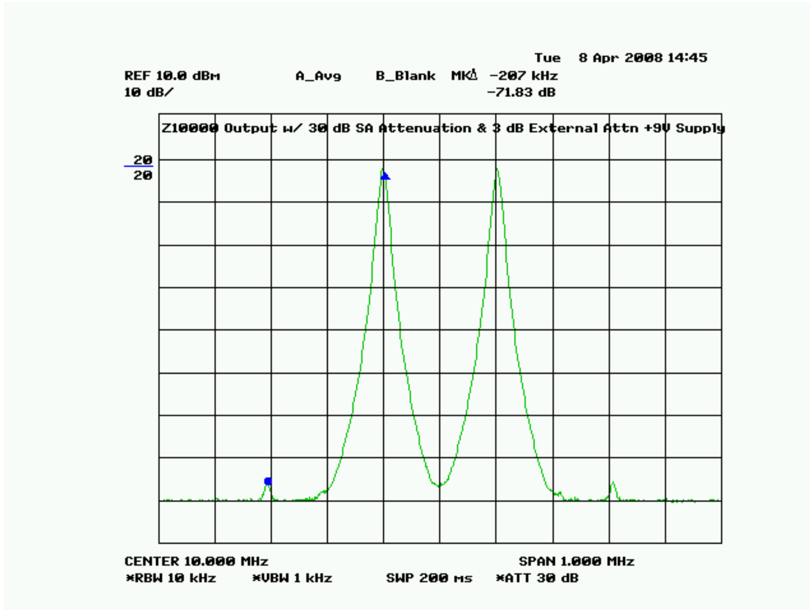
The buffer amplifier's reverse isolation is a function of frequency, as illustrated in the amplifier measurements presented at the right for Unit 1. At 8 MHz, the measured sample exhibited 115 dB reverse isolation.

Reverse isolation is also affected by how the amplifier is housed, lead dress, shielding, etc. Accordingly, the isolation illustrated at the right may not be achieved in every instance.



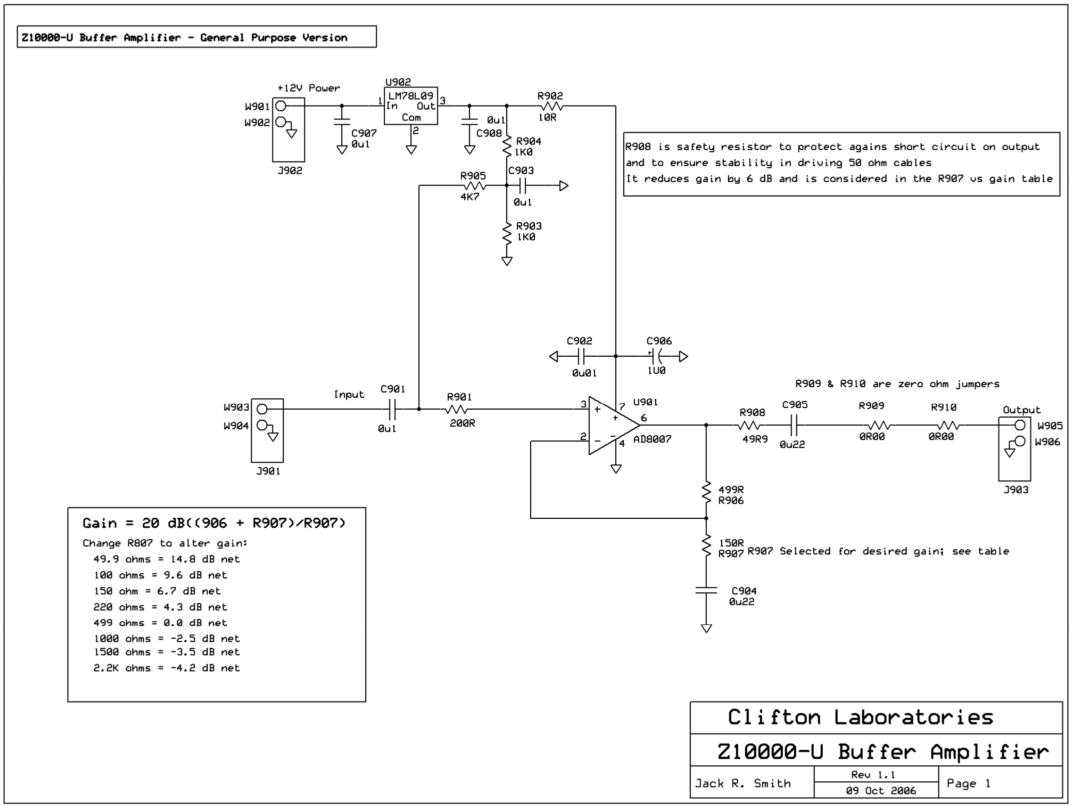
1.3.4 Intermodulation Performance

The illustration at the right shows the output of Unit 1 with two equal signals (9900 KHz and 10100 KHz) of -10 dBm applied to the amplifier input. The amplifier output is 0 dBm (a 3 dB attenuator is applied ahead of the spectrum analyzer in this plot.)
The third order intermodulation product is -71.8 dBm down from either tone. With an output based reference, therefore, the IP3 is thus +35.9 dBm.

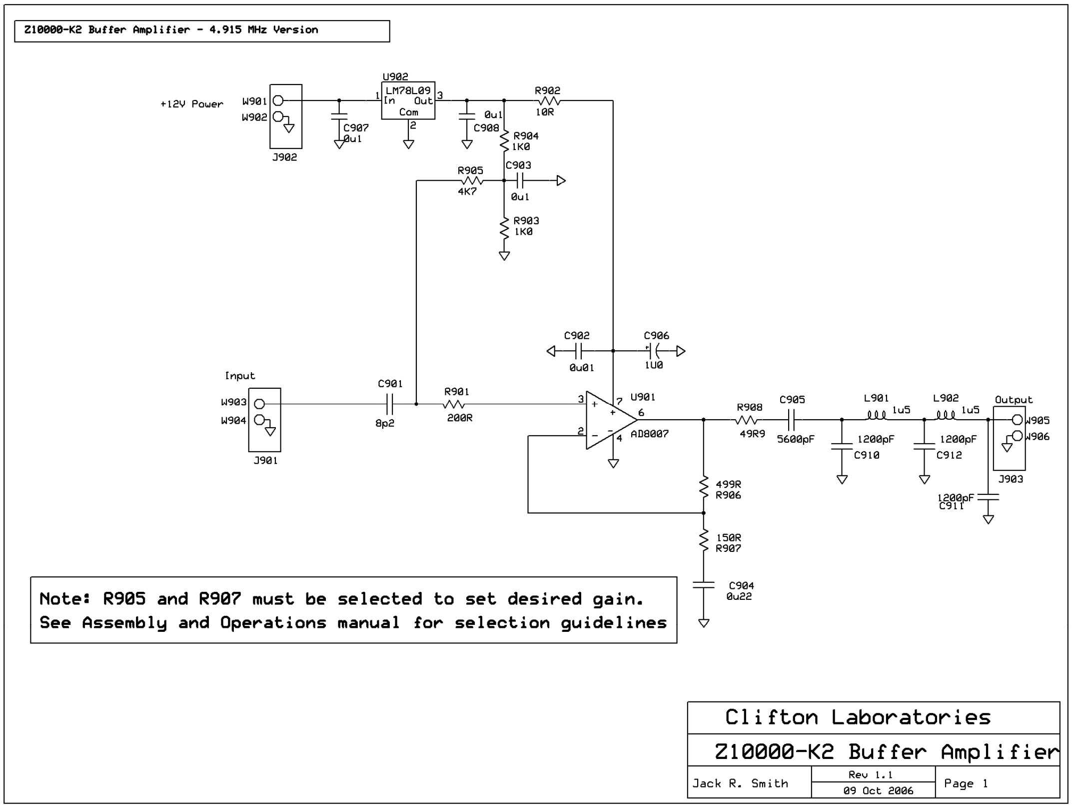


2.0 Schematic and Circuit Description

2.1 Universal Version



2.2 K2 Version



2.3 Theory of Operation

The operational circuitry of both buffer amplifiers is similar, with differences in component selection for frequency shaping in the K2 version.

2.3.1 Power Supply.

The AD8007 amplifier is rated at an absolute maximum operating voltage of 12V. In order to provide a safety margin, and to decouple the amplifier from the power supply, U902, a three-terminal fixed regulator, provides a source of stable +9V to U901. C907 and C908 provide additional decoupling. U901, the AD8007 amplifier, obtains its power via the RC decoupling network comprised of R902, C902 and C906.

Since the circuit operates from a single positive power supply, it is necessary to bias U901's input to approximately V/2. This is accomplished by the 2:1 voltage divider chain of R902/R903. C903 bypasses the V/2 reference voltage; whilst R905 increases U901's input impedance by isolating C903's RF ground. R905's maximum value is determined by the U901's input bias current on the positive pin, specified by Analog Devices as 8µA. For 4.7 KΩ, this bias current represents an IR drop of 38 mV. With a DC gain of 4, the corresponding output DC offset will be about 150 mV. If absolutely necessary for high input impedance, R905 may be substituted with a higher value resistor, up to approximately 22 KΩ. However, at frequencies above a few MHz, the input impedance is dominated by shunt capacitance; increasing R905 should be done only with an understanding of all the factors affecting the input impedance.[3]

2.3.2 Amplifier

U901, an Analog Devices AD8007, is a high performance, low noise *current feedback* amplifier, with a gain-bandwidth product exceeding 650 MHz. A current feedback amplifier is also known as a "transimpedance" amplifier. Analog Devices describes how a current feedback amplifier works:

> First, the negative input of a CFA responds to current; the output voltage is proportional to that current, hence *transimpedance (V(out) = Z(t) I(in))*. Instead of keeping the negative input current small by maintaining high input impedance, and using feed-back and voltage gain to keep the input voltage difference small, the CFA keeps the voltage difference small by virtue of its low input impedance (like looking back into a low-offset emitter follower); and it keeps its net input current small dynamically by feedback from the output.
>
> When an ideal CFA is driven at the high-impedance positive input, the negative input, with its low impedance, follows closely in voltage; and the high gain for error current and the negative feedback through Rf require that the currents through Rf and Rin be equal; hence *V(out) = V(in)[R(f)/R(in)* + 1], just like for voltage-feedback amplifiers. A major difference is that the slew rate can be quite high, because large transient currents can flow in the input stage to handle rapid changes in voltage across the compensating capacitor(s). Also, the low impedance at the negative input means that stray input capacitance will not substantially affect the amplifier's bandwidth.

U901's gain (in dB) is determined by the ratio of resistors R906 and R907:

$$Gain = 20\log_{10}\frac{R906 + R907}{R907}$$

In the Z10000-K2 version, R905 and C901 form a high-pass RC filter and input attenuator. Adjusting R905 to values below 4.7K will increase the input attenuation, which is desirable to achieve the desired amplifier gain when used in a K2.

The Z1000-K2's output stage also uses RC high pass filtering (R908 & C905) to roll off frequencies below approximately 5.6 MHz. The AD8007's output is connected through a five element low pass filter, consisting of L901, L902, C910, C911 and C912. The low pass filter sharply rolls off frequencies above 7 MHz.

C910, C911 and C912 are removed in the Z10000-U model and L901 and L902 are replaced by zero ohm jumpers. In addition, C901 is changed in the Z10000-U to 0u1 and C905 to 0u22 to provide a flat frequency response down into the 50 KHz range.

R908, 49.9 Ω, allows U901 to drive capacitive loads, such as coaxial cable and also protects U901 against operation into short circuits. However, the voltage divider effect of

[3] Clifton Laboratories will provide interested Z10000 owners with the LTSpice model of the AD8007 and an LTSpice model of the amplifier circuits upon request. SPICE modeling will allow the user to determine the effects of component changes with a reasonable degree of accuracy.

R908, which is in series with the load, reduces the net available gain into a 50 ohm load by 6 dB.

2.3.3 Gain Setting in the Z10000-U Buffer Amplifier

Note: This section applies only to the Z10000-U amplifier. See later discussion for gain setting of the Z10000-K2 amplifier.

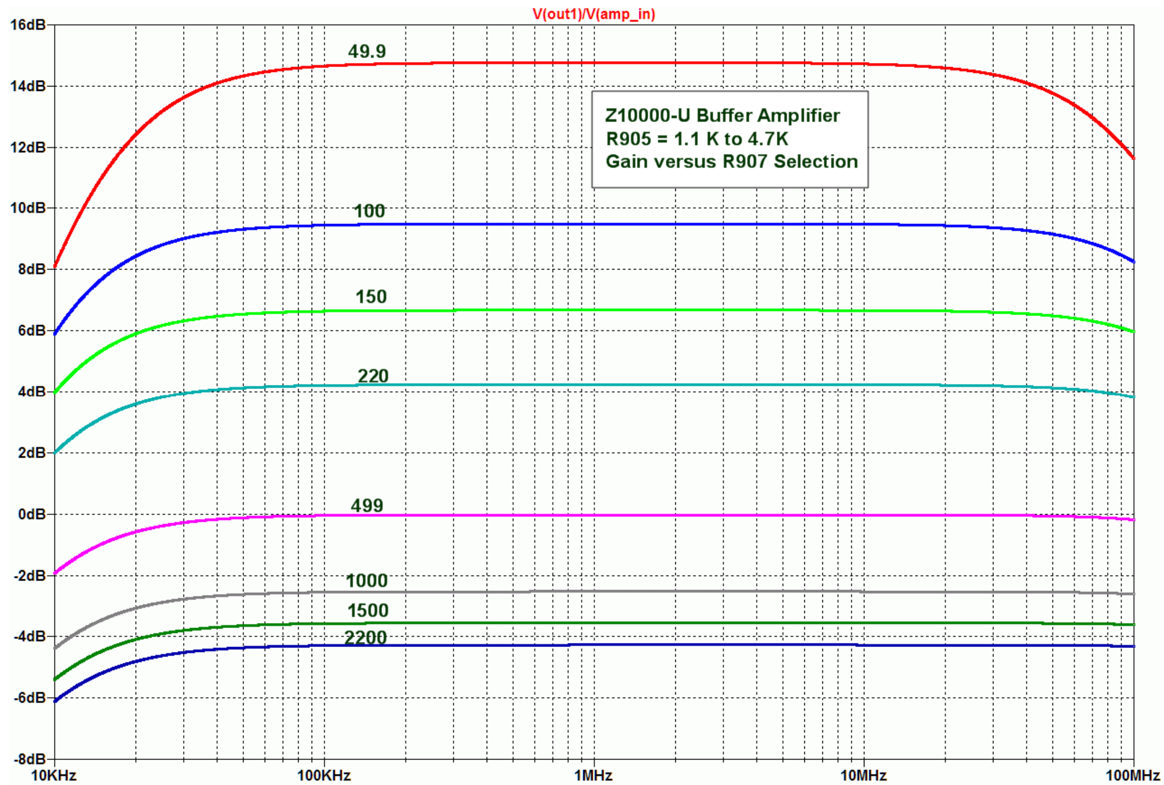
To vary buffer amplifier's gain, select R907 using the following table or the provided graph.

Net Gain (net of R908 series resistance)	**R907**
+15 dB	49.9 Ω
+10 dB	100 Ω
+6.7 dB	150 Ω
+4.3 dB	221 Ω
0 dB	499 Ω
-2.5 dB	1000 Ω
-3.5 dB	1500 Ω
-4.2 dB	2200 Ω

R906 and R901 should not be varied from their design values without a thorough analysis of the circuit.

The effect of changing R907 upon gain and bandwidth is illustrated in the following plot. The plot is based upon SPICE simulation of the circuit and is representative of the actual circuit.

In the –U version, R905 will normally be 4K7Ω.



If it is necessary to operate the Z10000-U with less than -4.2 dB gain, C901 can be reduced, or in the event extreme gain reductions are required, R905 may also be reduced to provide an RC voltage divider at the amplifier's input. Although this will introduce some RC frequency shaping in the Z10000-U's frequency response, the passband tilt will be insignificant when used with a Z90 panadapter.

Section 4.4.2 of this Manual further discusses gain selection considerations for general receiver connections.

2.3.4 Gain Setting in the Z10000-K2 Buffer Amplifier

☞ There are two connection point options in the K2. Please read the section of this manual (page 31) describing the connection point options first, as there are different gain settings required for the two options.

If you go with connection point Option 1, as a starting point, I recommend the following values:

R905 = 2.2K

R907 = 2.2K

If you go with connection point Option 2 as a starting point, I recommend the following values:

R905: 4.7K Ohms

R907: 220 Ohms (this is a starting point; depending on your sound card gain it may be necessary to reduce R907 to 100 ohms or even 49.9 ohms for increased net gain.)

Note that as the Z10000's gain is increased, the clipping point of the amplifier decreases. Larry, N8LP, reports that with R907 at 120 ohms, the clipping point is -5 dBm. Of course, -5 dBm represents an extremely strong signal, unlikely to be encountered in most K2 environments.

If you decide to use connection point Option 1, gain setting in the K2 version buffer amplifier is a bit more complex, because the normal operating mode in a K2 transceiver requires a negative net gain—in other words, a net loss—of about -14 to -15 dB. Part of the negative gain is obtained by intentional rolloff in C901 and R905.[4]

This combination provides a net gain of about -14 dB. This much loss is required because the recommended K2 connection point has approximately 18 dB net gain from the K2's post-mixer amplifier, Q22 (2N5109). The Z90 is designed for optimum signal level when the net gain between the antenna and the Z90's input is approximately 0 dB.[5] When combined with the approximately 3.5 dB loss of the supplied 4.915 MHz bandpass filter, setting the Z10000-K2's gain at -14 dB meets the "net zero gain" requirement. (This computation assumes the K2 is operating in the "normal" mode, *i.e.*, pre-amp off and attenuation off.) Don't worry, by the way, about achieving this "net zero gain" objective perfectly. A few dB one way or the other is not critical. If you are to err, however, better results will usually be found if you err on the side of operating the Z10000-K2 with a greater loss than operating it for higher gain.

Although developed with Clifton Laboratories Z90/91 panadapter, measurements shows that net 0 dB transfer gain (from K2 antenna input to Z10000 sample output) is an excellent operating point for the Softrock Lite 6.2 receiver when used as a panadapter or second receiver. If desired, of course, the Z10000's gain can be increased as discussed herein.

The following three figures show the net gain out of the Z10000-K2 as a function of R907 for three values of R905, 4.7K, 2.2K and 1.1K.

