

AT-100AMP
Automatic Input Tuner
Manual Version 1.1



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Introduction

Congratulations on selecting the AT-100AMP tuner. This is a new category of product for LDG; where most LDG tuners are stand-alone products, or in a few cases boards to be installed in specific radios, this tuner is intended to be installed in a homebrew amplifier. For that reason, the instructions in this manual are necessarily general, leaving the details of installation to you as you build your amp.

LDG pioneered the automatic, wide-range switched-L tuner in 1995. From its laboratories near the nation's capitol, LDG continues to define the state of the art in this field with innovative automatic tuners and related products for every amateur need.

Specifications

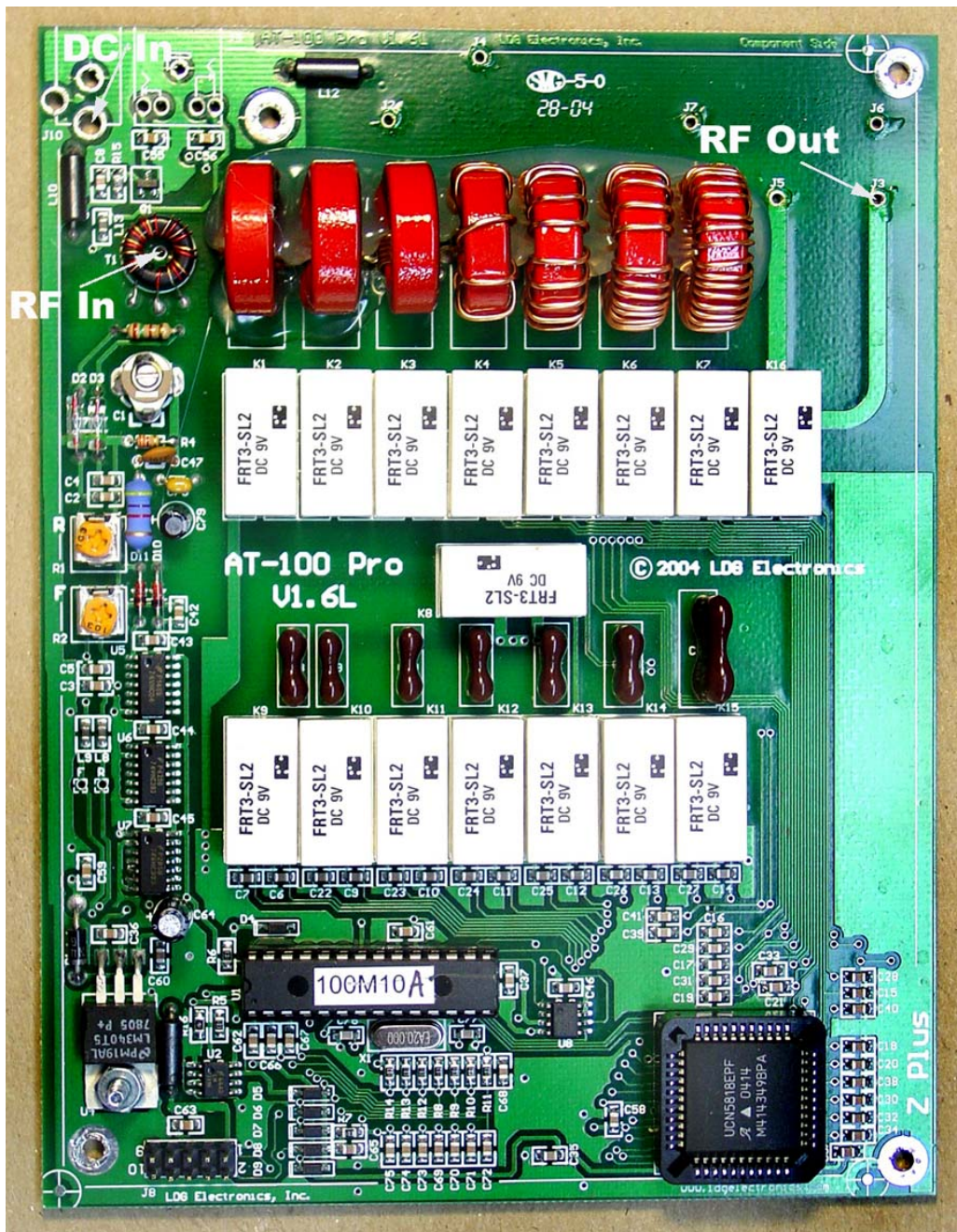
- 1 to 125 watt power range (SSB and CW).
- 1.8 to 54.0 MHz coverage. Built-in frequency sensor
- Provides automatic input tuning for any amplifier
- Tunes 6 to 1000 ohm loads (16 to 150 on 6M)
- Over 4,000 memories for nearly instant retuning
- Tuning time: 0.2 to 2.5 seconds full tune, 0.2 second memory recall
- Uses latching relays, retains tuned setting indefinitely even when DC power is removed
- Enhanced tuning algorithms for fast, consistent tuning even on SSB
- Power requirements: 11 to 16 volts DC at 500 mA Max, 7mA idle

