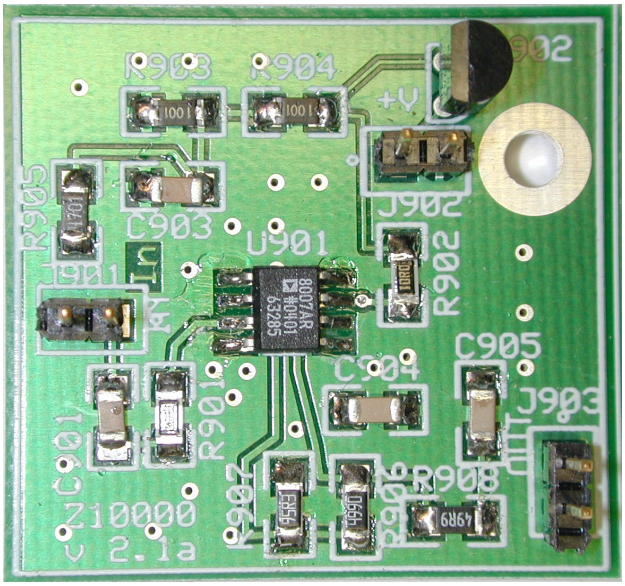
Assembly and Operations Manual

Z10000-U Broadband Buffer Amplifier





Version 3.3 / 03 April 2009

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Assembly and Operations Manual

Z10000-U

Version 3.3 April 2009

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Last Revised 03 April 2009

1 Introduction and Specifications

Introduction

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

- Z10000-K2 model—optimized to be used with an Elecraft K2 transceiver, with bandpass response shaping for a 4915 KHz IF;
- Z10000-U or "Universal" model—same PCB as the Z10000-K2, but with a flat frequency response. The Z10000-U is broadband and is suitable to use with Elecraft's K3 transceiver for additional isolation and/or gain from the 8215 KHz IF output port. This manual covers the –U version.

1.1 Specifications

Parameter	Specification
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 24V 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.
Output Impedance	50 ohms; short circuit protected.
Active Devices	78L09 voltage regulator AD8007 amplifier
Reverse Isolation	Typically 100 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.
Bandwidth	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 frequency and attachment technique. Greater than 1.5 K ohm to 10 MHz, (See typical performance plot)
Gain	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 is for one Z10000 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.

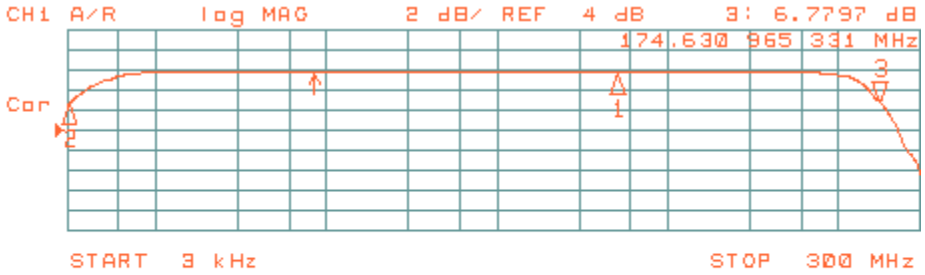
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[1] It is possible to extend the Z10000's low frequency response to 3 KHz by replacing all 0.22µF capacitors with 1.0µF. The Z10000-U used in the test data presented has this modification.

[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.