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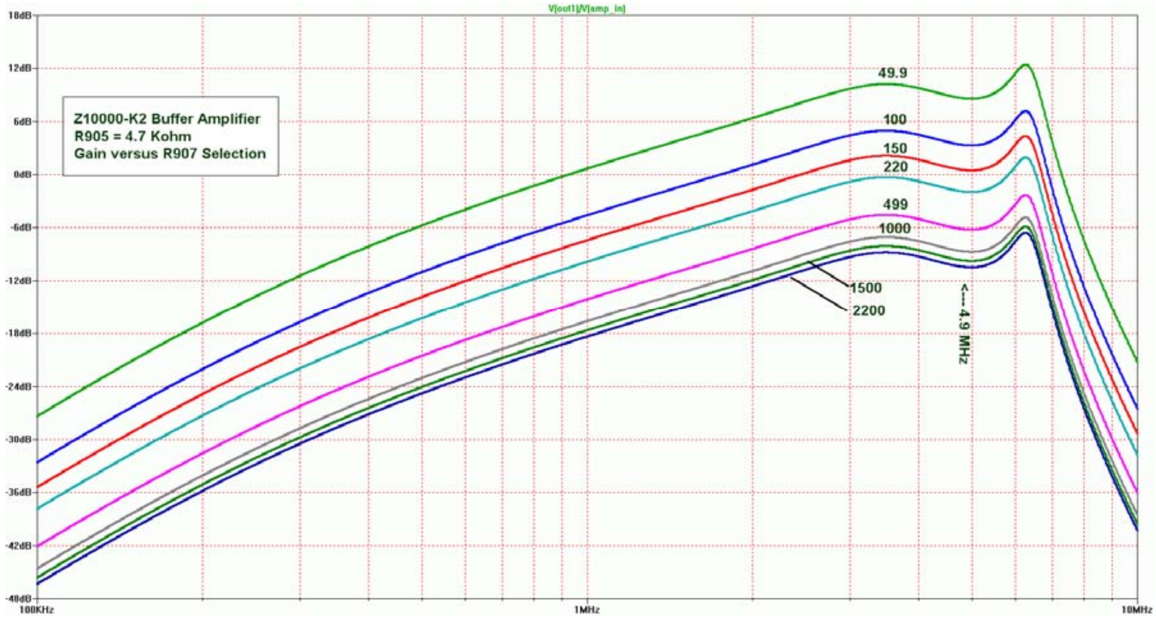
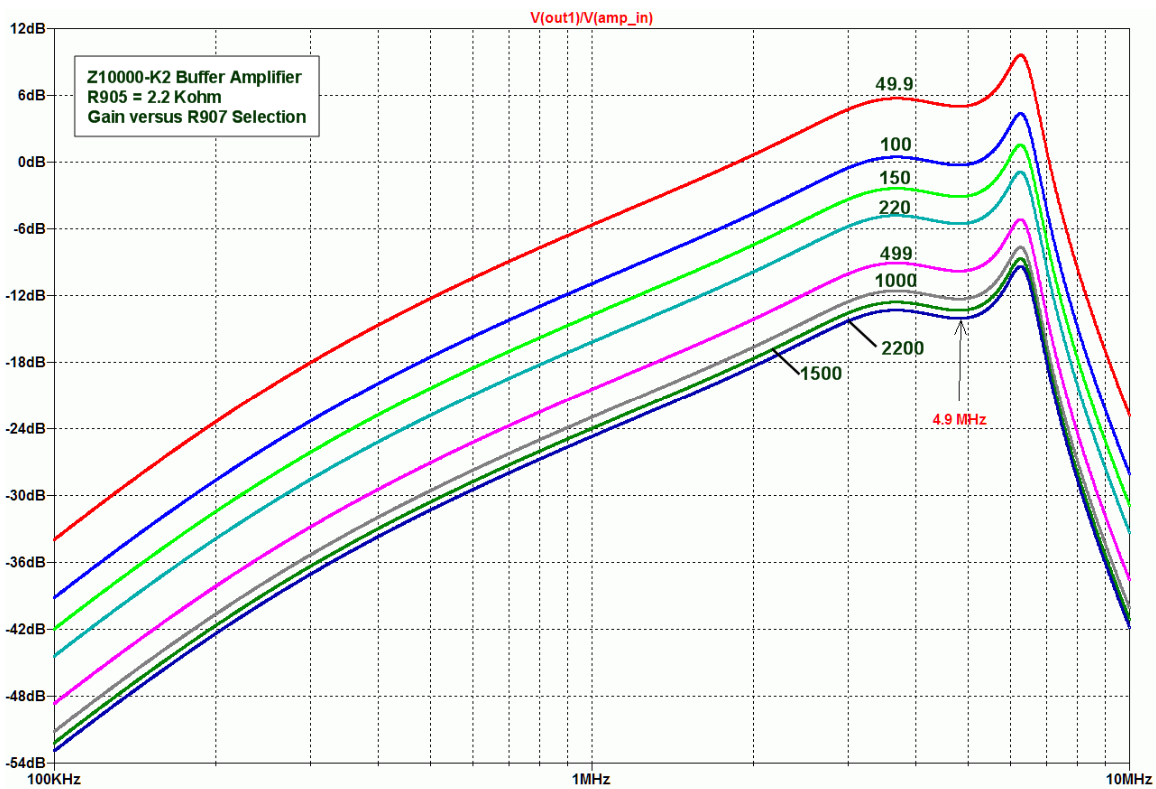
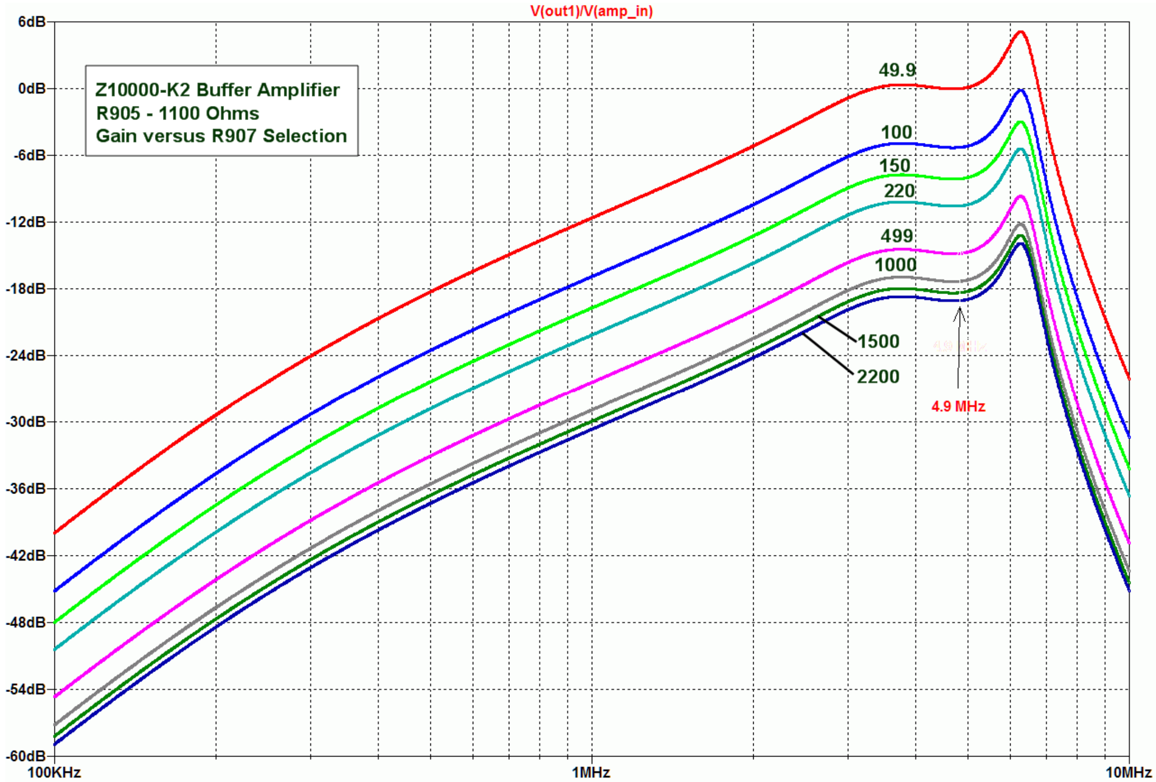
[4] It would be possible, of course, to dispense with the buffer amplifier completely and connect the Z90 to the K2's IF with a resistive matching pad. However, the resistive matching pad will not provide isolation as does the Z10000-K2. Although the Z90 has relatively low undesired emissions from its input connector, the extra isolation of the buffer amplifier provides additional protection against unwanted signals entering the K2's IF amplifier chain.

[5] In other words, a 1 µV signal at the frequency the receiver it tuned to should yield about a 1 µV signal at 4915 KHz into the Z90.


V(out1)/V(amp_in)
Z10000-K2 Buffer Amplifier
R905 = 4.7 Kohm
Gain versus R907 Selection
49.9
100
150
220
499
1000
1500
2200
<--- 4.9 MHz
100KHz
1MHz
10MHz


V(out1)/V(amp_in)
Z10000-K2 Buffer Amplifier
R905 = 2.2 Kohm
Gain versus R907 Selection
12dB
6dB
0dB
-6dB
-12dB
-18dB
-24dB
-30dB
-36dB
-42dB
-48dB
-54dB
49.9
100
150
220
499
1000
2200
1500
4.9 MHz
100KHz
1MHz
10MHz



3.0 Assembly

3.1 Parts List

The Z10000 parts are packaged in a several small envelopes, depending upon the option purchased.

<u>All Z10000 kits</u>:

- Resistors. All surface mount resistors, for both the –U and –K2 versions. [**All R**]
- Capacitors for the –U version [**All Cap**]
- Printed circuit board [**PCB**]
- Semiconductors (AD8007 and 78L09) [**Semi**]

<u>K2 Frequency Sensitive Parts</u>

- Capacitors and inductors necessary to shape the amplifier's frequency response to peak at 4.9 MHz. [**K2 Freq**]

<u>Internal Mounting</u>

- Parts associated with mounting the Z10000 (either U or K2) inside a receiver. **[Int**]
- K2-specific internal connectors are supplied where the purchaser selects the Internal Mounting option and also the K2 frequency sensitive parts. [**K2 Con**]

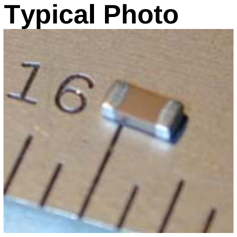
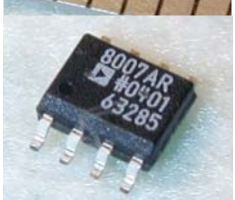
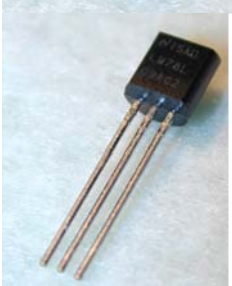
If ordering a Z10000-K2, therefore, you will have several extra capacitors and resistors that are not used in the –K2 version, as all kits are shipped with the full set of –U parts.

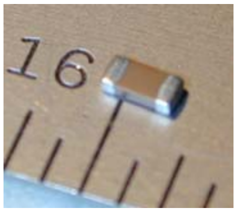
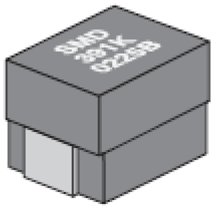
When working with capacitors particularly, do not removed the individual parts from their color-coded packaging until you are ready to use the component, as their values are not marked on the part and cannot normally be visually distinguished. Hence, if you mix up the capacitors, you will have to measure their values with a capacitance meter.

Also, do not confuse 100 ohm 1% resistors (identified as 1000) with 1.0K ohm 1% parts, identified as 1001.

Note that the schematic identifies parts with the multiplier as the "decimal" point. For example a 1K ohm resistor is identified as a 1K0, and a 49.9 ohm resistor as 49R9.

Common Components - K2 and Universal Models

Typical Photo	Designation	Value	Marking	Envelope Number	Qty
	C902	0u01	Not marked	All Cap	1
	C903	0u1	Not marked	All Cap	1
	C904	0u22	Not marked	All Cap	1
	C906	1u0	Not marked	All Cap	1
	C907	0u1	Not marked	All Cap	1
	C908	0u1	Not marked	All Cap	1
	R901	200R	2000	All R	1
	R902	10R	10R0	All R	1
	R903	1K0	1001	All R	1
	R904	1K0	1001	All R	1
	R906	499R	4990	All R	1
	R908	49R9	49R9	All R	1
	U901	AD8007	AD8007ARZ	Semi	1
	U902	LM78L09	KA78L09AZ	Semi	1

Typical Photo	Designation	Value	Marking	Envelope Number	Qty
Z10000-K2 Only					
	C901	8p2	Not marked	K2 Freq	1
	C905	5600pF	Not marked	K2 Freq	1
	C910	1200pF	Not marked	K2 Freq	1
	C911	1200pF	Not marked	K2 Freq	1
	C912	1200pF	Not marked	K2 Freq	1
	L901	1u5		K2 Freq	1
	L902	1u5		K2 Freq	1
Z10000-U Only					
	C901	0u1	Not marked	All Cap	1
	C905	0u22	Not marked	All Cap	1
	L901	0 ohm jumper		All R	
	L902	0 ohm jumper		All R	

Gain Setting Parts - For both Z10000-K2 and Z10000-U

Typical Photo	Designation	Value	Marking	Envelope Number	Qty
	See manual to determine proper value				
	Resistor Supplied for Selection				
	R905	4K7	4701	All R	1
	R905	2K2	2201	All R	1
	R905	1K1	1101	All R	1
	Resistor Supplied for Selection				
	R907	49R9	49R9	All R	1
	R907	100R	1000	All R	1
	R907	150R	1500	All R	1
	R907	220R	2200	All R	1
	R907	499R	4990	All R	1
	R907	1K0	1001	All R	1
	R907	1K5	1501	All R	1
	R907	2K2	2201	All R	1

External and Mechanical Parts

Both Z10000-K2 and Z10000-U

Z10000-01	RG178 2 ft	INT
Z10000-02	Bulkhead Connector	INT
Z10000-03	6" red wire	INT
Z10000-04	1/2" MF 4-40 standoff	INT
Z10000-12	fish paper	INT
Z10000-08	Printed circuit board	
Z10000-10	4-40x1/4" machine screw	INT
Z10000-11	4-40 hex nut	INT
Z10000-12	3/32" x .5" red heat shrink tubing	INT
Z10000-13	3/32" x .5" black heat shrink tubing	INT
Z10000-14	3/32" x .5 green heat shrink tubing	INT
Z10000-16	3/16" x 2" heat shrink tubing	INT

Z10000-K2 Only

Z10000-05	8-pin female header	All R
Z10000-06	3-pin female header	All R
Z10000-07	3-pin male header	All R

Multiple part values are provided for R905 and R907, to be selected by the builder as discussed in the text.

Printed instructions are not supplied; this manual is to be downloaded from the Clifton Laboratories web site.

Heat shrink tubing supplied may differ in diameter, length and color from the values in the above parts table.

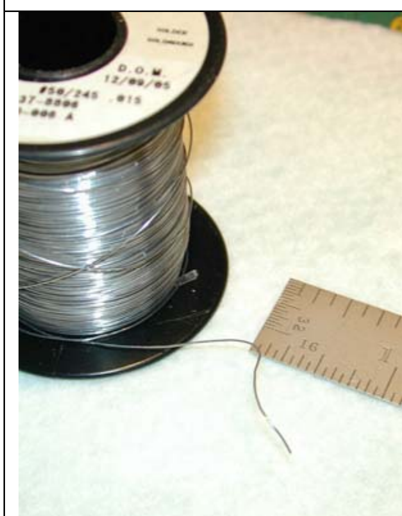
3.2 Working with Surface Mount Components

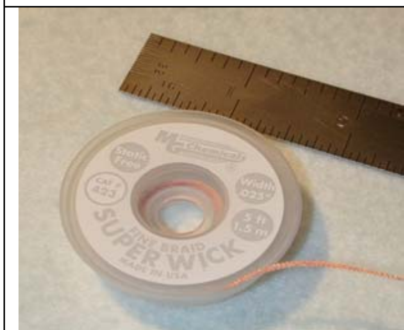
If you are unfamiliar with installing surface mount components, you should review this section of the Assembly Manual. The surface mount components in this kit are considered "large" by industry standards, and should not represent difficulty if you have prior kit assembly experience, either surface mount or through-hole.

3.2.1 Tools

I use the following tools in assembling surface mount printed circuit boards:

Tool	Comments	Approximate Cost	Source
	I use curved nose forceps to hold parts while soldering. I prefer the pattern 7-SA forceps with gently curved tips, but the angular pattern 6-SA may be preferred by some. These are by Technik and are non-magnetic stainless	$9.00 each	MSC part number: 7-SA pattern: 88348099 6-SA pattern: 88348081

Tool	Comments	Approximate Cost	Source
	steel.		
	I find clip-on magnifiers essential to view small parts. I keep both 1.75 x and 3.5 x magnification types at hand. The 3.5 x magnifiers have a working distance of 4", so it gets you "up close and personal" with the parts! (I'm not a fan of the headband style magnifiers, but personal tastes differ in this regard.) Of course, if you don't wear glasses, a different style magnifier will be in order.	$20 each	MSC part numbers: 1.75X: 06533202 3.5X: 06533236
	Small diameter solder is essential. I use either 0.015" diameter or 0.022" diameter solder. If you can find it, I find solder with a slight amount of silver (3% typically) produces a better appearing joint. My 0.015" solder is Kester "44 rosin, 63/37 eutectic mixture. My 0.022" solder is (believe it or not) Radio Shack 62/36/2, with 2% silver.	$15 for ½ pound Kester	Mouser part number 533-23-6337-07
	If the pad being soldered to is at all tarnished, a touch of solder flux will clean it up. Some like to use flux regardless of the pad condition. I prefer a pen-type dispenser.	$4	Mouser part number: 533-0951

Tool	Comments	Approximate Cost	Source
	Solder wick can't be beat for cleaning up unwanted solder, or for removing solder from a pad after a part is changed. For small surface mount parts, I like narrow solder wick, 0.025 to 0.030."	$2.50	Mouser part number: 5878-80-1-5
 	Finally, you need something to hold the PCB in place whilst you work on it. I use a Panavise #301 (with nylon jaws) for small boards and a Panavise #324 board holder for larger projects.	$45 for the standard Panavise $85 for the PCB holder	#324 PCB Holder is Mouser PN: 591-324 #301 Standard Panavise is Mouser PN: 591-301

Mouser: http://www.mouser.com/ (excellent line of electronic parts and no minimum order size)

MSC: http://www1.mscdirect.com/ (Tools of variety almost unimaginable and it's all in stock. No minimum order, prices may be a bit on the high side, but I've never bought a tool from them that I've been disappointed in. Their customer service is among the best I've seen.)

The tool not to use—self-closing forceps. These tools are quite useful for many purposes around the electronics workbench, but when it comes to holding surface mount parts, I've found them to excel at being "parts launchers" with the ability to shoot a small surface mount component across the room in an instant.

This tools list assumes you have a suitable soldering iron. I use two Hakko 936 soldering stations. For integrated circuits such as U801/U901, I use a 0.032" diameter long taper conical tip. For larger surface mount and through-hole parts, I use a 1/8" screwdriver tip. My experience is that a lower power soldering iron isn't adequate, and one of much greater power is too much. Whether this is a true Goldilocks optimum or just my personal preference remains to be determined.

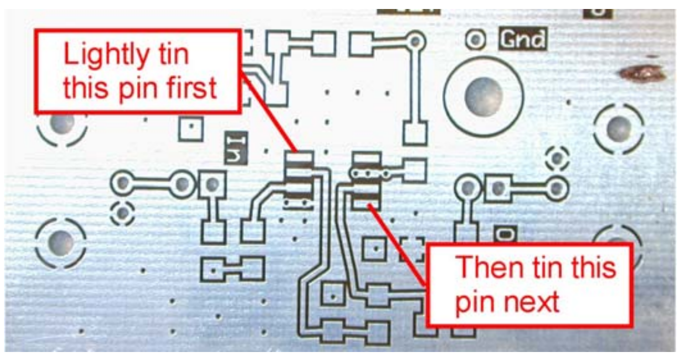
If you are thinking of purchasing a new soldering station, I recommend the Hakko Model 936.