IMPORTANT SAFETY WARNING

Never install antennas or transmission lines over or near power lines. You can be seriously injured or killed if any part of the antenna, support or transmission line touches a power line. Always follow this antenna safety rule: the distance to the nearest power line should be at least twice the length of the longest antenna, transmission line or support dimension.

AT-100AMP Auto Tuner Overview

The LDG AT-100AMP offers homebrewers the opportunity to include a fully automatic tuned input stage to their amplifier. Similar in performance to the popular LDG AT-100, the AT-100AMP is customized for use in the input stage of an amplifier. It offers fully automatic operation, and requires only three connections: 12 vdc, RF in and RF out. As you operate, the AT-100AMP automatically tunes the input of your amp in seconds so the exciter is always optimally matched to the amp. The AT-100AMP's 4,000 memories automatically store tuning parameters for your favorite bands and frequencies for nearly instant recall when you transmit on or near the same frequency again. The AT-100AMP is basically an LDG AT-100Pro tuner absent the case and user interface, hard-wired to the auto-tune mode.



The RF input is at the upper left of the figure above. It is the hole in the PC board in the center of the toroid inductor. The RF output is at the upper right as shown. DC input is the PC board hole indicated at the upper left. In all three cases, ground is chassis ground, providing that the tuner board is mounted in such a way that the ground lands around the mounting holes contact the chassis.

Never apply more than 125 peak watts to the input terminal. The tuner will definitely be damaged or destroyed by power levels significantly above this level. Just so there's no misunderstanding, let us emphasize that this tuner is intended for use on the INPUT of your amp, not the OUTPUT! Putting this tuner on the output of even a small amp would result in a brief but spectacular indoor fireworks display, with severe damage to your rig, your rug and your rumpus room.

DC power input is 11 - 16 vdc at 500ma maximum from any suitable source.

Application Notes

Since the AT-100AMP is intended to be installed in your homebrew amp, installation details are up to you. Here are a few guidelines to help make things go smoothly:

Mount the tuner in a shielded compartment if possible. Best practice is to build in a shielded compartment specifically for the tuner, as far from the RF components as possible. The AT-100AMP is not especially sensitive to stray RF, but inside a 1KW amp there's plenty to go around. The more shielded the tuner is, the better.

Make sure the bottom of the tuner PC board does not short on the chassis. Use spacers to keep it from touching. However, make sure the mounting screws make good contact with the ground lands around the mounting holes on the tuner PC board. This helps insure good grounding to the chassis.

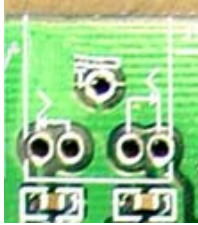
Use a regulated DC power supply if possible. Best practice is to feed the DC power through an RF choke at the tuner PC board. At the very least, put a ferrite bead or two on the DC power line.

Use "real" coax for the RF input and output (like RG-8X or similar). Small diameter "spaghetti" coax is lossy and inefficient.