1.3.1 Frequency Response and Gain

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

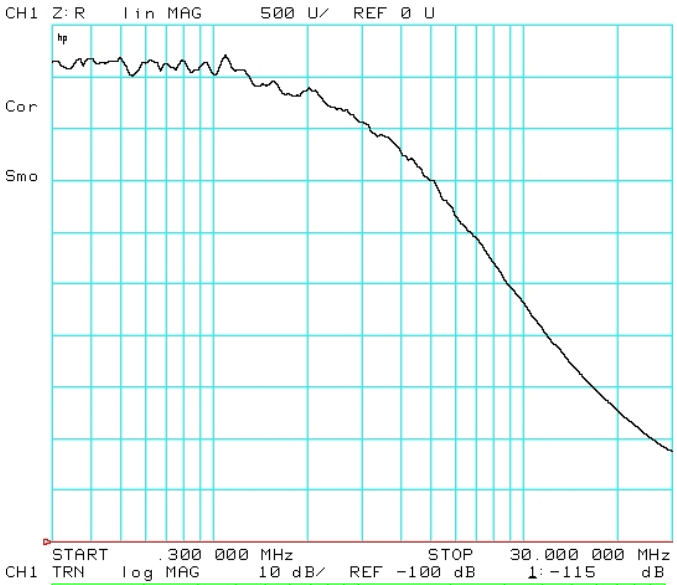


N	STIMULUS	val
1	5 MHz	9.7809 dB
2	3.123 354 kHz	6.7379 dB
3	174.630 965 331 MHz	6.7797 dB

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 Z10000-U's normal configuration) and shunt capacitance from the PCB traces, connecting wires to the amplifier and the amplifier's input capacitance.

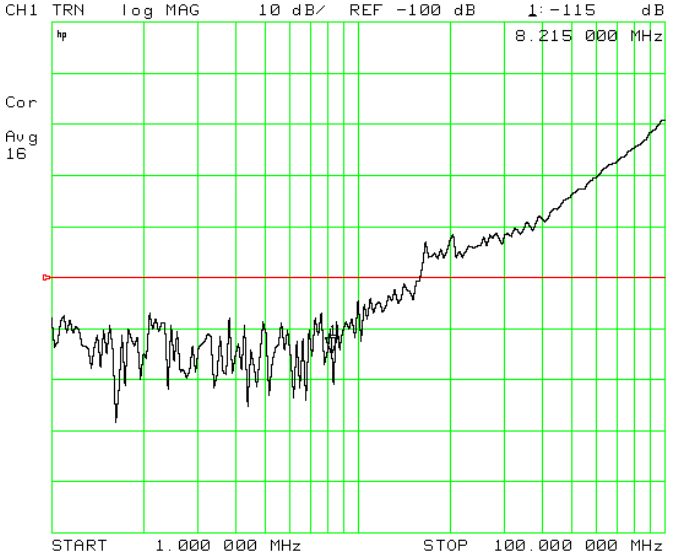
The measured data presented at the right should be considered as representative of a Z10000-U amplifier with short (a two inches / 50 mm) coaxial cable input leads.



1.3.3 Reverse Isolation

The buffer amplifier's reverse isolation is a function of frequency, illustrated in the amplifier measurements presented at the right. 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,



as

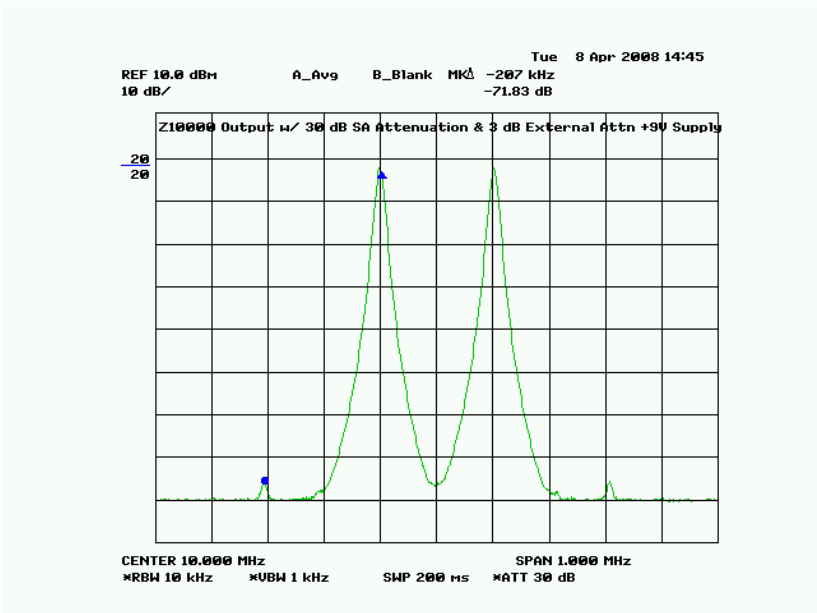
the

isolation illustrated at the right may not be achieved in every instance.