3.2.2 Installing Surface Mount Components

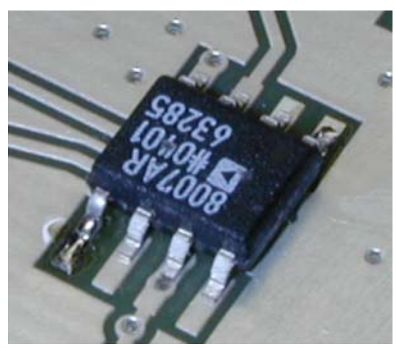
3.2.2.1 Integrated Circuits

U901 is a reasonably easy to install surface mount IC, if you have the correct tools and follow a few simple steps.

- Before starting, remember to apply proper anti-static procedures. Study the IC's marking and the PCB layout so that you know the correct orientation.
- The idea is to hold the IC in place by soldering two diagonal corners in place and then solder the remaining pins. Start by applying a sparing amount of solder on one of the corner pads. Then apply a similar amount of solder to the diagonal corner pad. Place the IC on the PCB, correctly oriented, with pins centered on the pads. While holding the IC in place, touch the soldering iron to the first tinned pad, tacking the IC's pin in place. The small figure shows an AD8007 after the diagonal pins have been tack soldered in place. Note how the pins are centered over the PCB pads.



- Check the orientation of the IC, verifying that it is properly centered over the pads. If you don't get this right now, it will be far more difficult to correct when the second pin is soldered in place. When you are satisfied that the IC is centered on its pads, touch the other diagonal tinned pad with your soldering iron.



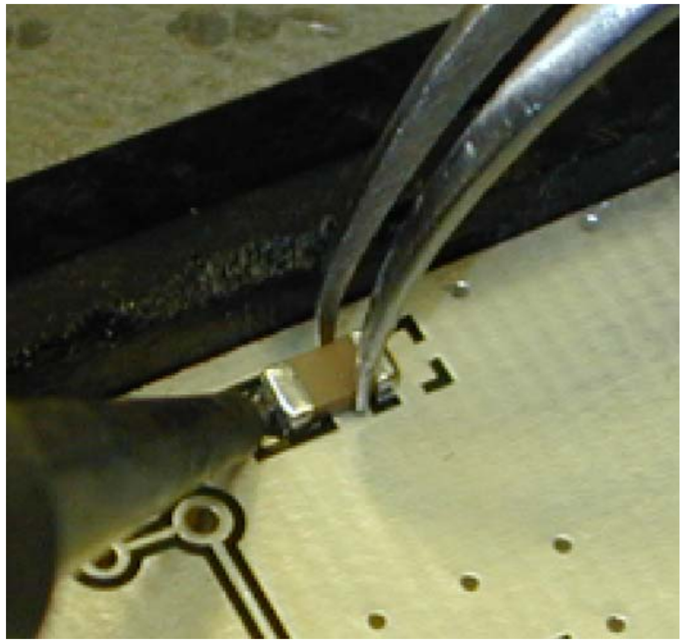
- Double check that the IC has not shifted during the earlier steps and that the IC's pins are centered on their respective pads. Then solder the remaining pins to their pads. Depending on how the PCB was constructed, it may have sufficient solder plating so that additional solder is unnecessary—simply touching the soldering iron to the pin and pad flows enough solder to form a reliable joint. If this isn't possible with your PCB, then apply a small amount of solder to form the joint.

- After each time you touch the solder to the soldering iron, check the end of the solder for a blob or ball. If you find the solder has formed a ball, cut it off at an angle to form a pointed end. Otherwise, it will be difficult to control the amount of solder deposited.

- After soldering, check for bridged pins or shorts to ground. Clean up any problems with solder wick.

3.2.2.2 Passive Components

To install a passive component, use a similar approach:



- Lightly tin one pad.
- With angled forceps (or your favorite tool) hold the part in place and solder the part to the tinned pad with a light touch of the soldering iron. This will anchor the part in place. Notice how nicely Technik pattern 7A forceps hold the part in place without obscuring vision or blocking the soldering iron.
- Solder the remaining pad(s). If necessary rework the first pad connection.

It does not take a large amount of solder to properly attach a surface mount component. A correctly installed part will be flush against the board and have a small filet at the end caps.

3.2.3 Removing Defective Parts

In almost every instance, trying to salvage a surface mount part installed wrong is a waste of time. A 1% 1206 size surface mount resistor, for example, costs about 2 cents in 100 lots. It's much easer to use a pair of cutters and snip the part in half. (Resistors and capacitors are ceramic based—they shatter when cut.)Then use solder wick to remove the two halves. Clean up the pads with additional applications of solder wick.

To remove a multi-pin IC, a similar approach can be used—carefully cut the part into pieces with cutters, exercising care to avoid damaging traces or the PCB. A hot air gun can also be used to simultaneously liquefy the solder at all IC pins. The IC can then be lifted free of the PCB. Care must be taken, of course, to avoid damaging nearby parts with the heat gun.

An alternative IC removal approach is ChipQuik (DigiKey PN SMD1-ND, approximate price $15). ChipQuik's kit includes special flux and a low temperature melting point solder that mixes with the normal solder and allows the chip to be removed without extensive heating.

Because I do so much surface mount work, I've purchased a Hakko 950 SMT tweezer handpiece and several blades. Although not cheap, it's an excellent tool, like all other Hakko products I've purchased.

3.2.4 Most common error

The most common error I make in installing a surface mount resistor or capacitor is to not center the part on the pads, resulting in the metalized end of the component shorting to ground, where it bridges the pad's isolation. This error can be completely avoided by carefully centering the part and holding it in the correct position whilst soldering one end. It's much easier to fix this type of error before soldering the second end!

With integrated circuits, the most common error is to bridge solder across adjacent pins. In most cases, applying solder wick will remove the bridge and leave the pins correctly soldered in place.

3.2.5 Teflon Coax

The coaxial cable supplied with this kit is RG178, with Teflon outer jacket and center insulation. Teflon will not melt during normal soldering operations, unlike, for example, RG174, with a center conductor insulation that melts if you look at it crossways. However, RG178 requires some special handling:

- Most wire strippers do not work well with Teflon. I use a Hakko FT800 thermal wire stripper. Before acquiring the FT800, I used either a special micrometer-type wire stripper or an X-Acto knife. It is extremely easy to cut through the shield or the center condutor when stripping the coax, so apply light pressure when cutting.
- RG178 is small (about 0.078" [1.8mm] diameter) so be careful when stripping it. The shield is comprised of #38 AWG wire, which is tiny. It's easy to wind up with small pieces of shield in places where you don't want them, so look over your work with a magifying glass for stray bits of shield.
- Likewise, the center conductor is #30 AWG and it's very easy to cut through it when stripping the center insulation.
- Gently does it when using the X-Acto knife. Let the sharpness of the blade do the work, and do not apply more than the absolute minimum pressure necessary.
- You might practice stripping the jacket and center conductor on the free end of the cable to get a feel for how easy or difficult it will be for you before doing it "for real."
- Cutting the cable with a bit of excess length is not a bad idea as it may save you from redoing a lot of work if your first attempt at stripping the cable fails.

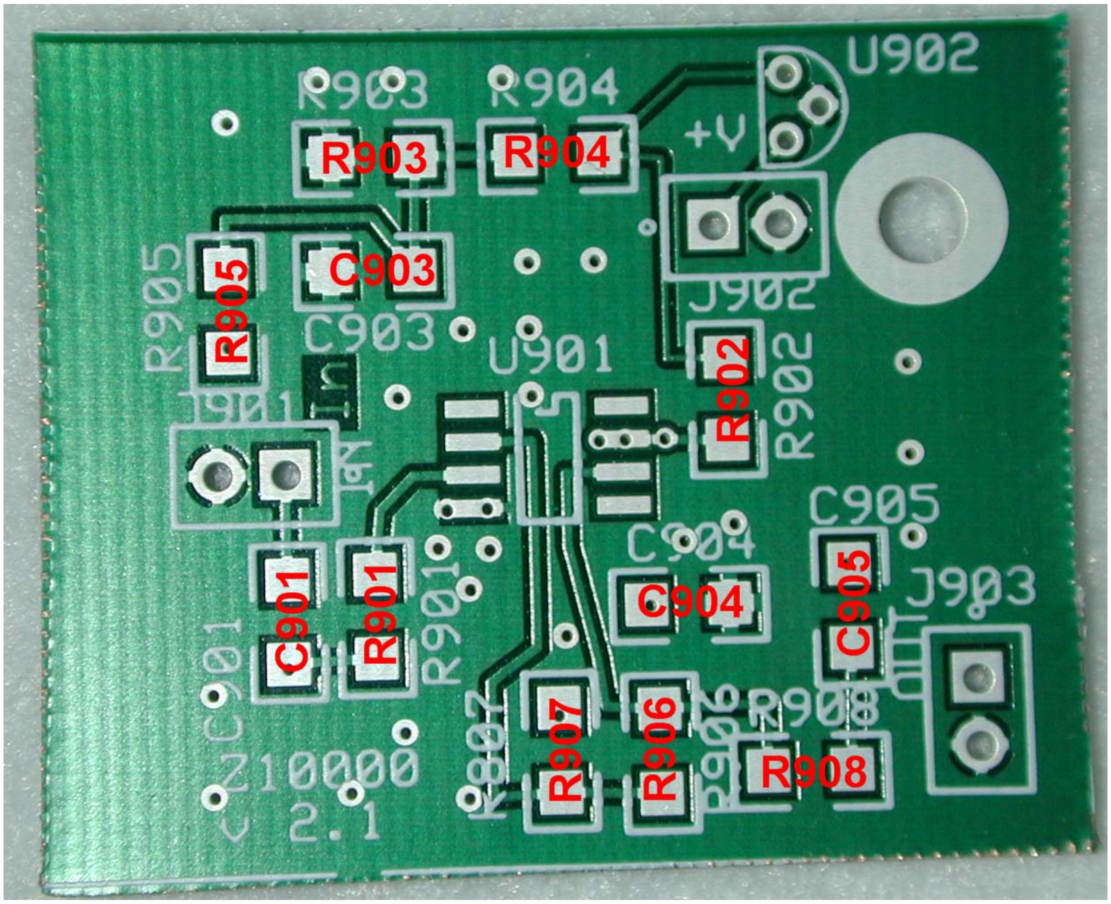
You have only one opportunity to cut the connector end of the cable. The old carpenter's rule of "measure twice, cut once" applies with force here. Replacement cables are $15 from Clifton Laboratories.

After soldering the RG178 to the input and output printed circuit board pads, be careful not to apply excessive mechanical force to the cables. It's easy to rip the pad off the printed circuit board or break the cable where it is soldered. It's also easy to wind up with a stray wire from the shield floating around and shorting the input and output pads. Any stray bits of shield wire should be carefully removed.

4.0 Assembly

4.1 Component Placement

Locate the appropriate PCB and orient yourself with the board. Identify the top and bottom. The top has silk screening as well as solder masking.

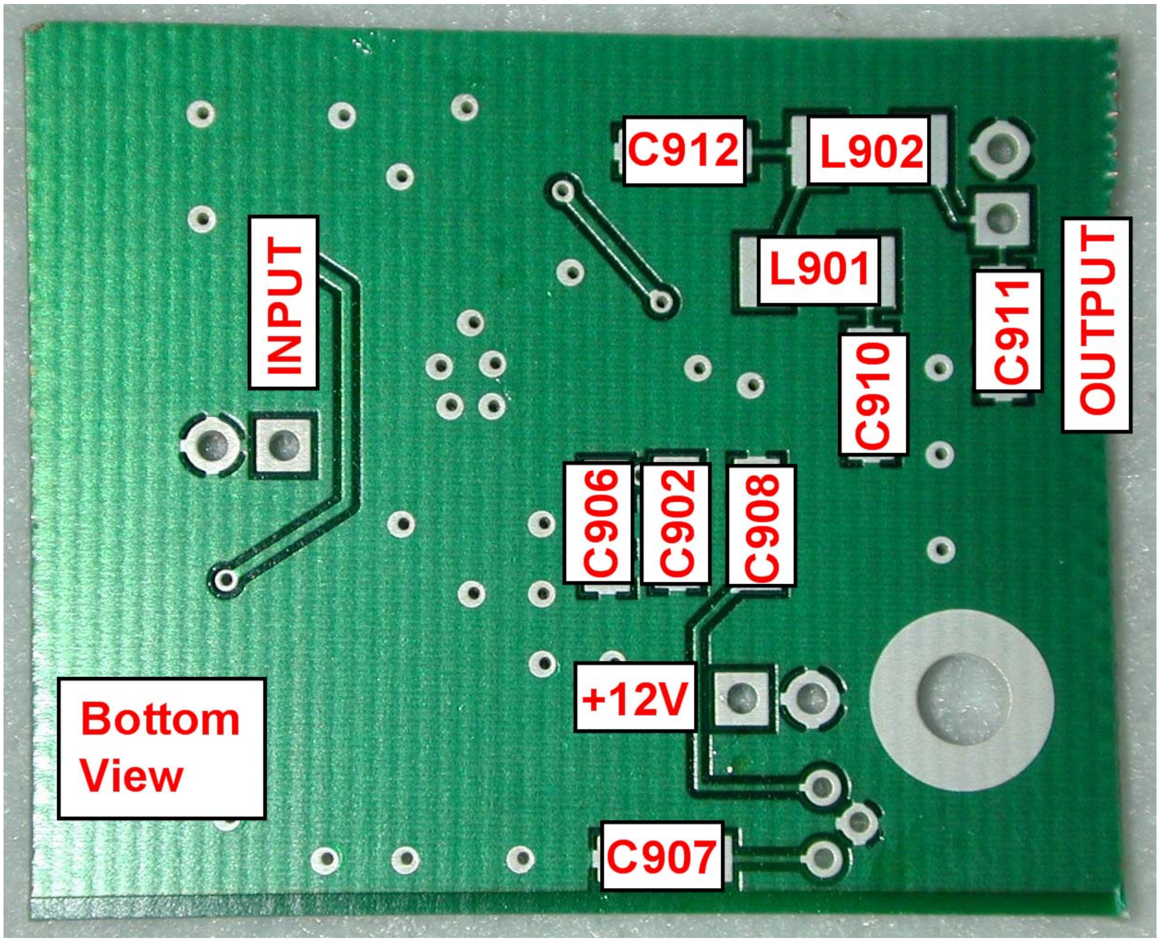


The photograph shows an earlier version of the PCB. Later PCBs correct the silk screen error identifying R907 as R<u>8</u>07, and slightly rearrange other silk screen legends. In addition, production circuit boards may be slightly smaller than in the photographs.

This photograph shows parts placements for <u>both</u> the -K2 and -U versions of the Z10000.

The bottom PCB surface is solder masked but not silk screened. Please use the following annotated photograph for parts placement.

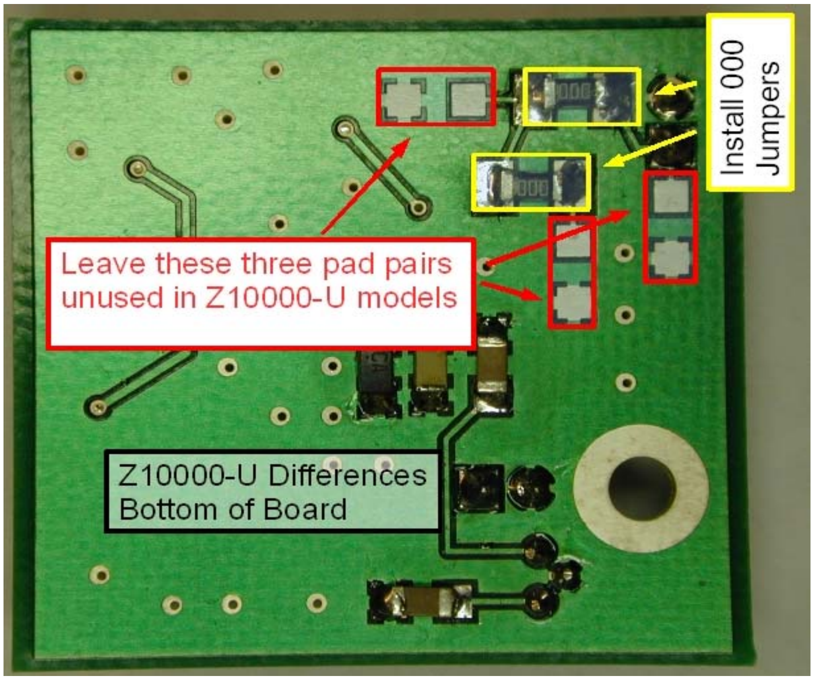
The photograph below shows the parts placement for the -K2 version and, with respect to C902, C906, C907 and C908, the -U version as well.



The Z10000-U differs on the bottom assembly in several respects from the -K2 version:

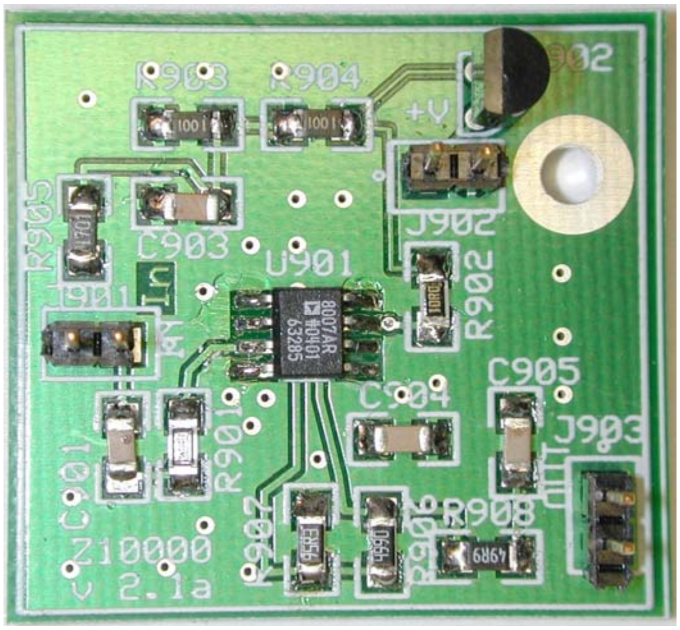
- Low pass filter capacitors C910, C911 and C912 are not used.
- L901 and L902 are not used. Instead, 000 ohm jumpers are installed in their place.

The photograph shows the most recent (2008) PCB board. C906 in the photograph is a tantalum electrolytic capacitor. Normally a ceramic capacitor is supplied with the Z10000, although a tantalum electrolytic may be provided in some instances.