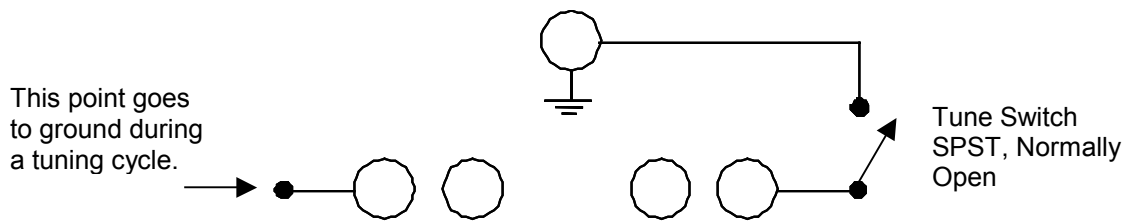
You can, if you wish, include a **TUNE** button in your design. This is not required, as the tuner is capable of autonomous, fully automatic operation. However, a **TUNE** button would allow you to manually start a tuning cycle, selecting between full and memory tunes, and put the tuner in bypass mode. The button should be an SPST, normally open, momentary contact switch.

The tuner also provides an indication that it is tuning; a connection on the tuner PC board goes from high impedance to ground during a tuning cycle. You could hook up an LED with a suitable power source and current limiting resistor to indicate a tuning cycle was under way.

The input/output interface is a set of PC holes on the back of the tuner board. The holes look like this:



The TUNE button connects between the single hole at the top of this picture (ground) and the right-most hole in the row of four. The tune indication appears between the left-most hole and ground.



Operation

Your AT-100AMP is fully automatic. It "wakes up" in automatic mode whenever DC power is applied, and will automatically start a tuning cycle whenever RF is present and the SWR exceeds 1.7. In practice, you will simply operate normally, transmitting, tuning the amp, etc. Your AT-100AMP will automatically adjust the match between your exciter and amp as needed.

If you have installed a **TUNE** button, pressing it manually controls tuner operation. There are three lengths of button press: short (less than .5 seconds), medium (.5 – 2.5 seconds) and long (more than 2.5 seconds). A short press of the **TUNE** button puts the tuner in Bypass mode; RF goes directly from your exciter to your amp without matching. Another short press resets the last tuned state.

A medium press starts a memory tuning cycle; stored tuning parameters for the present frequency will be used if available. If not, a full tuning cycle begins. A long press starts a full tuning cycle even if stored parameters for the present frequency are available.



The above picture shows the AT-100AMP installed in Jerry Pittenger's (K8RA) homebrew amp, as featured in the 2006 ARRL handbook. Jerry's web site (http://www.k8ra.com/index_011.htm) has more information on this design. Picture used with permission.

Theory Of Operation

Some Basic Ideas About Impedance

The theory underlying antennas and transmission lines is fairly complex, and in fact employs a mathematical notation called “complex numbers” that have “real” and “imaginary” parts. It is beyond the scope of this manual to present a tutorial on this subject¹, but a little background will help you understand what your AT-100AMP is doing, and how it does it.

In simple DC circuits, the wire resists the current flow, converting some of it into heat. The relationship between voltage, current and resistance is described by the elegant and well-known “Ohm’s Law”, named for Georg Simon Ohm of Germany, who first discovered it in 1826. In RF circuits, an analogous but far more complicated relationship exists.

RF circuits also resist the flow of electricity. However, the presence of capacitive and inductive elements causes the voltage in the circuit to lead or lag the current, respectively. In RF circuits this resistance to the flow of electricity is called “impedance”, and can include all three elements: resistive, capacitive, and inductive.



The output circuit of your transmitter consists of inductors and capacitors, usually in a series/parallel configuration called a “pi network”. The transmission line can be thought of as a long string of capacitors and inductors in series/parallel, and the antenna is a kind of resonant circuit. At any given RF frequency, each of these can exhibit resistance, and impedance in the form of capacitive or inductive “reactance”.

Transmitters, Transmission Lines, Antennas and Impedance

The output circuit of your transmitter, the transmission line, and the antenna all have a characteristic impedance. For reasons too complicated to go into here, the standard impedance is about 50 ohms resistive, with zero capacitive and inductive components. When all three parts of the system have the same impedance, the system is said to be “matched”, and maximum transfer of power from the transmitter to the antenna occurs. While the transmitter output circuit and transmission line are of fixed, carefully designed impedance, the antenna presents a 50 ohm, non-reactive load only at its natural resonant frequencies. At other frequencies, it will exhibit capacitive or inductive reactance, causing it to have an impedance different from 50 ohms.