1.3.4 Intermodulation Performance

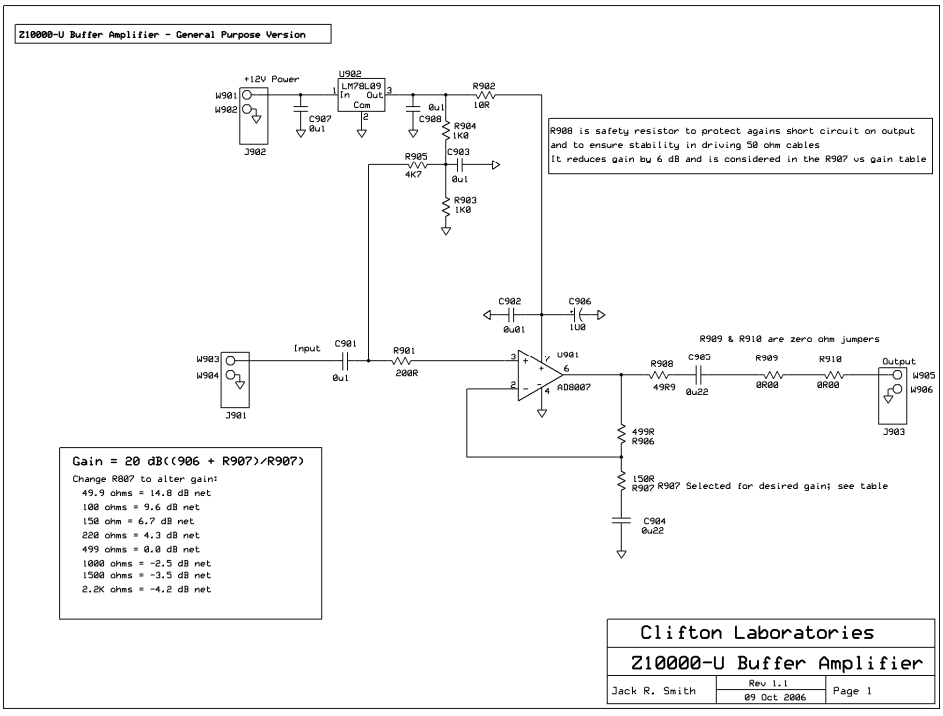
The illustration at the right shows the output of the test unit with two equal signals (9900 KHz and 10100 KHz) of -10 dBm applied to the amplifier input. The amplifier output is 0 dBm (a 3 dB attenuator is applied ahead of the spectrum analyzer in this plot.)

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 Schematic and Circuit Description

2.1 Schematic



2.2 Theory of Operation

2.2.1 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]

2.2.2 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:

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[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.

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

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

2.2.3 Gain Setting in the Z10000-U Buffer Amplifier

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

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.

2.2.4 Values to use with Elecraft K3 Transceiver

When using a Z10000-U with an Elecraft K3 transceiver to provide additional gain and isolation over that provided with the K3's standard IF output port, the following component values should be used:

If you have not made modifications to the K3's IF sample circuitry, the K3 will exhibit about 15 dB net transfer loss between the antenna port and the IF output port when measured with the K3's preamplifier off and with a 50 ohm instrument on the IF port. In order to bring the transfer gain to 0 dB, build the Z10000 for 10 db nominal gain. (Approximately 6 dB gain will be added due to the Z10000's high input impedance, thereby netting out at 16 dB transfer gain.)

R905: 4K7 Ω

R907: 100R Ω

If you have made the modification to the K3's IF sample circuit described by Larry, N8LP, at http://groups.yahoo.com/group/LP-PAN/files/K3_Buffer_Mod/, the K3's transfer gain will be increased to 6 dB loss, an improvement of 9 dB from the unmodified case. In this event, you will wish to build the Z10000 for 0 dB nominal gain.

R905: 4K7 Ω

R907: 499R Ω

The Z10000 kit includes extra resistors with these values.

3 Parts List

The Z10000-U parts are packaged in a several small envelopes.