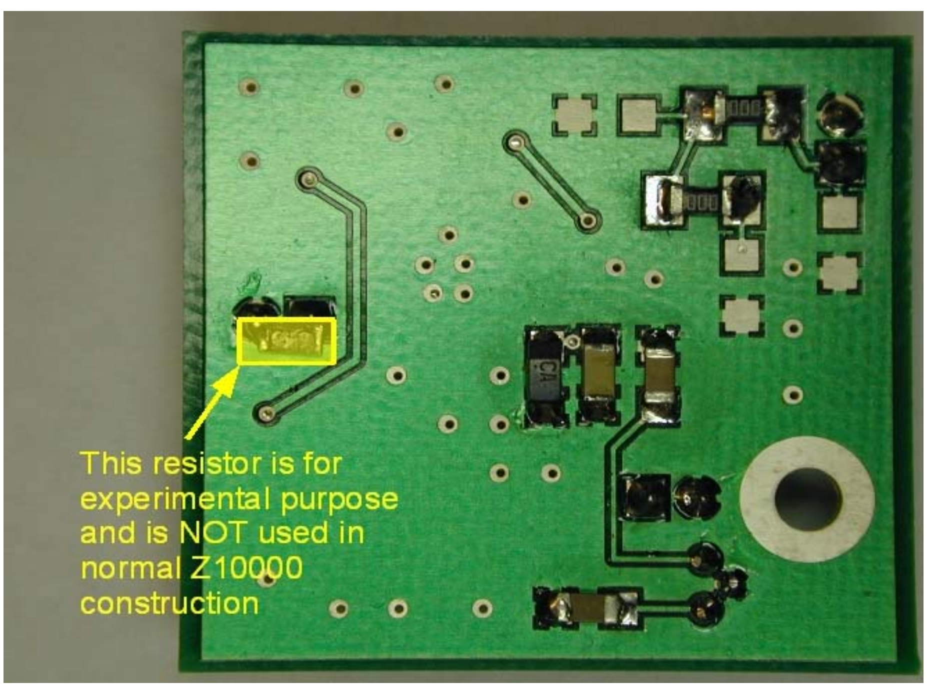


The assembled Z10000 top view photo below is identical in appearance for both the -U and -K2 models, as the differences are only in component values.

The board shown uses plug-in headers for test purposes. Your board will normally use direct wire connections to the power, input and output pads, although you are, of course, free to use header pins if so desired.



The photo below shows the bottom view of an assembled Z10000-U.



4.2 Component Installation

The assembly instructions are almost identical for both the K2 and Universal board. Where appropriate, the following instructions will identify the differences.

☞ Before starting construction, it is necessary to select the gain programming resistor (R907) and the input resistor (R905). In the case of an Elecraft K2 transceiver and Option 1 connection point, the recommended values are R905=2.2K, R907=2.2K For Option 2 connection, the starting point should be R905=4.7K, R907=220 ohms. For assistance in determining the programming resistor value read Sections 2.3.3, 2.3.4 and 4.4.2 of this document.

- ☐ If the internal installation option is purchased, locate the fish paper[6] (black, stiff paper) and the printed circuit board. Align the 1/8" hole in the fish paper with the PCB's mounting hole and trim the fish paper to approximately the same size as the buffer amplifier PCB using scissors or an X-Acto knife. Return the fish paper to a safe location.

Now the surface mount parts on the top are installed:

- ☐ **[Semiconductor Package]** Install U901 (AD8007) using the technique discussed earlier.
- ☐ **[K2 Freq –K2; All Cap for -U]** Install C901 (0.1 uF for –U; 8.2pF for –K2, both unmarked)
- ☐ **[All Cap]** Install C903 (0.1 µF, unmarked)
- ☐ **[All Cap]** Install C904 (0.22 µF, unmarked)
- ☐ **[All R]** Install R901 (200 Ω, marked 2000)
- ☐ **[All R]** Install R902 (10 Ω, marked 10R0)
- ☐ **[All R]** Install R903 (1 KΩ, marked 1001)
- ☐ **[All R]** Install R904 (1 KΩ, marked 1001)
- ☐ **[All R]** Install R906 (499 Ω, marked 4990)
- ☐ **[All R]** Install R908 (49.9 Ω, marked 49R9)
- ☐ **[K2 Freq for –K2; All Cap for -U]** Install C905 (5600 pF for –K2; 0.22 µF for -U, both unmarked)
- ☐ **[Select R905 from [All R] following instructions at Sections 2.3.3, 2.3.4 and 4.4.2]** Install R905
- ☐ **[Select R907 from [All R] following instructions at Sections 2.3.3, 2.3.4 and 4.4.2]** Install R907

Flip the board upside down and install the remaining surface mount components:

- ☐ **[All Cap]** Install C902 (0.01 µF, unmarked)
- ☐ **[All Cap]** Install C906. (1.0 µF, unmarked)
- ☐ **[All Cap]** Install C907 0.1 µF, unmarked)
- ☐ **[All Cap]** Install C908 (0.1 µF, unmarked)

If you are building the –K2 version, install the frequency-sensitive parts [these parts are not included with the –U version]:

- ☐ **[K2 Freq]** Install L901 (1u5 inductor)

---

[6] Why this is called "fish paper" remains a mystery. The best I can find is a conversation with a ham in his 70's (K8AQC) said that when he was a young man, the old time electricians called it "fish oil paper" which leads him to believe that the insulating paper at the time was coated with fish oil, and then heated and rolled. That's the most plausible explanation I've heard for the name.

- ☐ **[K2 Freq]** Install L902 (1u5 inductor)

You may find the two inductors a bit more difficult to install than the resistors or capacitors due to the way the leads are formed. After soldering one end in place, check the associated pads for an inadvertent short circuit to ground. Both pads associated with each inductor should be an open circuit to ground when checked with an ohmmeter. Repeat the ohmmeter check after soldering the second end of each inductor.

- ☐ **[K2 Freq]** Install C910. (1200pF, unmarked)
- ☐ **[K2 Freq]** Install C911 1200pF, unmarked)
- ☐ **[K2 Freq]** Install C912 (1200pF, unmarked)

<u>If you are building the –U version, install the filter bypass parts:</u>

- ☐ **[All R]** Install L901 bypass (Zero-ohm jumper)
- ☐ **[All R]** Install L902 bypass (Zero-ohm jumper)

The two zero-ohm jumpers are slightly small for the pad spacing but will work if you carefully center the parts on the pads. After soldering one end of each zero ohm jumper in place, check for an inadvertent short to ground. Both ends of both pads should be open circuit to ground when measured with an ohmmeter. Check again after soldering the second end of each zero ohm jumper.

<u>For all versions:</u>

Now install the remaining through-hole parts:

- ☐ **[Semi]** Install U902. This is a 78L09 3-terminal regulator in a TO-92 package. Note the orientation of the device as shown in the silk screen outline. You will have to form the leads to fit the hole. Assess how much vertical clearance is needed above the PCB. In the –K2 version, press U902 into place so that the body is approximately 1/8” (3mm) from the top of the PCB. If necessary to have a lower profile in your particular installation, you may leave the leads longer and bend the regulator as necessary, avoiding, of course, shorting the leads together. Otherwise, follow the –K2 installation practice.

The Z10000 is supplied with a length of RG178 coaxial cable with an attached cable jack bulkhead connector. This cable is to be cut as necessary for your installation, with the connector on the output and the remaining cable to be for the input connection.

Clifton Laboratories offers an optional 3’ RG174 cable with a male SMA connector on one end and a male BNC connector on the other end. This cable is not part of the Z10000 buffer amplifier kit.

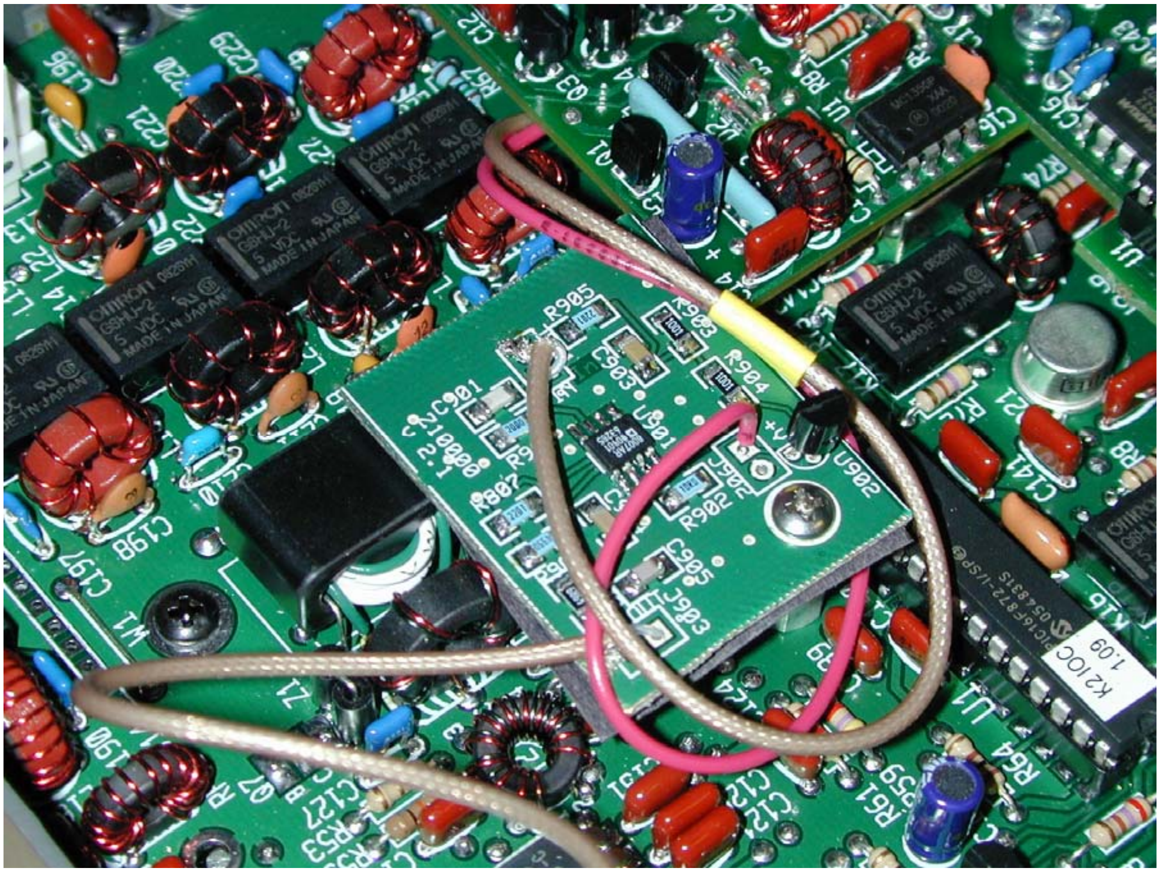
Since the Z10000-U may be employed in a variety of receivers or transceivers, explicit installation instructions cannot be provided. Clifton Laboratories suggests the K2 installation guidelines provided below be used to develop your own installation strategy.

For installation in a K2, prepare the supplied coaxial cable and power hookup wire as follows.

Examine your K2:

Before cutting the coaxial cable, remove the cover on your K2 and determine where you wish to mount the SMA bulkhead output connector. Study the photographs in this manual to understand where the buffer amplifier will be mounted. In a normal installation, it will be placed next to the noise blanker board, or the place where the noise blanker board would be installed if your K2 has that option.

The following photograph shows the normal K2 installation location. The buffer amplifier mounts on a ½" (12.6 mm) male-female aluminum standoff that replaces one of the screws holding the K2 main board in place.



Now that you know where the buffer amplifier will be located, determine where the output SMA connector will be installed.

My K2 has the optional KPA100 100 watt output stage but does not have the K60XV 60 meter band / transverter board. This leaves two open holes (XVTR IN and XVTR OUT) in my K2, which are the correct size for the SMA bulkhead connector:

Note that the RCV. ANT. hole is a bit large to properly hold the SMA connector.

If you need to punch or drill a hole in your K2 for the SMA connector, the connector nominal outer diameter is ¼" (6.4mm). Both nuts require a 5/16" wrench.

Using the cable or a piece of string, determine the cable length required from the SMA connector mounting position to the buffer amplifier board. In my K2, the length of required output cable is approximately 6" (152 mm), but yours may vary, and you may also wish to route the cable differently than I did.

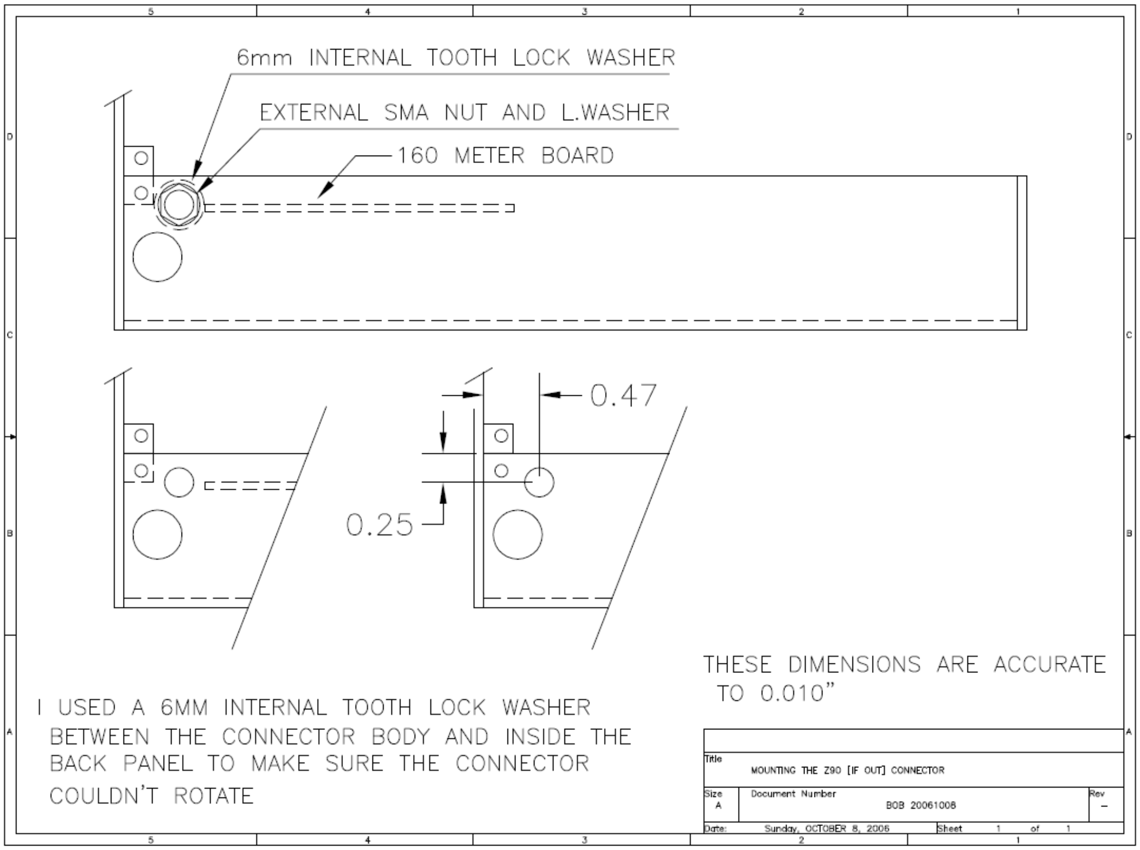
This is a critical dimension, in that if cut too short, you will require a replacement cable.

After cutting the cable, reserve the cut-off piece for the input connection.

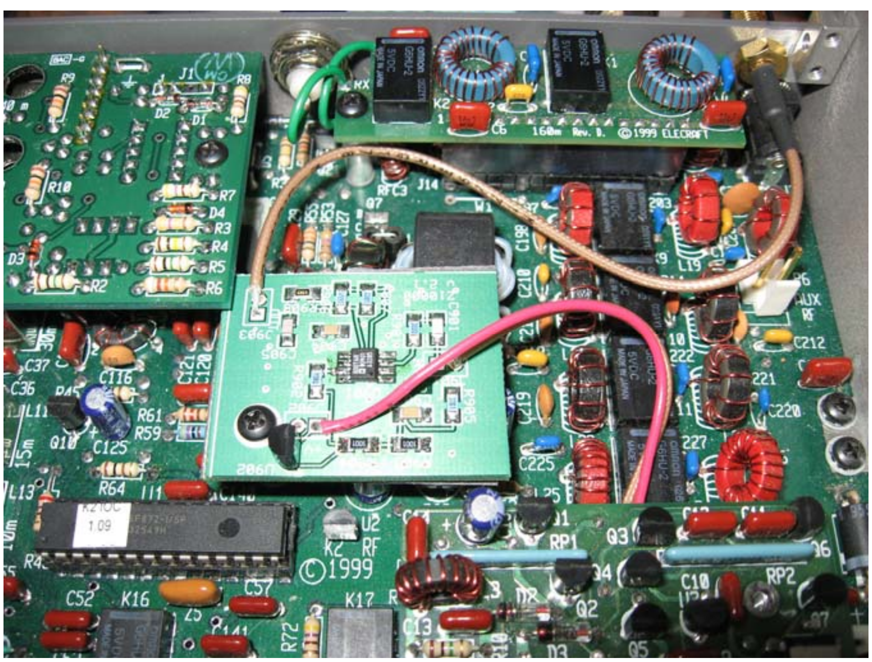
Now, determine the length of cable required for the input connection. In the K2, assuming the Z10000-K2 is installed in the normal location, the input coaxial cable will be approximately 5 inches (125 mm) long. You should determine if this length is adequate for your installation and preferred routing.

After you have determined the correct input cable length, cut a section of RG178 to that length.

Bob, K7HBG, has provided the following drawing showing where he located the SMA bulkhead in his K2, which is equipped with all possible options and hence has no unused holes.



Bob notes that the 6mm (¼") (internal diameter) lock washer just fits in between the "D" chassis bracket and the 160 Meter board so it is necessary to carefully measure the hole's location.



Bob's K2 with the buffer amplifier in place. Note the SMA connector mounting in the space between the 160 meter board and the edge of the back panel.

The SMA bulkhead connector is supplied with one lockwasher intended to be used on the outside of the enclosure, between the nut and panel. Bob suggests using a second internal tooth lockwasher on the inside. If you follow this suggestion, a ¼" (6mm) internal tooth lockwasher can be obtained at any hardware store.