When the impedance of the antenna is different from that of the transmitter and transmission line, a “mismatch” is said to exist. In this case, some of the RF energy from the transmitter is reflected from the antenna back down the transmission line, and into the transmitter. If this reflected energy is strong enough it can damage the transmitter’s output circuits.

The ratio of transmitted to reflected energy is called the “standing wave ratio”, or SWR. An SWR of 1 (sometimes written 1:1) indicates a perfect match. As more energy is reflected, the SWR

¹ For a very complete treatment of this subject, see any edition of the ARRL Handbook for Radio Communications (previously the Handbook For Radio Amateurs)

risers to 2, 3 or higher. As a general rule, modern solid state transmitters must operate with an SWR of 2 or less. Tube exciterers are somewhat more tolerant of high SWR. If your 50 ohm antenna is resonant at your operating frequency, it will show an SWR close to 1. However, this is usually not the case; operators often need to transmit at frequencies other than resonance, resulting in a reactive antenna and a higher SWR.

$$SWR = \frac{1 + \sqrt{R/F}}{1 - \sqrt{R/F}} \quad \text{where F = Forward power (watts), R = Reflected power (watts)}$$

SWR is measured using a device called an “SWR bridge”, inserted in the transmission line between the transmitter and antenna. This circuit measures forward and reverse power from which SWR may be calculated (some meters calculate SWR for you). More advanced units can measure forward and reverse power simultaneously, and show these values and SWR at the same time.

An antenna tuner is a device used to cancel out the effects of antenna reactance. Tuners add capacitance to cancel out inductive reactance in the antenna, and vice versa. Simple tuners use variable capacitors and inductors; the operator adjusts them by hand while observing reflected power on the SWR meter until a minimum SWR is reached. Your LDG AT-100AMP automates this process.

No tuner will fix a bad antenna. If your antenna is far from resonance, the inefficiencies inherent in such operation are inescapable; it’s simple physics. Much of your transmitted power may be dissipated in the tuner as heat, never reaching the antenna at all. A tuner simply “fools” your transmitter into behaving as though the antenna were resonant, avoiding any damage that might otherwise be caused by high reflected power. Your antenna should always be as close to resonance as practical.

		Forward Power (Watts)								
		20	30	40	50	60	70	80	90	100
2	Reflected Power (Watts)	1.92	1.70	1.58	1.50	1.45	1.41	1.38	1.35	1.33
4	Reflected Power (Watts)	2.62	2.15	1.92	1.79	1.70	1.63	1.58	1.53	1.50
6	Reflected Power (Watts)	3.42	2.62	2.26	2.06	1.92	1.83	1.75	1.70	1.65
8	Reflected Power (Watts)	4.44	3.14	2.62	2.33	2.15	2.02	1.92	1.85	1.79
10	Reflected Power (Watts)	5.83	3.73	3.00	2.62	2.38	2.22	2.09	2.00	1.92
12	Reflected Power (Watts)	7.87	4.44	3.42	2.92	2.62	2.41	2.26	2.15	2.06
14	Reflected Power (Watts)	11.24	5.31	3.90	3.25	2.87	2.62	2.44	2.30	2.20
16	Reflected Power (Watts)	17.94	6.42	4.44	3.60	3.14	2.83	2.62	2.46	2.33
18	Reflected Power (Watts)	37.97	7.87	5.08	4.00	3.42	3.06	2.80	2.62	2.47
20	Reflected Power (Watts)	-	9.90	5.83	4.44	3.73	3.30	3.00	2.78	2.62
22	Reflected Power (Watts)	-	12.92	6.74	4.94	4.07	3.55	3.21	2.96	2.77
24	Reflected Power (Watts)	-	17.94	7.87	5.51	4.44	3.83	3.42	3.14	2.92
26	Reflected Power (Watts)	-	27.96	9.32	6.17	4.85	4.12	3.65	3.32	3.08
28	Reflected Power (Watts)	-	57.98	11.24	6.95	5.31	4.44	3.90	3.52	3.25
30	Reflected Power (Watts)	-	-	13.93	7.87	5.83	4.79	4.16	3.73	3.42
32	Reflected Power (Watts)	-	-	17.94	9.00	6.42	5.18	4.44	3.95	3.60
34	Reflected Power (Watts)	-	-	24.63	10.40	7.09	5.60	4.75	4.19	3.80
36	Reflected Power (Watts)	-	-	37.97	12.20	7.87	6.07	5.08	4.44	4.00
38	Reflected Power (Watts)	-	-	77.99	14.60	8.80	6.60	5.44	4.71	4.21
40	Reflected Power (Watts)	-	-	-	17.94	9.90	7.19	5.83	5.00	4.44
42	Reflected Power (Watts)	-	-	-	22.96	11.24	7.87	6.26	5.31	4.68
44	Reflected Power (Watts)	-	-	-	31.30	12.92	8.65	6.74	5.65	4.94
46	Reflected Power (Watts)	-	-	-	47.98	15.08	9.56	7.27	6.02	5.22
48	Reflected Power (Watts)	-	-	-	97.99	17.94	10.63	7.87	6.42	5.51
50	Reflected Power (Watts)	-	-	-	-	21.95	11.92	8.55	6.85	5.83