- Resistors.
- Capacitors
- Printed circuit board
- Semiconductors (AD8007 and 78L09)

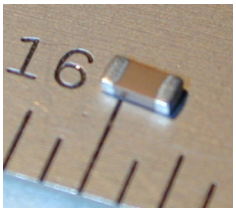
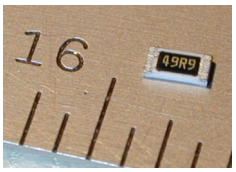
When working with capacitors particularly, do not removed the individual parts from their color-coded packaging until you are ready to use the component, as their values are not marked on the part and cannot normally be visually distinguished. Hence, if you mix up the capacitors, you will have to measure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

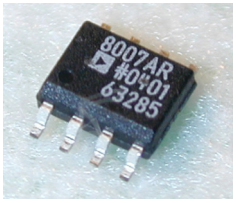
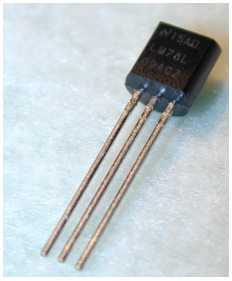


Also, do not confuse 100 ohm 1% resistors (identified as 1000) with 1.0K ohm 1% parts, identified as 1001.



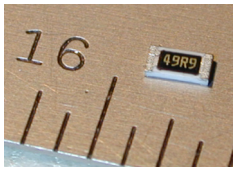
Note that the schematic identifies parts with the multiplier as the “decimal” point. For example a 1K ohm resistor is identified as a 1K0, and a 49.9 ohm resistor as 49R9.

Typical Photo	Designation	Value	Marking	Qty
	C901	0u1	Not marked	1
	C902	0u01	Not marked	1
	C903	0u1	Not marked	1
	C904	0u22	Not marked	1
	C906	1u0	Not marked	1
	C907	0u1	Not marked	1
	C908	0u1	Not marked	1
	R901	200R	2000	1
	R902	10R	10R0	1
	R903	1K0	1001	1
	R904	1K0	1001	1
	R905	4K0	4701	1
	R906	499R	4990	1
	R908	49R9	49R9	1
	L901	Zero ohm jumper	000	1
	L902	Zero ohm jumper	000	1

Typical Photo	Designation	Value	Marking	Qty
	U901	AD8007	AD8007ARZ	1
	U902	LM78L09	KA78L09AZ	1

Gain Setting Parts

See manual Section 2.2.3 and 2.2.4 to determine proper value



Optional Resistor Supplied			
R905	2K2	2201	1
R905	1K1	1101	1
R907	49R9	49R9	1
R907	100R	1000	1
R907	150R	1500	1
R907	220R	2200	1
R907	499R	4990	1
R907	1K0	1001	1
R907	1K5	1501	1
R907	2K2	2201	1
Z10000-08	Printed circuit board		1

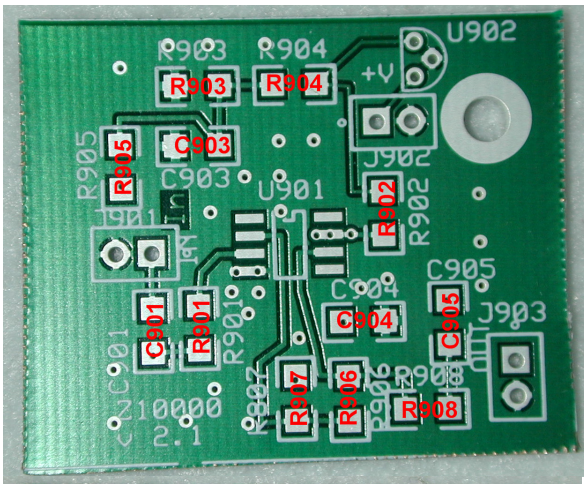
Multiple part values are provided for R905 and R907, to be selected by the builder as discussed in at Section 2.2.3 and 2.2.4.