K2 Connection Options

Option 1

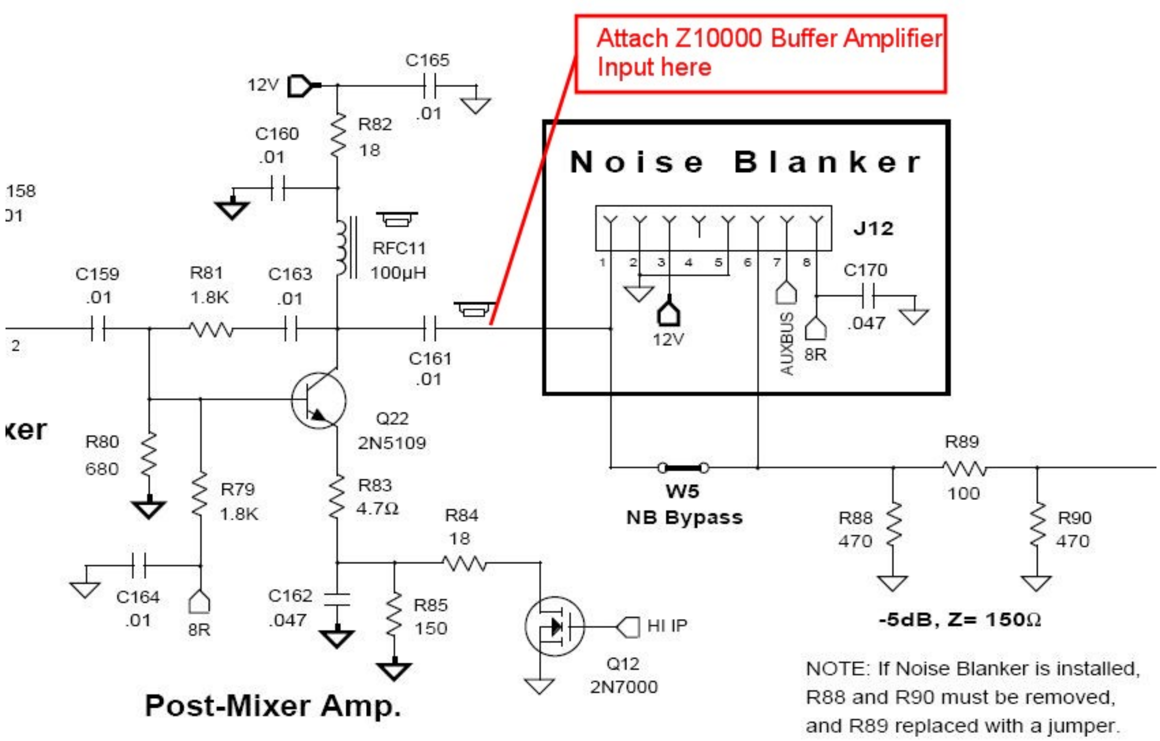
The Z10000-K2 was originally developed and tested with the connection point shown in the schematic below. This connection point has two advantages and one disadvantage:

Advantages:

- Connects at a low impedance point, and takes advantage of the K2's low noise post-mixer amplifier, Q22.
- Allows use of a 3-pin plug connector that minimizes modifications to the K2 and allows easy removal of the Z10000-U for maintenance, if necessary.

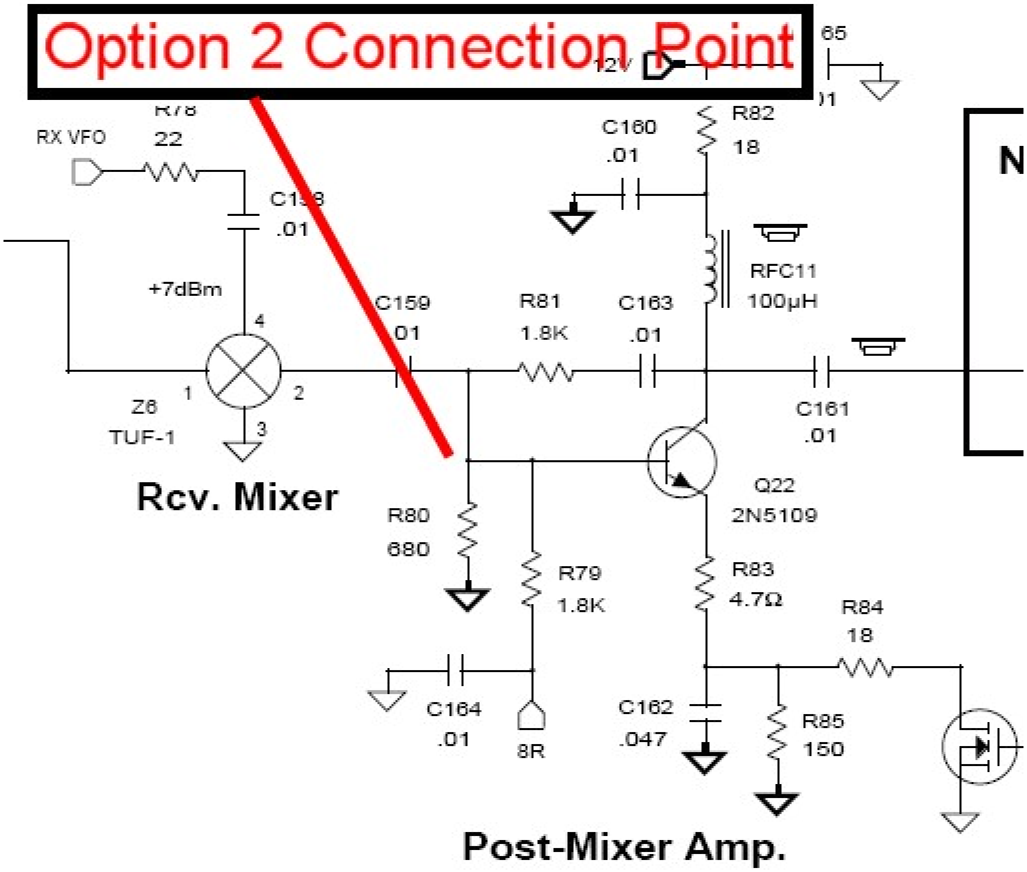
Disadvantage:

- The K2's BFO leakage backwards through the IF chain places an unwanted "pip" in the spectrum analyzer. (See section 4.6 of this manual for a discussion of why the K2 has BFO leakage.)



Option 2

Larry, N8LP, has developed an alternative connection option; take the IF sample at R80, Q22's 680 ohm base resistor.



This connection point also has advantages and disadvantages:

<u>Advantages:</u>

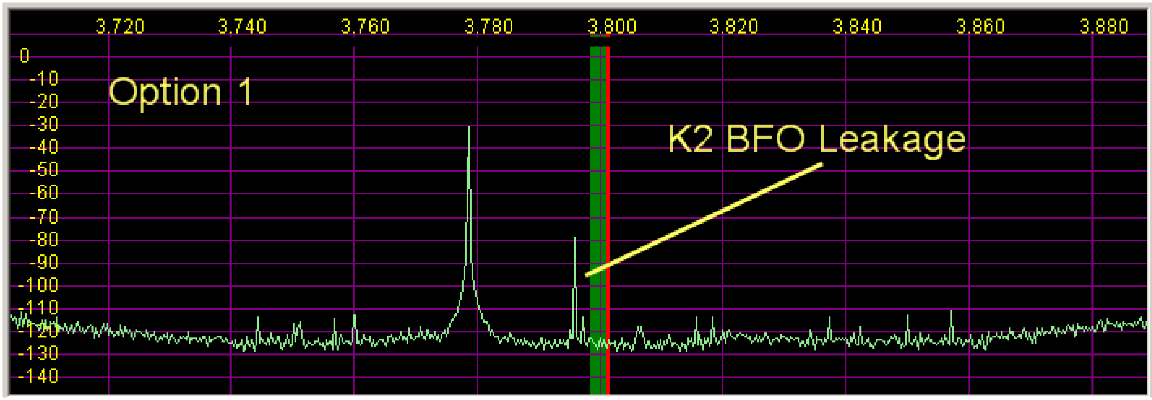
- Reduced BFO leakage back into the panadapter. This is because the BFO leakage is reduced by the post-mixer amplifier's isolation, which is around 30 dB.

<u>Disadvantages:</u>

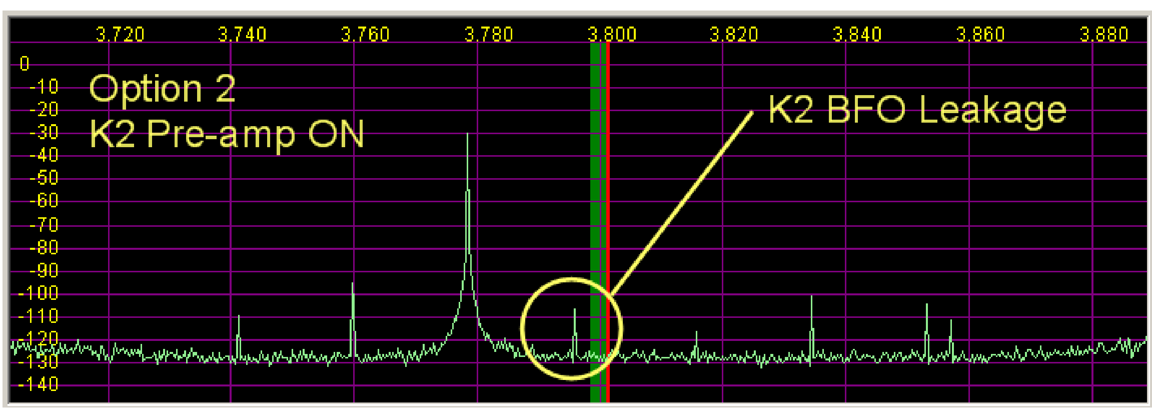
- Less gain from the K2's low noise post-mixer amplifier. This will reduce the overall usable sensitivity of the K2/panadapter combination. On most bands, and with most antennas, when used with the LP-PAN, this reduction in sensitivity will likely not prove significant.
- Requires soldering to the PCB parts and is not as easily reversible as Option 1,

To illustrate the difference in BFO leakage, Larry has supplied three screen images captured with an LP-PAN panadapter and the Z10000-K2 buffer amplifier connected at Option 1 and Option 2 points.

With the K2's Preamp OFF



With the K2's Pre-amp ON



The images show a significant reduction in BFO leakage, on the order of 30 dB.

When the K2's pre-amp is off, the noise floor is higher, by around 10 dB. This is because the low noise post-mixer amplifier gain is not available in Option 2. Larry has increased the Z10000-K2's gain slightly to offset part of the loss of the post-mixer amplifier gain, but the Z10000-K2 is optimized for isolation, not noise figure. Hence the composite noise figure of K2, Z10000-K2 and LP-PAN is not as good under Option 2. However, operating the K2 with its internal pre-amp on significantly improves the composite noise floor of the K2/Z10000/LP-PAN combination.

In Option 2, Larry recommends building the Z10000-K2 with the following gain setting resistor values:

R905: 4.7K Ohms
R907: 220 Ohms (this is a starting point; depending on your sound card gain it may be necessary to reduce R907 to 100 ohms or even 49.9 ohms for increased net gain.)

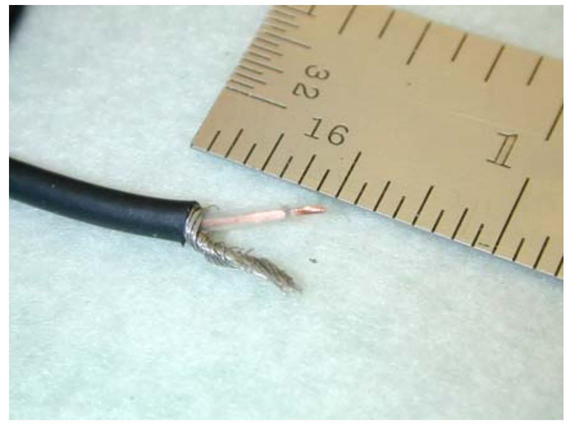
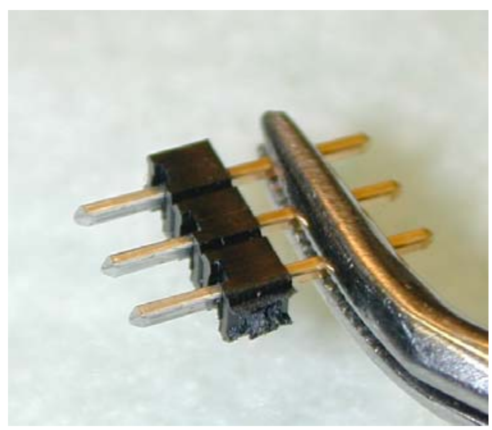
Note that as the Z10000's gain is increased, the clipping point of the amplifier decreases. Larry reports that with R907 at 120 ohms, the clipping point is -5 dBm. Of course, -5 dBm represents an extremely strong signal, unlikely to be encountered in most K2 environments.

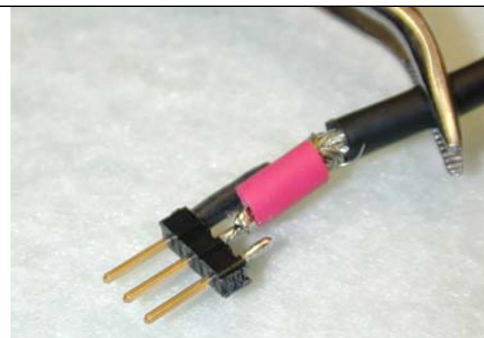
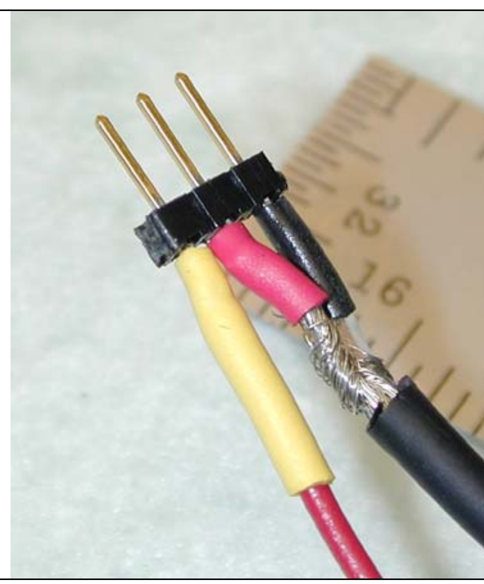
<u>Use these values only if you use Option 2; do not use these values if you connect using Option 1.</u>

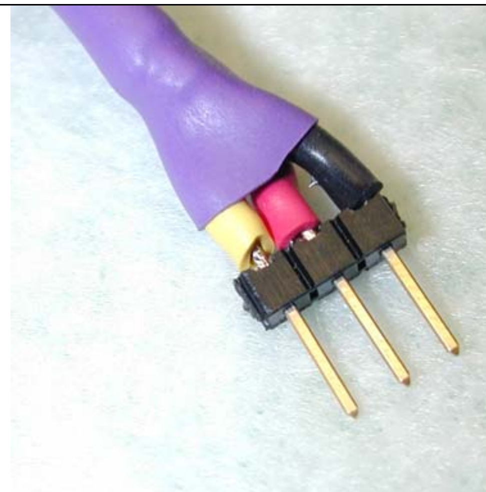
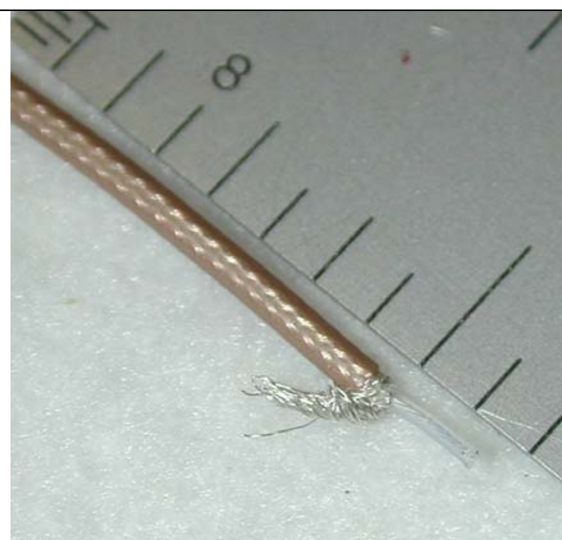
<u>Each connection option is separately described.</u>

Input Connections for Option 1

Note: The photographs show RG174 cable, not the RG178 cable supplied. The stripping dimensions and installation instructions remain the same.

Strip the outer jacket back about ½" (12 mm) using an X-Acto or sharp hobby knife, being careful not to nick the braid. See Section 3.2.5 concerning working with Teflon cable. Slip the center conductor through the braid and form a pigtail as illustrated. Strip approximately 1/8" (3 mm) from the center conductor and lightly tin the bare wire. Lightly tin the end of the braid to a length of about 1/8" (3 mm)	
Locate the 3-pin male header plug in Envelope 13. [supplied only with the –K2 version] Lightly tin the short side pins. (This is a good use for the locking forceps, by the way!)	

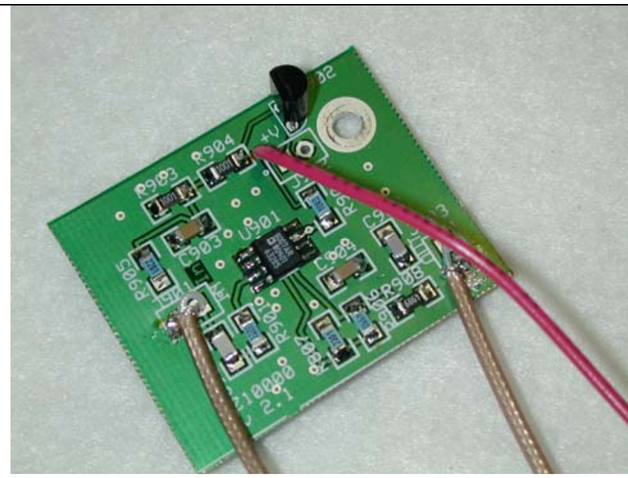
Locate the length of green small diameter heat tubing in Envelope 11 and slip it over the center conductor. It may be necessary to trim the heat shrink tubing. Solder the center conductor to one of the outside pins of the 3-pin male header plug. Slide the heat shrink tubing to be flush with the header plug plastic base and apply heat to the tubing to shrink it into place. [note – colors changed after photos taken]	
Locate the length of black heat shrink tubing in Envelope 11 and slip it over the stripped and twisted braid. Trim the tubing's length to fit. Solder the braid to the center pin of the 3-pin male header plug. Slide the heat shrink tubing to be flush with the header plug plastic base and apply heat to the tubing to shrink it into place. Don't worry if some of the braid near the jacket is still exposed. [note – colors changed after photos taken]	
Strip approximately 1/8" from the red hookup wire and lightly tin it. Solder the tinned end to the remaining pin of the 3-pin male header plug. Locate the length of red heat shrink tubing in Envelope 11. Slide the heat shrink tubing over the red wire to be flush with the header plug plastic base and apply heat to the tubing to shrink it into place. [note – colors changed after photos taken]	

Locate the length of larger diameter heat shrink tubing in Envelope 11. It may be of any color. Cut a length of about 1" (25 mm) and slip it over the coaxial cable and hookup wire, sliding it down to the plug end. Ensure that the braid is completely covered by tubing. The connector end of the assembly should resemble the photograph, with no bare shield showing. Apply heat to shrink the tubing.	
Cut short lengths of the remaining large diameter tubing and apply to form the coaxial cable and hook up wire into a cable assembly. Leave the last 2" (50 mm) free.	
Strip the free end of the coaxial cable to a length of about 3/16" to ¼" (4.5mm to 6mm) Remove the center conductor insulation for about 1/16" (1.5mm). Prepare the braid as shown in the illustration. Strip the free end of the hook-up wire to a length of about 3/16" (4.5mm). The photograph shows RG178.	

Route the connections on the top of the PCB as shown in the photograph.

Solder the hookup wire to the +V side of J902, *i.e.*, the non-grounded side of J902.

Solder the coaxial cable center conductor to the non-ground side of J901. Solder the coaxial cable shield to the grounded pad at J901, trimming its length if necessary to ensure that the braid does not cause a short circuit to the input or any other component. Check the center conductor resistance to ground with an ohmmeter. It should read as an open circuit.



Input Connections for Option 2

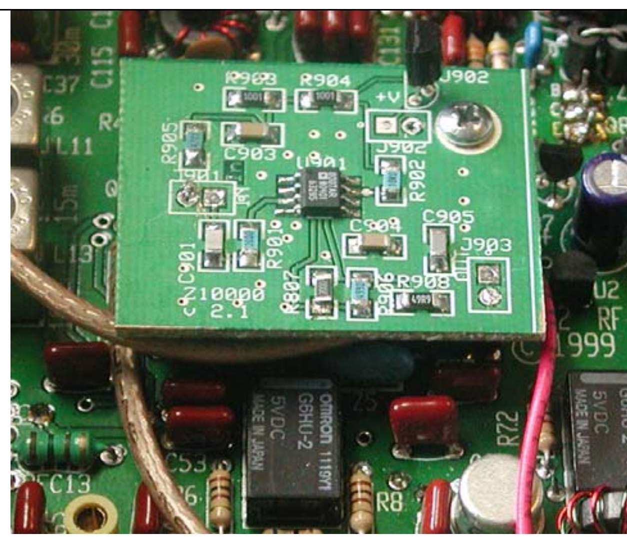
Note: Since Option 2 results in hard wiring the Z10000 to connection points in the K2, <u>before</u> making the connections described below, follow the check out procedures described in Section 4.3 of the manual.

Cut a length of the coaxial cable approximately six inches (150 mm) long. Strip both ends of this piece of coaxial cable to expose approximately 0.5" (12 mm) of the center conductor. Solder it to J903; the ground shield to the ground connector of J903 and the center conductor to the non-grounded pad.

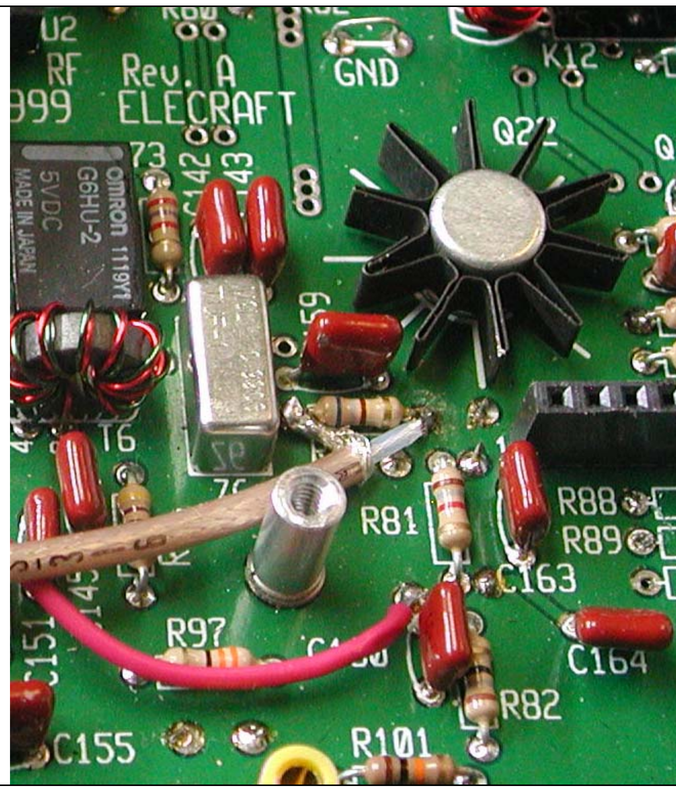
Route the connections on the bottom of the PCB as shown in the photograph.

Strip 0.25 inches (6 mm) from both ends of the short length of red hookup wire. Solder the hookup wire to the +V side of J902, *i.e.*, the non-grounded side of J902.

Strip the free end of the long coaxial cable with the SMA connector to expose 0.5" (12 mm) of the center conductor. Solder the coaxial cable

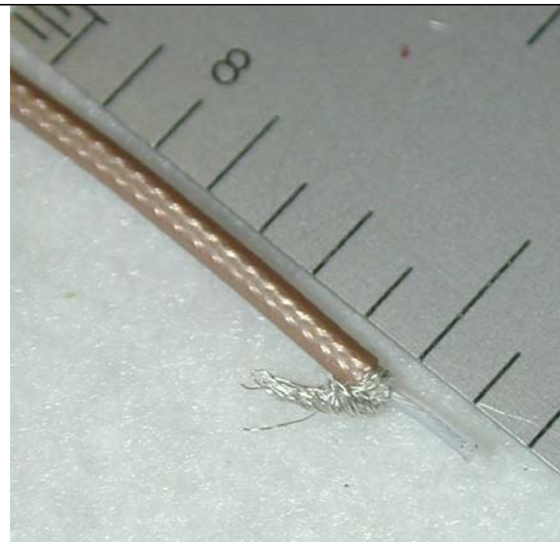
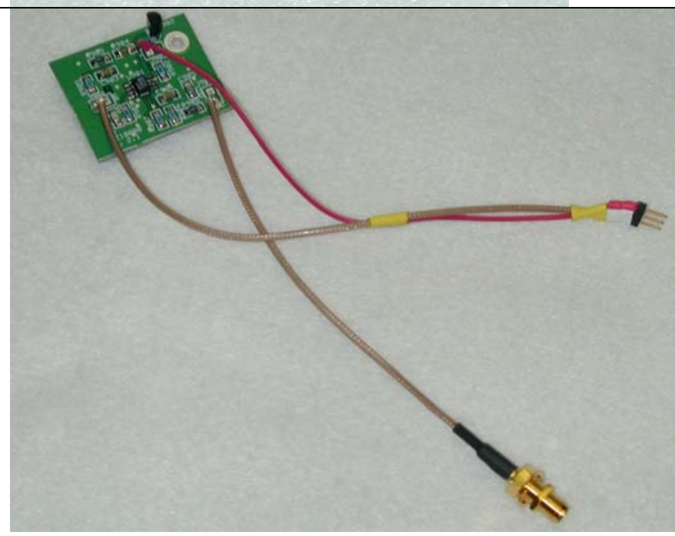


center conductor to the non-ground side of J901. Solder the coaxial cable shield to the grounded pad at J901, trimming its length if necessary to ensure that the braid does not cause a short circuit to the input or any other component. Check the center conductor resistance to ground with an ohmmeter. It should read as an open circuit.	

Connect the free end of the short coaxial cable to R80. The shield goes to the ground side of R80, and the center conductor to the base pin side of R80, as illustrated in the photograph to the right. Connect the red hookup wire as illustrated.	

Output Connection Under Option 1

If you have not already done so, locate the length of coaxial cable with the SMA bulkhead connector and cut it to the length you have determined, following the earlier instructions.	

Strip the free end of the coaxial cable to a length of about 3/16" to ¼" (4.5mm to 6mm) Remove the center conductor insulation for about 1/16" (1.5mm). Prepare the braid as shown in the illustration. The photograph shows RG178.	
Solder the coaxial cable center conductor to the ungrounded pad at J903. Solder the coaxial cable shield to the grounded pad at J903, trimming its length if necessary to ensure that the braid does not cause a short circuit to the input or any other component. Check the center conductor resistance to ground with an ohmmeter. It should read as an open circuit. At this point, your completed buffer amplifier should resemble the photograph.	

4.3 Checkout

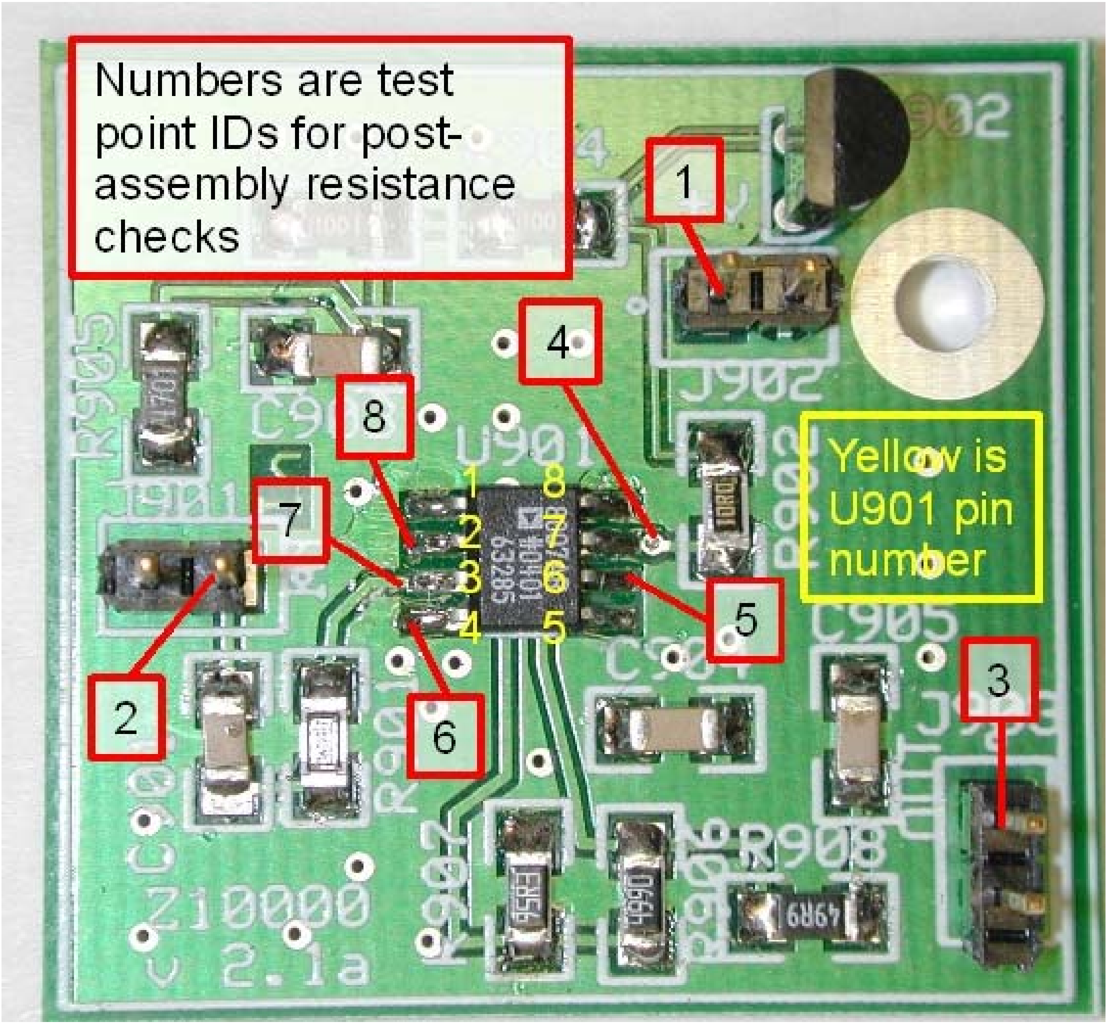
Note: If you are following Option 1, the Z10000 is a free standing board, with plug-in connections. If you follow Option 2, the board is hard wired into the K2. In this case, these measurements should be made before soldering the Z10000-K2 into the K2.

Before applying power, make the following resistance checks. The data presented is taken with a Fluke 189 digital multi-meter and different meters may provide differing readings. However, any significant variance from these values should be investigated for potential problems. The negative meter lead should be connected to a ground point on the Buffer Amplifier PCB. The test point (TP) Key numbers are depicted in the photograph below.

Measuring Point	TP Key	Reading	Comments
J902 (+12 V input)	1	2.5 K	This value may vary considerably from

Measuring Point	TP Key	Reading	Comments
			ohmmeter to ohmmeter.
J901 input pad	2	infinite	Should be infinite to ground as DC is blocked by C901
J903 output pad	3	infinite	Should be infinite to ground as DC is blocked by C905.
U901, pin 7 (Vcc)	4	2.0 KΩ	Reading dominated by R903/904 voltage divider impedance.
U901, pin 6 (output)	5	5 MΩ	Should be high impedance; hundreds of KΩ at least.
U901, pin 4 (ground)	6	0 Ω	
U901, pin 3 (+ input)	7	5.9 KΩ	This value may vary considerably from ohmmeter to ohmmeter.
U901, pin 2 (- input)	8	5 MΩ	Should be high impedance; hundreds of KΩ at least.

If the Buffer Amplifier meets these measurements, apply +12 V DC to the power input, with the negative return to the PCB ground. Measure the input current. It should be approximately 20 mA, and readings significantly over this value should be investigated.



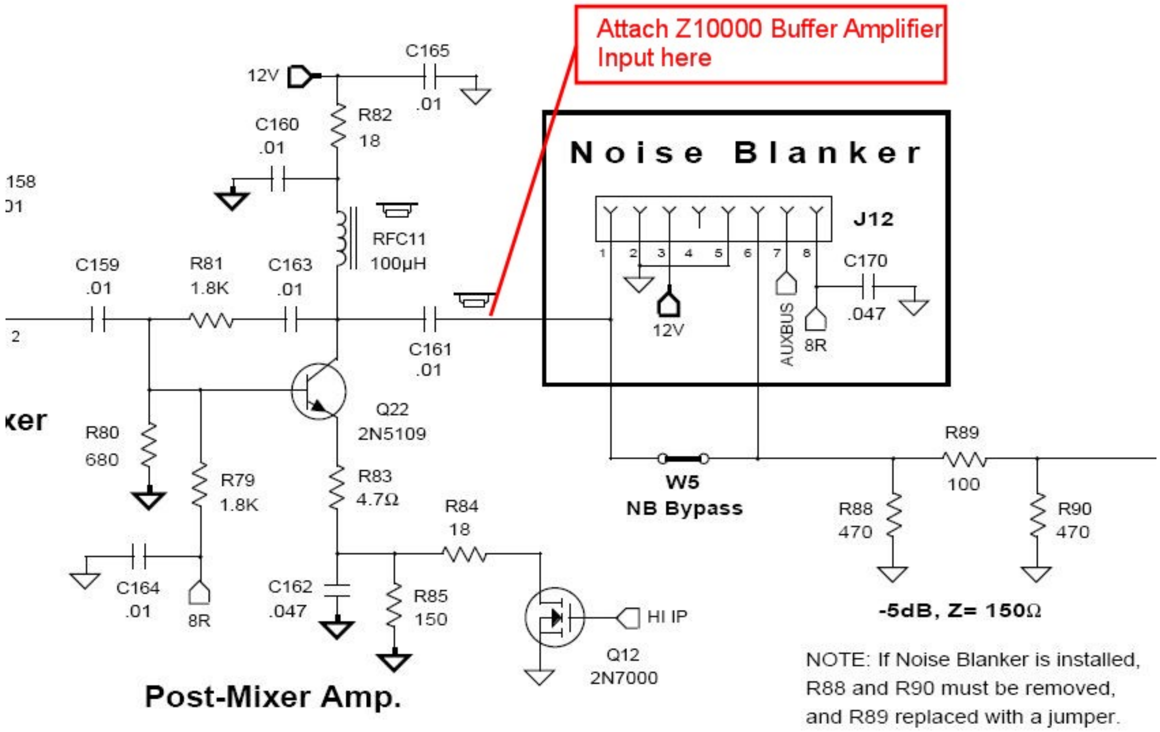
4.4 Installing the buffer amplifier

This section discusses installing the Buffer Amplifier in the K2 and other receivers and transceivers. Although specific detail is provided regarding the K2, installation in other equipment is up to the user, following the guidelines in this document.

Note: Although I've made the Buffer Amplifier installation as "no holes" as possible, you may find it necessary to add a small hole to fit the SMA connector to the K2's back panel for the signal output.

4.4.1 Elecraft K2 Transceiver-Option 1

The K2 connection concept following Option 1 is illustrated in the following figure.



Elecraft has conveniently provided the three connections the Buffer Amplifier needs (signal sample, ground and +12 V) at J12, the noise blanker connection socket, on three consecutive pins, no less. The following sections describe how the Buffer Amplifier is connected and installed, whether the noise blanker board is present or not. The Buffer Amplifier, if installed as described, will not interfere with the noise blanker's operation, should it be installed.

If your K2 does not have the optional noise blanker board installed, please first complete the steps described at Section 4.4.1.1.

4.4.1.1 Units without the Optional Noise Blanker Board

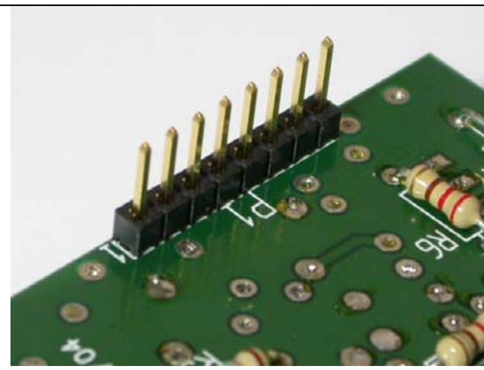
Locate the 8-pin female header socket provided with the K2 Buffer Board kit in Envelope 13. This socket will be installed at position J12 in the K2's RF board. These installation steps mimic Elecraft's noise blanker installation instructions, except for those steps associated with the noise blanker itself.

- ☐ Turn the K2 off and disconnect the power (either external supply or internal battery)
- ☐ Remove the top and bottom covers, but not the heat sink panel.
- ☐ Install the 8-pin female header socket on the RF board at location J12. Do not solder it in place yet; just mechanically install it from the top of the RF board.
- ☐ Solder one pin near the middle of the connector. It's important that the connector seats firmly against the PCB, so apply down pressure on it whilst soldering the pin. If the socket is not flush with the PCB, reheat the pin whilst applying downward pressure. Make sure the socket is not tilted up on one end or the other, but contacts the PCB for its full length.

- ☐ Do not make any other changes in your K2. If you later purchase the noise blanker board, it will not be necessary to remove the 8-pin socket, as it is identical with the socket installed in connection with the noise blanker board. (Of course, the other changes to the RF board required for the noise blanker installation will be necessary at that time.)
- ☐ Follow the installation instructions as for rigs with the noise blanker board, except that the 3-pin male header plugs directly into the newly installed 8-pin socket at J12. Pin 1 of the 3-pin header plug goes to Pin 1 of the 8-pin socket at J12.

4.4.1.2 Units with the Optional Noise Blanker Board

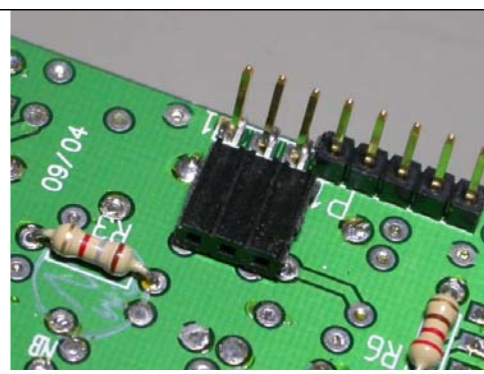
- ☐ Turn the K2 off and disconnect the power (either external supply or internal battery)
- ☐ Remove the top and bottom covers, but not the heat sink panel.
- ☐ Remove the noise blanker board by removing the 4-40 screw from the stand-off and unplug the noise blanker board.
- ☐ Turn the noise blanker board upside down and locate the 8-pin male header, P1.