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

4 Assembly

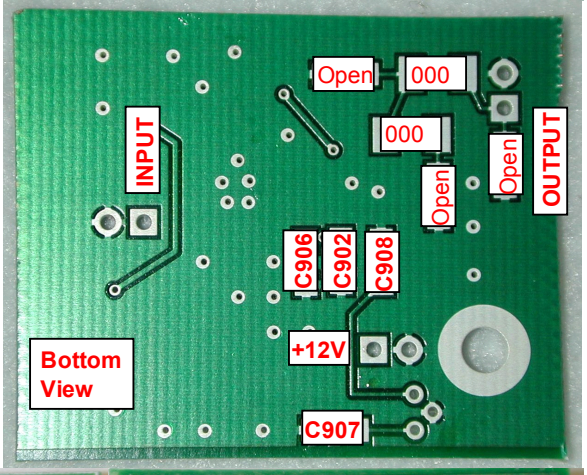
4.1 Orientation

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.



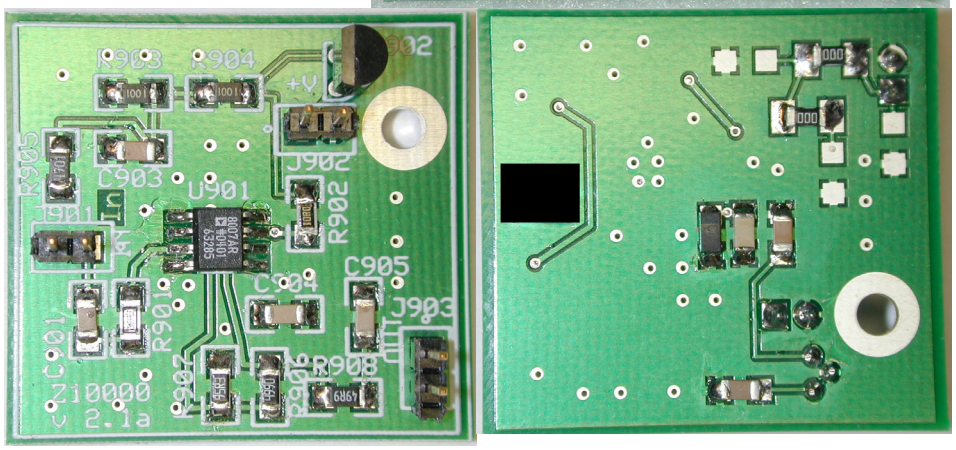
The photograph shows an earlier version of the PCB. Later PCBs correct the silk screen error identifying R907 as R807, and slightly rearrange other silk screen legends. In addition, production circuit boards may be slightly smaller than in the photographs.

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



Three capacitors, shown as “Open” in the photograph are not used in the U version and hence these pads are unused. The two areas marked “000” show the location of the two 0 ohm jumpers.

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 bottom view photograph blanks out a component added for test purposes. It also shows a tantalum capacitor at C906. Current kits are shipped with a ceramic C906.)



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) as described at Sections 2.3.3 and 2.3.4.

Install the surface mount parts on the top:

- ☐ Install U901 (AD8007)
- ☐ Install C901 0.1 uF unmarked
- ☐ Install C903 0.1 µF, unmarked
- ☐ Install C904 0.22 µF, unmarked
- ☐ Install R901 200 Ω, marked 2000
- ☐ Install R902 (10 Ω, marked 10R0)
- ☐ Install R903 1 KΩ, marked 1001
- ☐ Install R904 1 KΩ, marked 1001
- ☐ Install R906 499 Ω, marked 4990
- ☐ Install R908 49.9 Ω, marked 49R9
- ☐ Install C905 0.22 µF unmarked
- ☐ **Select R905 following instructions at Sections 2.3.3, 2.3.4;** Install R905
- ☐ **Select R907 following instructions at Sections 2.3.3, 2.3.4;** Install R907

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

- ☐ Install C902 0.01 µF, unmarked
- ☐ Install C906. 1.0 µF, unmarked
- ☐ Install C907 0.1 µF, unmarked
- ☐ Install C908 0.1 µF, unmarked
- ☐ Install L901 bypass Zero-ohm jumper marked 000
- ☐ Install L902 bypass Zero-ohm jumper marked 000

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.