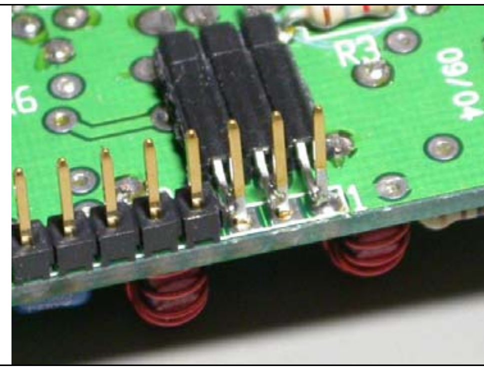


There is no definitive way to install the three-place female header socket onto the noise blanker PCB. Two ways that have been successful are:

Variant Procedure A

- ☐ With an X-Acto knife, trim away the plastic from the male header pins 1, 2 and 3, leaving the pins soldered in place. To help hold the pins in place whilst soldering, you may find it useful to slip the provided 8-pin female header partway over the noise blanker board's pins.
- ☐ Solder the provided 3-pin female header socket to the three header pins, with the socket parallel to the noise blanker PCB, at right angles to P1's pins.



☐ Another view of how the three-pin socket is solder to the modified noise blanker header.	

Variant Procedure B

Bob, K7HBG, describes how he installed the three-pin female header on the bottom of his noise blanker board:

1. I used a small razor saw to carefully cut through the insulating strip of the board male header (P1) between pins 3 and 4. I then lifted the cut loose insulating strip from the board surface and slid this strip up the pins toward their tops and left it there to hold the pins at the proper spacing and attitude on the chance I melted the solder holding a pin to the board. I did not but felt better for the precaution.

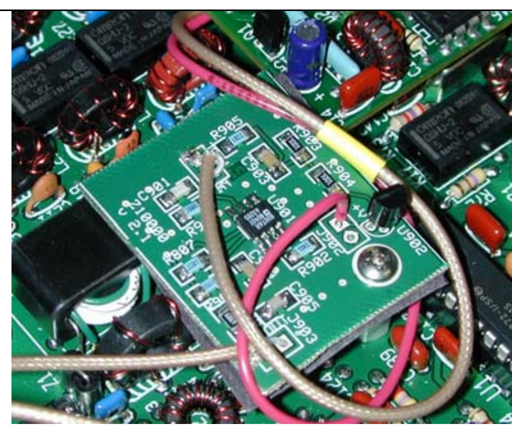
2. I then rotated the solder tabs of the 3 pin female socket strip until they were 90 degrees from where they were originally and flat on to the male connector pins. I gripped the pins a bit out from the connector body in order to allow the pin blades to rotate without undue stress on the metal in the bend area. This seemed to work well to position the ears flat against the male header pins. I tried connecting the female connector to a male header before and after pin bending to see if I could detect any loosening of the contact pin force. I could feel no degrading of the pin grip.

3. I made sure that I didn't over do the amount of solder on each pin. I ended up with a good fillet of solder between flat and pin.

4. One more thing to watch for is to keep the solder and female connector pins below the level of the rest of the male connector (P1) insulating strip so that the board plugs into its fem connector (J12) on the K2 RF board as before the mod.

   A thought here. A fella might want to angle the female connector away from the board just a bit so that the 3 pin male header with its coax and heat shrink misses R3's lead.

☐ Plug the 3-pin male plug into the	

newly installed socket. Orient the plug so that the pin with the green heat shrink tubing (coax center conductor) plugs into position 1. (If the plug is accidentally inserted backwards, it will not damage either your K2 or the Buffer Amplifier. Of course, the Buffer Amplifier won't work.)	
☐ Reinstall the noise blanker board, being careful to apply only the minimum necessary stress to the newly installed 3-pin socket and cable assembly. Route the cable as shown in the photograph.	
☐ Remove the 4-40 screw at as shown in the photograph and install the provided ½" (12 mm) male/female 4-40 threaded standoff from Envelope 11. Retain the removed screw. ☐ Remove the fish paper from Envelope 12. You should have trimmed the fish paper to match the PCB according to the earlier instructions. If you have not already done so, do it now.	
☐ Mount the Buffer Amplifier board and fish paper as shown in the photograph, using the retained 4-40 machine screw. If you cannot find the screw, an extra one is provided in Envelope 11. ☐ The fish paper is placed below the PCB to insulate the components on the bottom of the PCB from contacting the electrolytic capacitors on the K2's main board. The photo shows the fish paper's edges near the mounting screw.	

☐ Mount the output connector at the location you have decided on. Route the SMA connector to that location and install, using 5/16” open end wrenches to fit the nuts. Do not overtighten! ☐ The photo shows my K2’s mounting position. You may need to use a different strategy, depending on the options installed in your K2.	
☐ Check your work for possible problems and correct any problems found. ☐ Restore +12 V power to the K2 and proceed to the checkout stage.	

4.4.1.3 Post-Installation Checkout

If you have the Z90 or Z91 working, you may use that to check out the Buffer Amplifier. Connect the Z90/91 to the Buffer Output with the supplied BNC-to-RCA cable. Set the Z90/91 to 4415 KHz following the instructions in the Z90/91 Operating Manual. Tune your K2 around the bands and see how the signals display on the Z90/91.

If satisfactory, re-install the K2’s panels you have removed.

If you do not have a working panadapter or other device to connect to the Buffer Amplifier output port, you may wish to verify the installation through simple tests. For example, check the +12 V input to the Buffer Amplifier PCB and verify the +9 V regulated output from U902. You can measure the current drawn by U901 by measuring the voltage drop across R902. It should be approximately 0.1 volt, corresponding to 10 mA.

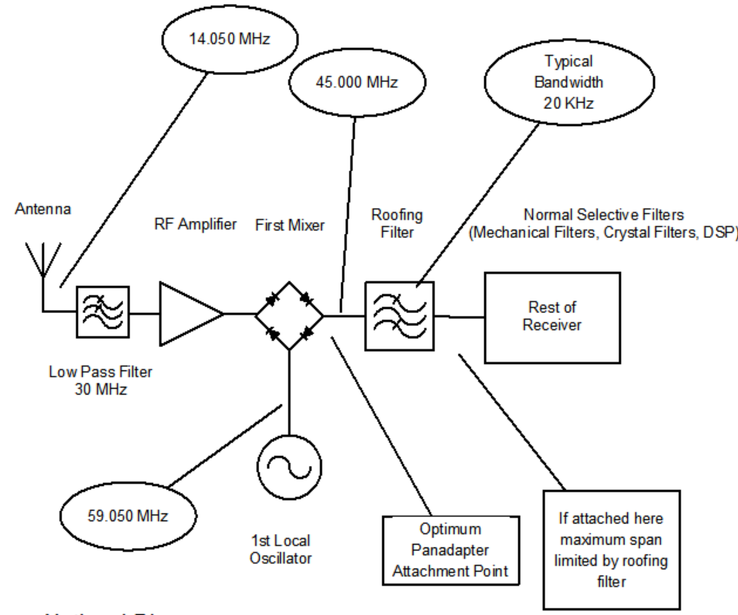
If you have a signal generator and an oscilloscope, you can input a strong signal into the receiver and measure the buffer amplifier output voltage. The K2 connection point is after the RF preamplifier and post-mixer IF amplifier, so there should be a reasonable amount of gain ahead of the Buffer Amplifier. By comparing the signal level at the input to U901 to the output level, you may verify the gain.

4.4.2 Other Receivers and Transceivers

Before installing the Buffer Amplifier in a different transceiver, review the K2 installation instructions for ideas that might be adapted for your equipment.

While the information presented in this document are believed correct, connecting the Buffer Amplifier to your receiver should be done only if you are comfortable working on the equipment and if you have independently assessed the accuracy of this information. Clifton Laboratories is not responsible for damage to your equipment, whether or not you follow this document’s recommendations.

The concept is to connect the Buffer Amplifier at a point in the receiver chain ahead of the selective filter stages. Practically all receivers and transceivers manufactured in the last 20 years are "up-converting" style with a first IF in the 40 MHz to 70 MHz range.[7] In an up-converting receiver,

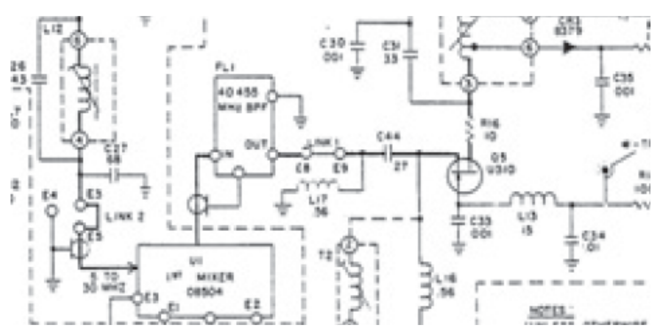


Notional Diagram
Up-Converting Receiver

immediately after the first mixer is a crystal filter of perhaps 20 to 25 KHz bandwidth, commonly called a "roofing filter." If the Panadapter is to have maximum utility, it must be connected ahead of the roofing filter.

Determining the optimum connection point requires analysis of the receiver's schematic diagram. Ideally, the point of connection will be at a low impedance point (50 Ω is ideal) so that the Buffer Amplifier's input impedance will not disturb the receiver's performance.

Unfortunately, the input impedance of the roofing filter is generally not indicated in the receiver's schematic. However, in some cases it can be inferred from other circuit values. Consider the Racal RA6790/GM receiver's first mixer area, shown in the above schematic fragment. The output of the first mixer module goes to the 40.455 MHz roofing filter module. The filter's output goes to a common gate FET amplifier, Q5. This arrangement strongly suggests that the mixer's impedance is designed for 50 Ω and that the necessary crystal filter matching is done internally to the roofing filter. (The RA6790/GM Technical Manual specifies the roofing filter as having a 20 KHz bandwidth, but is silent on its impedance.) Using the rough rule that bridging a circuit with impedance 10 times higher is "safe" we determine that so long as the Buffer Amplifier's input impedance > 500 Ω we can likely connect it to FL1's input port without seriously upsetting the receiver's performance by altering the terminating impedance seen by the first mixer. Looking at the impedance data presented earlier (although it cuts off at 30 MHz, it can be reasonably extrapolated, as the behavior seems to be that of a simple RC circuit) the buffer amplifier should meet this requirement, so long as the connection to the Buffer Amplifier is kept short.



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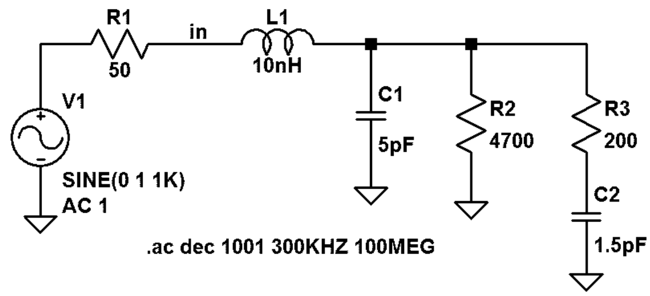
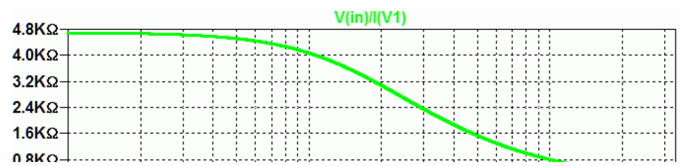
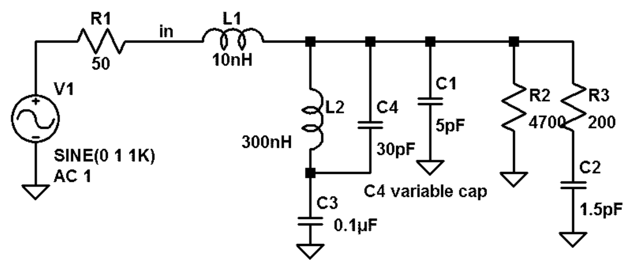
[7] Elecraft's K2, of course, is a notable exception to this design philosophy, as it is a single conversion receiver, with a nominal IF of 4915 KHz.

It's unlikely that all (most?) receiver designers will have been so accommodating as to provide a suitable low impedance pick-off point ahead of the roofing filter. Fortunately, it's relatively easy to "neutralize" the Buffer Amplifier's input capacitance, thereby increasing the input impedance.

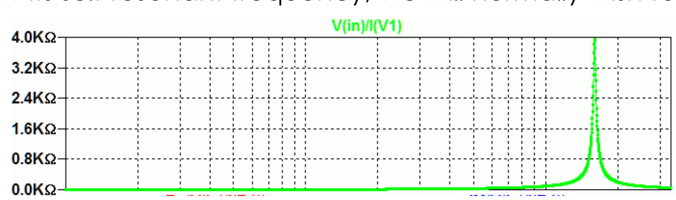


We'll start the analysis by examining a simple model of the Buffer Amplifier's input circuitry as shown at the right. This simple model does a reasonable job at modeling the Buffer Amplifier's input impedance, may be seen by comparing the computed impedance plot for the model with the measured input impedance data presented in Section 1.3.2.





Looking at the model immediately suggests a strategy for increasing the input impedance. Since the impedance above a few MHz is dominated by the shunt capacitance C1 (representing the input leads and PCB traces) we can resonate C1 and C2 with a parallel inductance. In order to obtain a reasonable size inductor that will operate below its self-resonant frequency, we will normally wish to add extra capacitance in parallel with the strays. For a 45 MHz IF, we, based on experience, use a 300 nH resonating inductor and a variable capacitor (usually a small variable plus a fixed capacitor) of about 30 pF, calculated from the normal parallel resonance formula. To avoid placing a DC short on the AD8007's input, the cold side of the parallel resonant circuit is returned to a bypass capacitor, not directly to ground.



Plotting the resulting input impedance shows that at 45 MHz the input impedance is increased to about 4 KΩ. The maximum input impedance is limited by L2's Q and the R905, the 4.7 bias isolation resistor.

Whether this solution works for any particular receiver requires further analysis. For example, terminating the mixer output with a frequency selective circuit may impair the receiver's IP3 performance as the mixer will not see the same impedance over a wide range of frequencies.

4.5 Selecting R907

The object in setting the Buffer Amplifier's gain is to provide just enough gain to optimize the Panadapter's performance. To understand how to accomplish this task, we must consider the Panadapter and receiver as an integrated system.

The Z90/91 has a dynamic range of about 55 to 60 dB, depending on bandwidth selected. Although this is superior to other amateur radio Panadapters, it is does not approach the typical 100 dB+ dynamic range of a receiver. (The K2's dynamic range approaches or even exceeds 130 dB.) Receivers display large dynamic ranges because, amongst other things, they incorporate automatic gain control systems; as the signal level increases, lower level stages have their gain is reduced to prevent overloading later stages. Panadapters and spectrum analyzers do not generally employ AGC systems, instead relying upon log amplifiers and generous headroom in amplifier design.

Let's reduce this abstract discussion to practical numbers. Two signals, one of S1 and one of 40 dB over S-9 differ by about 94 dB, assuming the 1 S-unit = 6 dB standard. The Z90/91 will not accurately display two signals differing by 94 dB. For that matter, neither of my two HP spectrum analyzers will accurately display two signals with 94 dB difference in signal strength.

We should consider two cases: Where the stages ahead of the Z10000 Buffer Amplifier are not subject to the receiver's AGC and where they are.

In most receivers, AGC is not applied to the RF amplifier stage. The K2, for example, applies AGC only to the IF stages; the RF amplifier and post-mixer amplifier are run at fixed gain. (The RF amplifier is switchable in and out, of course, via a front panel switch.) The standard Racal RA6790/GM has no RF amplifier and AGC is applied to the post-roofing-filter amplifier stage.

The user has two options to set the Z10000 Buffer Amplifier's gain; set it such that the strongest reasonable signal input to the receiver's antenna terminal causes the Buffer Amplifier to output a signal at about -40 dBm, the optimum maximum input level for the Z90/91. If this signal level corresponds to, say S9 + 40 dB, then the weakest signal that the Panadapter will display is about 60 dB below that, or S6. This is likely to be perceived (correctly so) as resulting in a "deaf" Panadapter. It will, however, accurately display strong signals. A more desirable strategy is to set the Buffer Amplifier's gain so that the weakest reasonable signal will produce a discernable "pip" on the Panadapter screen or computer display. If this threshold is, say, S1, then signal levels much beyond S9+10 dB will be compressed on the Panadapter's display.

To determine the correct gain setting resistor (R907) with this strategy, assuming that test equipment such as a calibrated signal generator and spectrum analyzer are available, start with a value of 0 dB (499 Ω) and tune to a weak signal, of the level you believe should be displayed. Based on the height of the signal's "pip" you can determine whether more or less gain is appropriate and the approximate magnitude of the required gain. Depending on how much gain is ahead of the Buffer Amplifier's point of connection, it may not be possible for the Panadapter to display the weakest discernable signal.

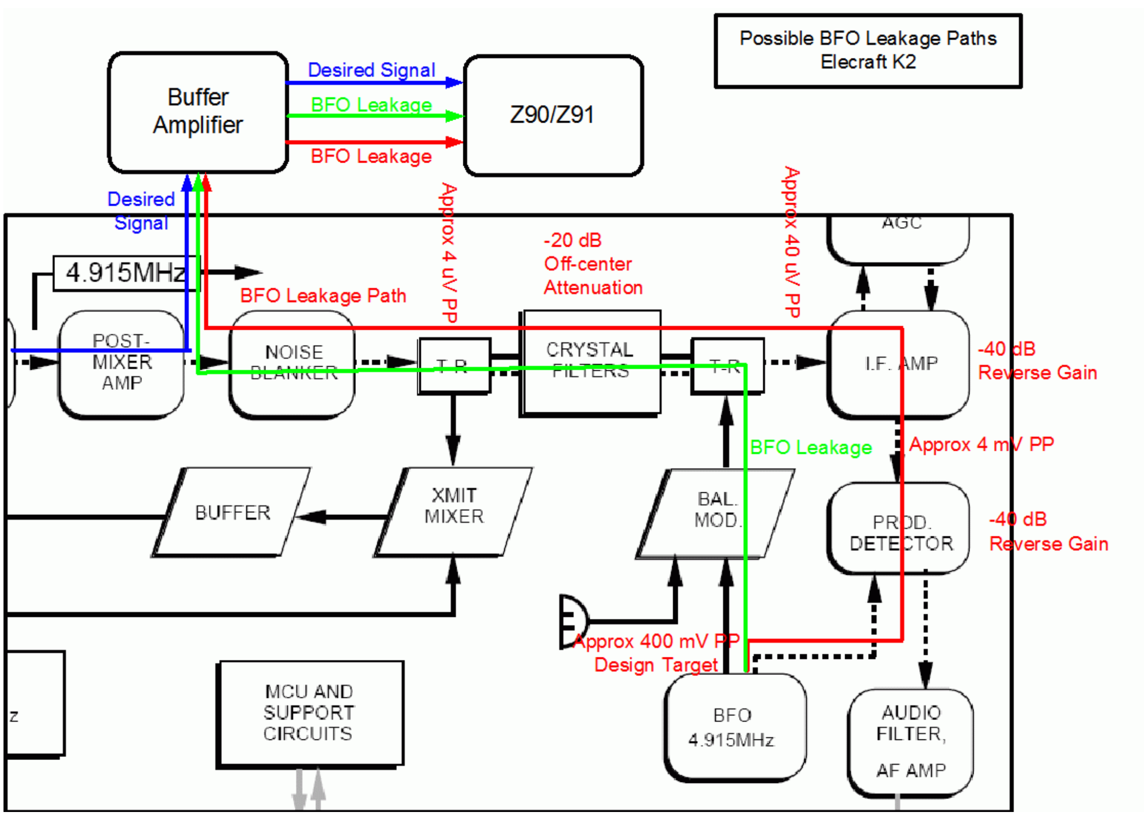
If necessary, the Z90/91's built-in attenuators may be switched in to provide up to 30 dB of gain reduction.

If the receiver has AGC applied to the stages ahead of the Buffer Amplifier's point of connection, a similar strategy should be used, but it is necessary to consider how the Panadapter will display signals. Suppose the Panadapter is displaying a weak signal, say 50 KHz below the frequency to which the receiver is tuned. Then, a strong signal comes on at the frequency on which the receiver is tuned. This signal causes the receiver's AGC to reduce the gain of the RF stages ahead of the Buffer Amplifier, thereby reducing the apparent signal strength of displayed signals. Hence, with a receiver applying AGC to the RF amplifier stages, when experimenting to determine the optimum Buffer Amplifier gain setting, it is necessary to remain cognizant of the effect of signals in the receiver's passband.

4.6 BFO Leakage in the K2

The K2's BFO leaks out of the IF with a signal level around -80 dBm.

It seems that the BFO signal is passed back to the buffer amplifier's input via one of two possible paths, as illustrated in the marked-up K2 block diagram below.



It's not clear which of the two possible paths the culprit is. Considering that the BFO signal is quite strong (I measured nearly 2 volts peak-to-peak at U11), even if it is attenuated 90 dB, it still shows up as a clearly visible signal at the IF pick-off point.

Why does the K2 have BFO leakage but other transceivers do not?

Several possible reasons:

* The K2 is a single-conversion design, and hence the BFO is at the same frequency as the point where we sample the IF frequency. A multiple conversion receiver will not have the BFO on the same frequency as the high IF.

* Relatively simple IF chain. There are only two active stages between the IF pick-off point and the BFO. Thus, the BFO suppression is critically dependent upon (a) U11 (NE602)

balance and the reverse gain of U12 (MC1350) IF amplifier. If both U11 and U12 have -40 dB reverse gain (how strong the signal at the amplifier's input is when fed into the output), the BFO will be attenuated only 80 dB at the IF sample pickup point. Other receivers have more IF amplification stages, which improves the overall BFO leakage proportionally.

* Single board construction. At one extreme, commercial and military grade receivers have each major module constructed in a separate, shielded compartment. The K2 has all its RF components on a single PCB. This provides a significant cost benefit, but may contribute to the BFO leakage.

* If you tap off an IF stage operating at the same frequency the BFO, you may well see BFO leakage.

Why Doesn't the BFO Leakage Bother Normal Receiver Operation?

Because it is at the same frequency as the BFO and because it is much weaker than the direct signal. The leakage that shows up on the Z90 panadapter (and on my HP8558B spectrum analyzer) will have no effect upon normal K2 operation.

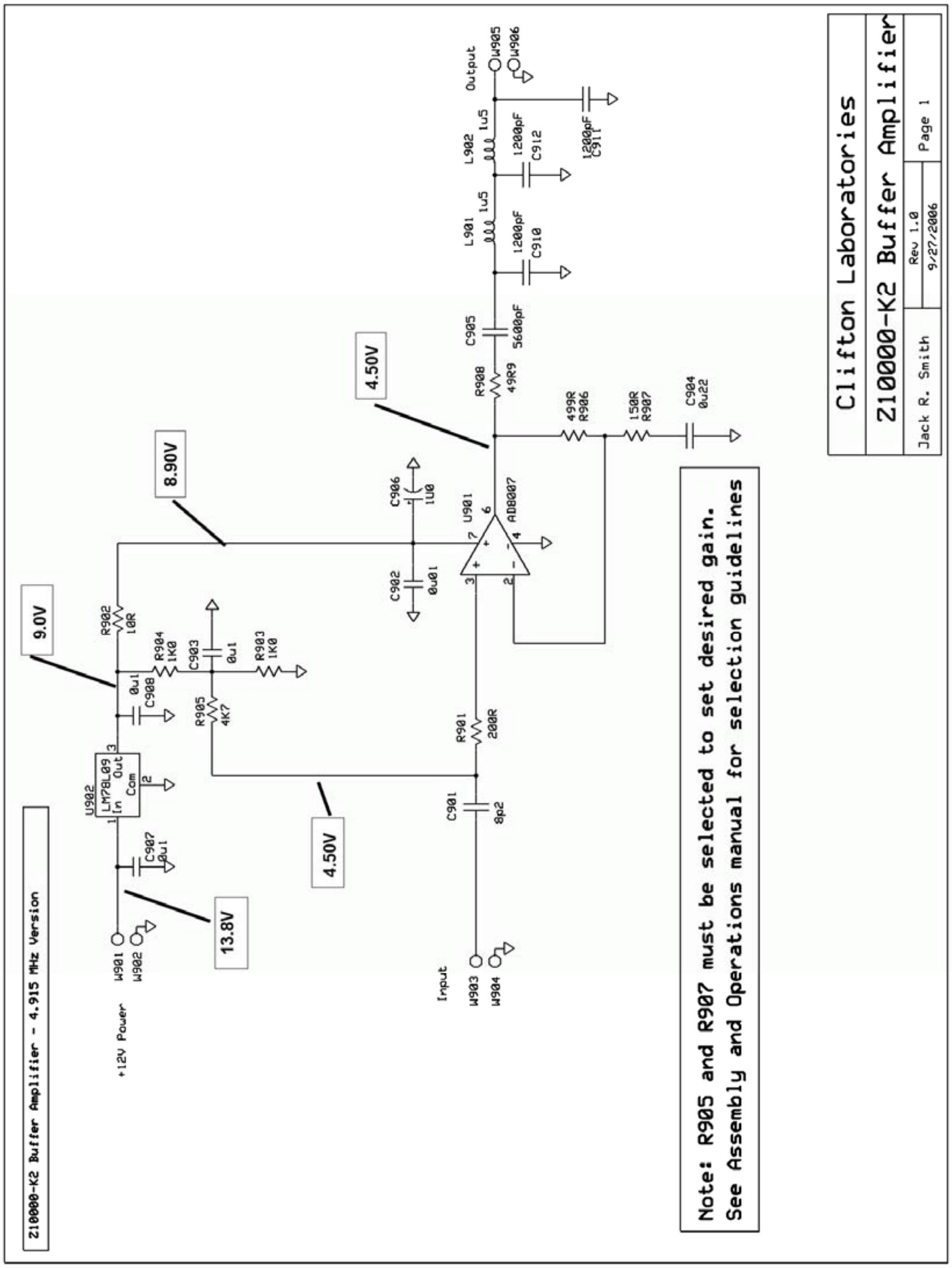
5.0 Troubleshooting

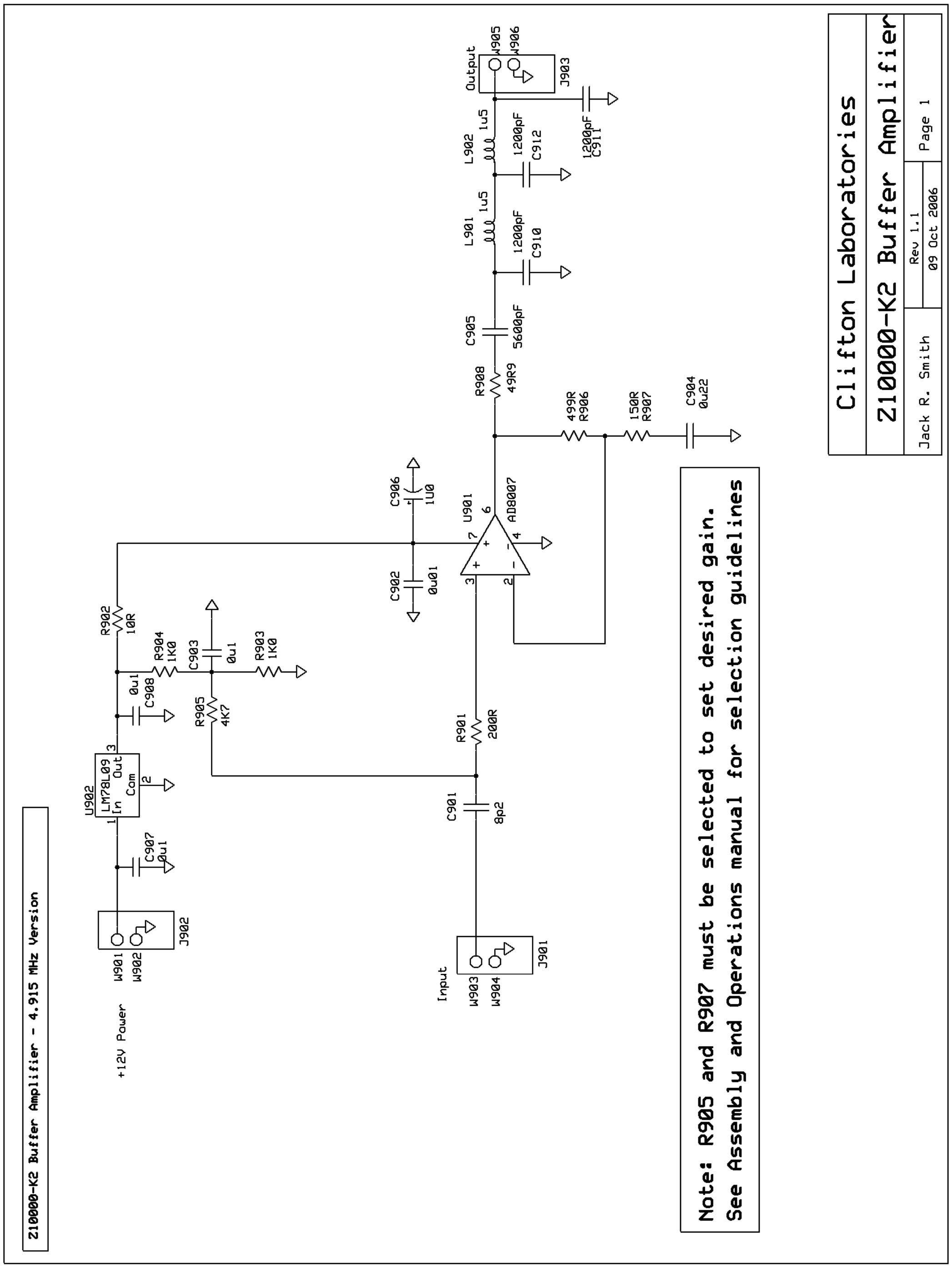
The Buffer Amplifier is a simple circuit and there are only two active devices to present problems; the voltage regulator, U902 and the AD8007 amplifier, U901.

Faults in U902 can be easily located by measuring the input and output voltage across the regulator. With 12 V input, the regulator output should be 9 V ± 0.5 V. If it is above 9 V, the 78L09 is likely defective. If it is below 9 V, then before determining that the 78L09 is defective, the possibility of a short circuit or low impedance load on the regulated output must be first eliminated.

Faults in U901 will normally manifest themselves as reduced gain or reduced signal level output from the Buffer Amplifier. In this case, where the supply and regulated voltages are within range, it may be best to conduct a gain test.

5.1 Schematic with Nominal DC Voltage Values and Normal Schematic


Z10000-K2 Buffer Amplifier - 4.915 MHz Version
Clifton Laboratories
Z10000-K2 Buffer Amplifier
Jack R. Smith
Rev 1.0
9/27/2006
Page 1
Note: R905 and R907 must be selected to set desired gain.
See Assembly and Operations manual for selection guidelines
+12V Power
W901
W902
Input
W903
W904
Output
W905
W906
13.8V
9.0V
8.90V
4.50V
4.50V
U902
LM78L09
In
Out
Com
C907
0u1
C908
0u1
R902
10R
R904
1K0
R903
1K0
C903
0u1
R905
4K7
R901
200R
C901
8p2
C902
0u01
C906
1U0
U901
AD8007
R906
499R
R907
150R
C904
0u22
R908
49R9
C905
5600pF
C910
1200pF
C912
1200pF
C911
1200pF
L901
1u5
L902
1u5


Z10000-K2 Buffer Amplifier - 4.915 MHz Version
+12V Power
W901
W902
J902
C907
0u1
U902
LM78L09
In
Out
Com
C908
0u1
R902
10R
R904
1K0
C903
0u1
R903
1K0
R905
4K7
R901
200R
C901
8p2
Input
W903
W904
J901
C902
0u01
C906
1U0
U901
AD8007
R908
49R9
R906
499R
R907
150R
C904
0u22
C905
5600pF
L901
1u5
C910
1200pF
L902
1u5
C912
1200pF
C911
1200pF
Output
W905
W906
J903
Note: R905 and R907 must be selected to set desired gain.
See Assembly and Operations manual for selection guidelines
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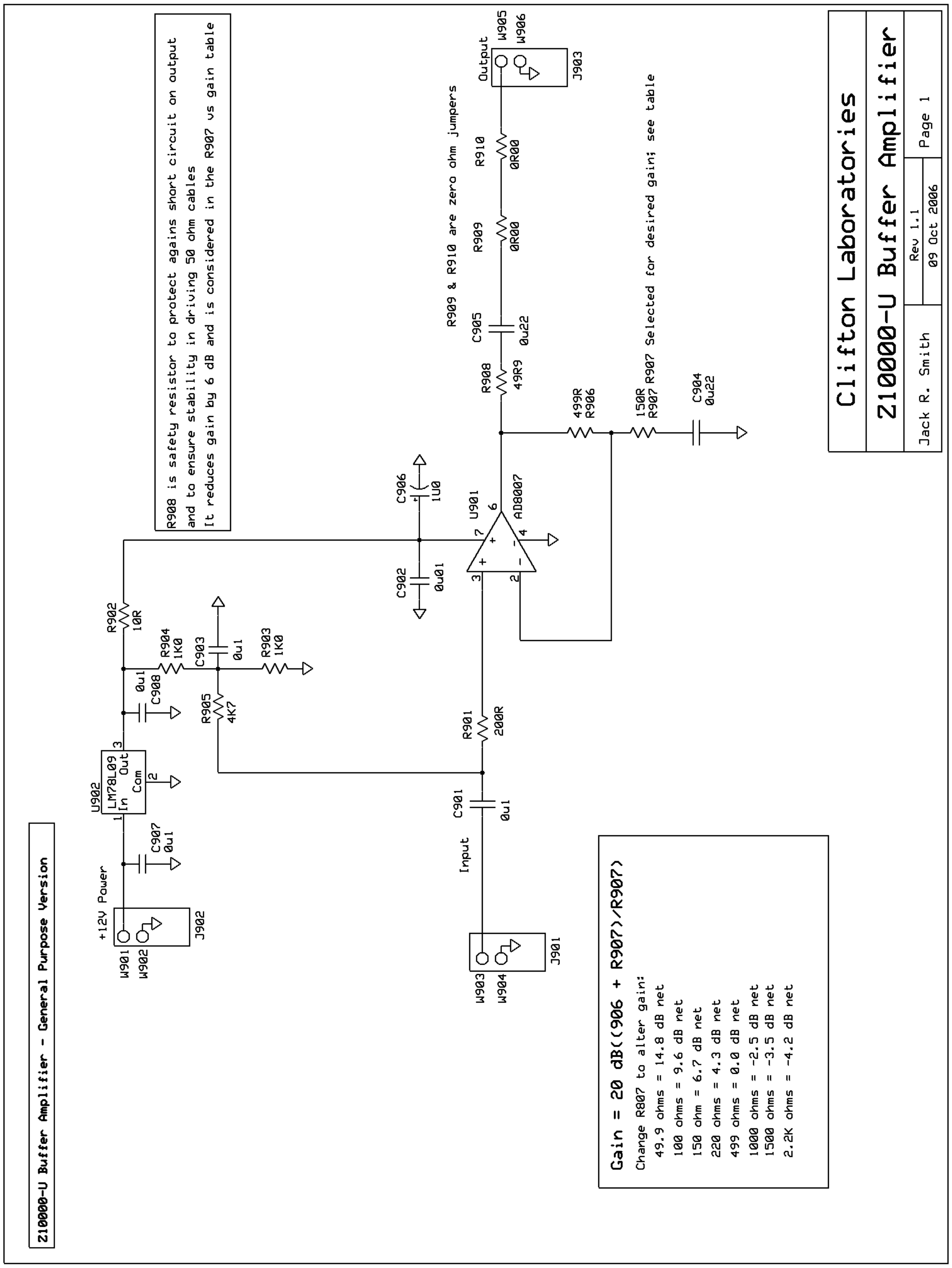
Z10000-U Buffer Amplifier - General Purpose Version
+12V Power
W901
W902
J902
C907
0u1
U902
LM78L09
In
Out
Com
C908
0u1
R902
10R
R904
1K0
C903
0u1
R903
1K0
R905
4K7
R908 is safety resistor to protect agains short circuit on output
and to ensure stability in driving 50 ohm cables
It reduces gain by 6 dB and is considered in the R907 vs gain table
C902
0u01
C906
1U0
Input
W903
W904
J901
C901
0u1
R901
200R
U901
AD8007
R909 & R910 are zero ohm jumpers
R908
49R9
C905
0u22
R909
0R00
R910
0R00
Output
W905
W906
J903
499R
R906
150R
R907
R907 Selected for desired gain; see table
C904
0u22
Gain = 20 dB((906 + R907)/R907)
Change R807 to alter gain:
49.9 ohms = 14.8 dB net
100 ohms = 9.6 dB net
150 ohm = 6.7 dB net
220 ohms = 4.3 dB net
499 ohms = 0.0 dB net
1000 ohms = -2.5 dB net
1500 ohms = -3.5 dB net
2.2K ohms = -4.2 dB net
Clifton Laboratories
Z10000-U Buffer Amplifier
Jack R. Smith
Rev 1.1
09 Oct 2006
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Warranty

This warranty is effective as of the date of first consumer purchase.

What is covered: During the ninety (90) days after date of purchase, Clifton Laboratories will correct any defects in the Z10000 due to defective parts or, if the Z10000 was assembled by Clifton Laboratories, workmanship, free of charge (post-paid). You must send the unit at your expense to Clifton Laboratories, but we will pay return shipping. Clifton Laboratories' warranty does not extend to defects caused by your incorrect assembly or use of unauthorized parts or materials or construction practices.

What is not covered: If the Z10000 is purchased as a kit, this warranty does not cover correction of assembly errors or misalignment; repair of damage caused by misuse, negligence, or builder modifications; or any performance malfunctions involving non-Clifton Laboratories accessory equipment. *The use of acid-core solder, water-soluble flux solder, or any corrosive or conductive flux or solvent will void this warranty in its entirety.* Whether purchased as an assembled unit or as a kit, also not covered is reimbursement for loss of use, inconvenience, customer assembly or alignment time, or cost of unauthorized service.

Limitation of incidental or consequential damages: This warranty does not extend to non-Clifton Laboratories equipment or components used in conjunction with our products. *Any such repair or replacement is the responsibility of the customer. Clifton Laboratories will not be liable for any special, indirect, incidental or consequential damages, including but not limited to any loss of business or profits.*

Under no circumstances is Clifton Laboratories liable for damage to your amateur radio equipment resulting from use of the Z10000, whether in accordance with the instructions in this Manual or otherwise.