Now install the through-hole part:

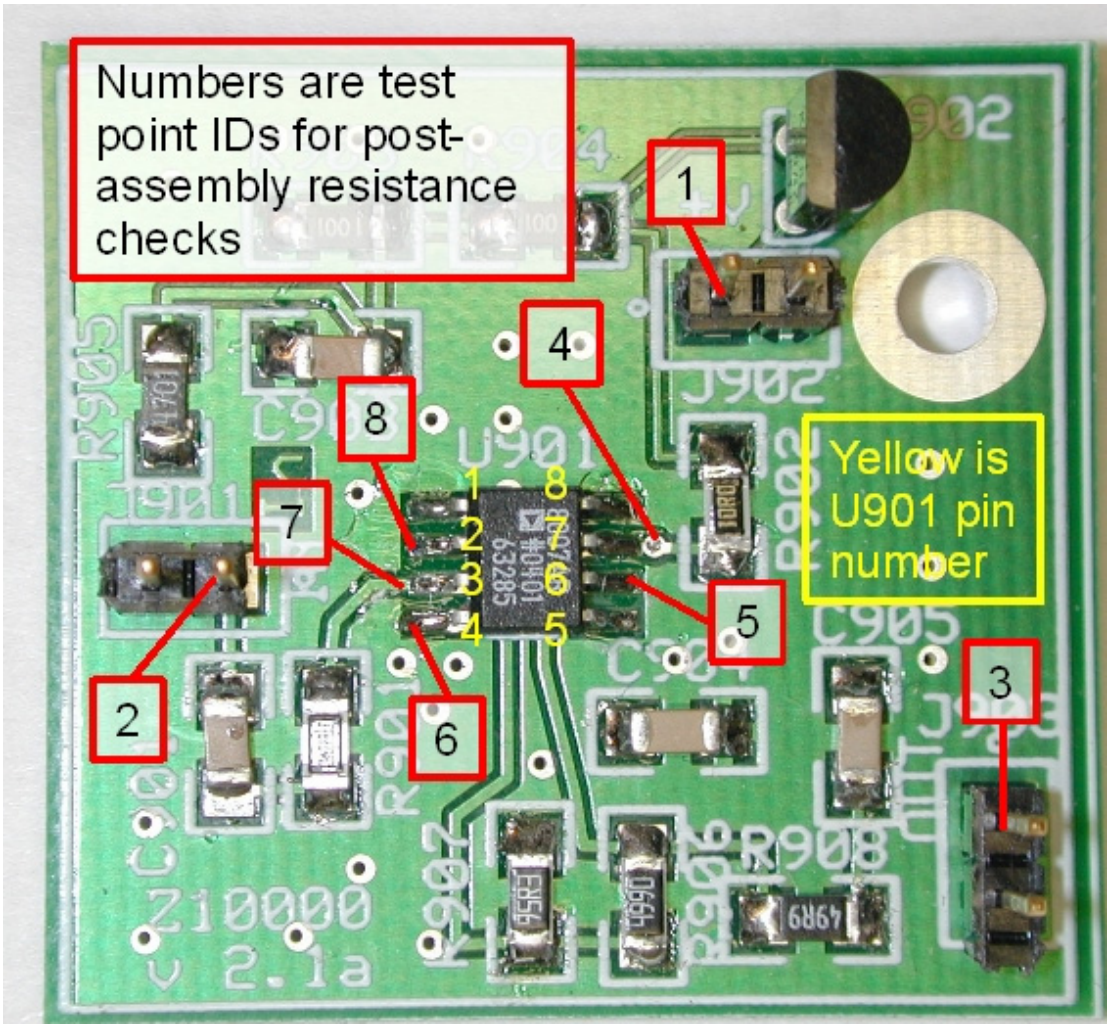
- Install U902. This is a 78L09 3-terminal regulator in a TO-92 package. Note the orientation of the device as shown in the silk screen outline. You will have to form the leads to fit the hole.

4.3 Checkout

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 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.



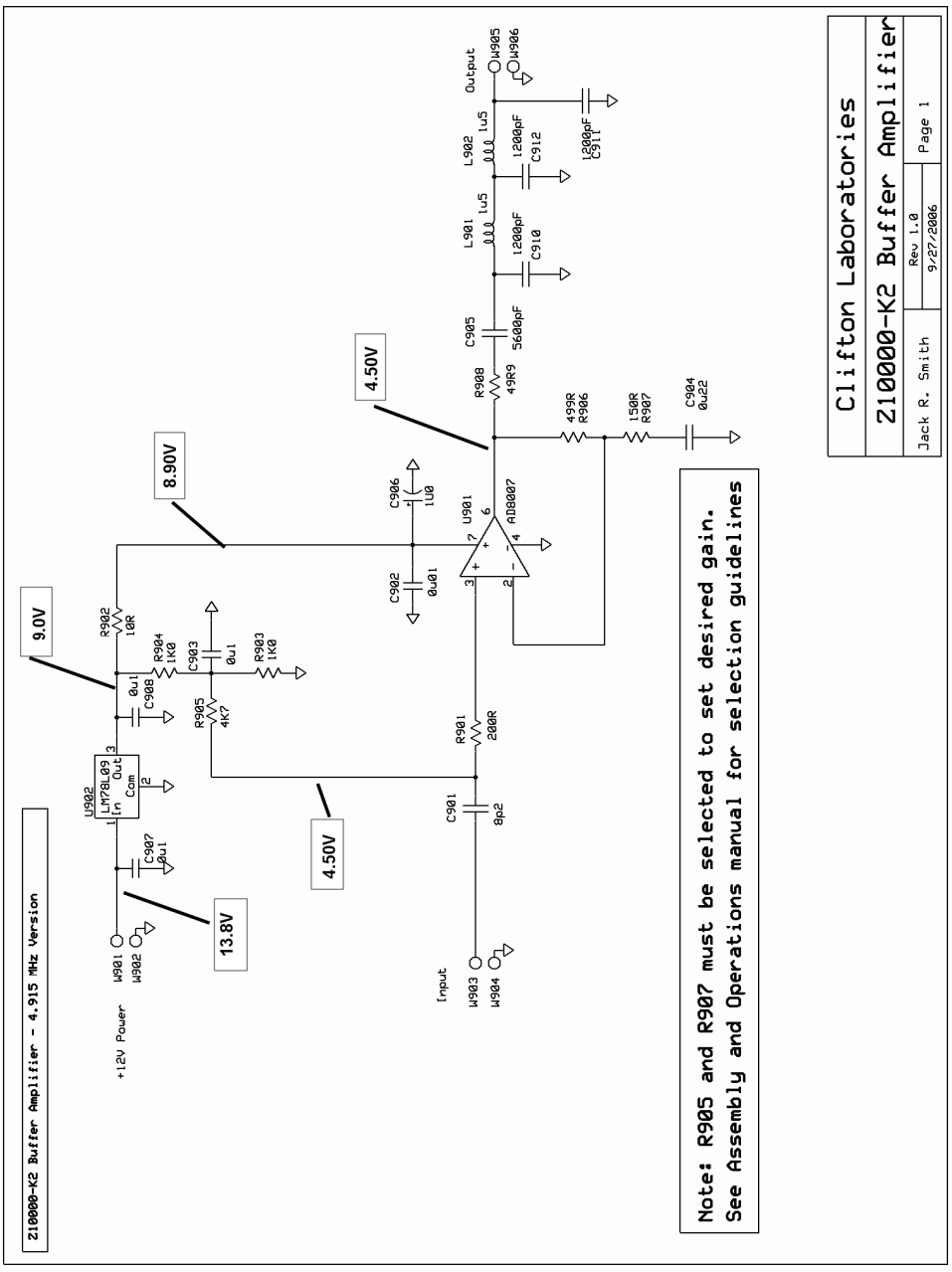
5. Troubleshooting

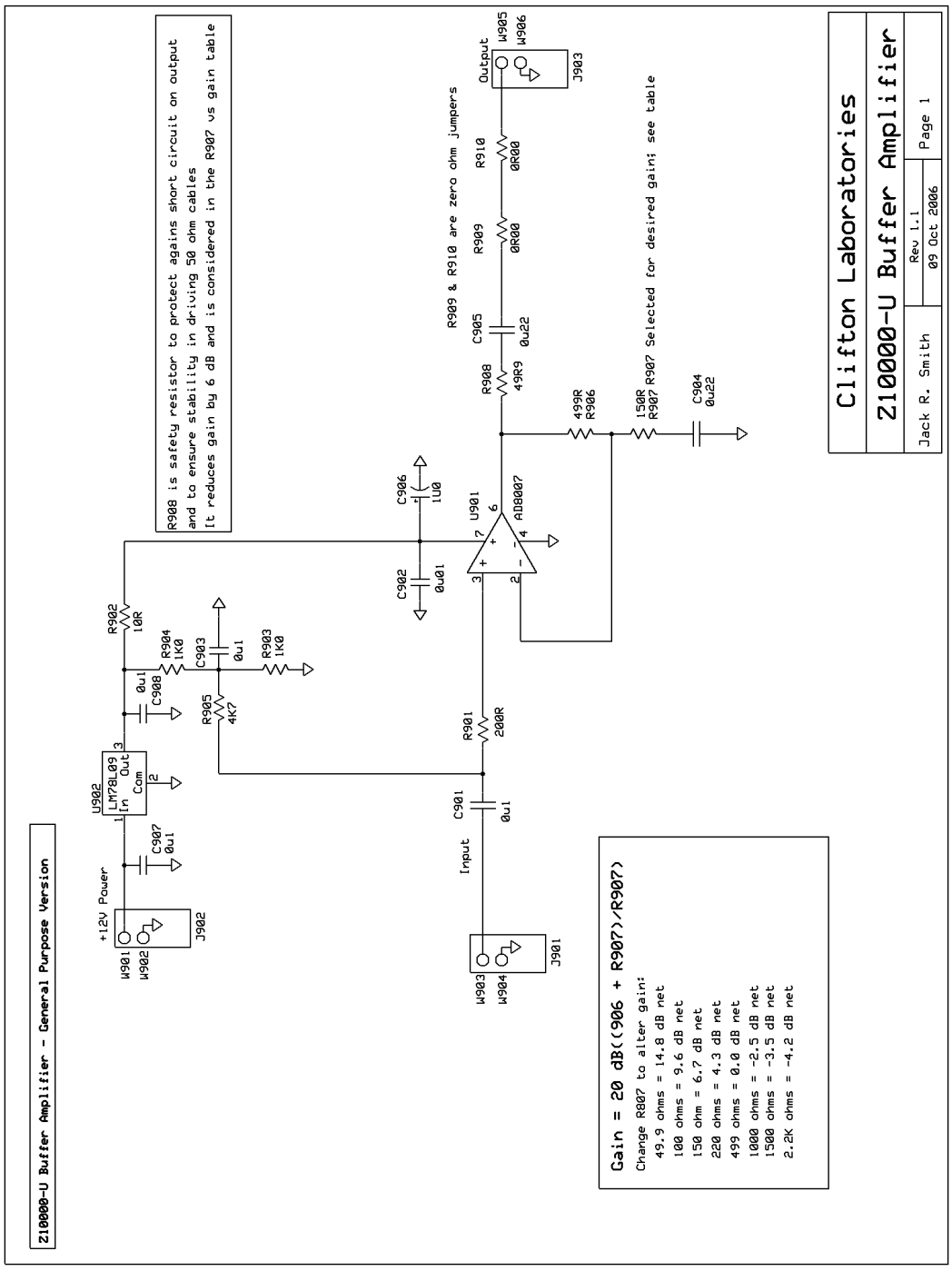
The Buffer Amplifier is a simple circuit and there are only two active devices to present problems; the voltage regulator, U902 and the AD8007 amplifier, U901.

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. Note: The schematic following is of the Z10000-K2 version. All DC voltages are identical with the –U version, however.

5.1 Schematic with Nominal DC Voltage Values and Normal Schematic




Z10000-U Buffer Amplifier - General Purpose Version
+12V Power
W901
W902
J902
U902
LM78L09
In
Com
Out
C907
0u1
C908
0u1
R902
10R
R904
1K0
R903
1K0
C903
0u1
R905
4K7
C906
1u0
C902
0u01
U901
AD8007
R901
200R
C901
0u1
Input
W903
W904
J901
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
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
Clifton Laboratories
Z10000-U Buffer Amplifier
Jack R. Smith
Rev 1.1
09 Oct 2006
Page 1
Gain = 20 dB((906 + R907)/R907)
Change R907 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

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.