SWR Lookup Table
Find SWR at intersection of forward power column and reflected power row.

The LDG AT-100AMP

In 1995 LDG pioneered a new type of automatic antenna tuner. The LDG design uses banks of fixed capacitors and inductors, switched in and out of the circuit by relays under microprocessor control. A built-in SWR sensor provides feedback; the microprocessor searches the capacitor and inductor banks, seeking the lowest possible SWR. The tuner is a “Switched L” network consisting of series inductors and parallel capacitors. LDG chose the L network for its minimum number of parts and its ability to tune unbalanced loads, such as coax-fed dipoles, verticals, Yagis; in fact, virtually any coax-fed antenna. The inductors are switched in and out of the circuit by relays controlled by the microprocessor. An additional relay switches between high and low impedance ranges.

The capacitors are connected to ground with the inductor relays. Another relay switches the entire capacitor bank to the input or output side of the inductor. This switching allows the AT-100AMP to automatically handle loads that are greater than 50 ohms (high setting) and less than 50 (low setting).

The SWR sensor is a variation of the Bruene circuit. This SWR measuring technique is used in most dual-meter and direct-reading SWR meters. Slight modifications were made to the circuit to provide voltages (instead of currents) for the analog-to-digital converters (ADCs) that provide signals proportional to the forward and reverse power levels. The single-lead primary through the center of the sensor transformer provides RF current sampling. Diodes rectify the sample and provide a dc voltage proportional to RF power. Variable resistors calibrate the FORWARD and REVERSE power levels. Once adjusted, the forward and reverse power sensors produce a calibrated DC voltage proportional to the forward and reverse RF power levels. These two voltages are read by the ADCs in the microprocessor. Once in a digital format, they are used to calculate SWR in real time.

The relays operate from DC supplied by the power input jack. The total current drawn by the AT-100AMP depends primarily on the number of energized relays, with the maximum current drain being approximately 250 mA, but only during the few seconds a tuning cycle is running. At all other times, the tuner is in a “deep sleep” mode drawing only a few milliamps. The last tuned setting is automatically reset on the next power-up.

The microprocessor’s oscillator runs at 20 MHz. The main tuning routine takes about 75 cycles to make a tuner adjustment and take a new SWR measurement, or 7 milliseconds per tuner adjustment. If running at maximum speed, the microprocessor can try all inductor-capacitor combinations in under 3 seconds. Unfortunately, the mechanical relays can’t react as quickly as the microprocessor, and the tuning speed must be slowed down to compensate for relay settling time.

The tuning routine includes an algorithm to minimize the number of tuner adjustments. The routine first de-energizes the high/low impedance relay if necessary, then individually steps through the inductors to find a coarse match. With the best inductor selected, the tuner then steps through the individual capacitors to find the best coarse match. If no match is found, the routine repeats the coarse tuning with the high/low impedance relay energized. The routine then fine tunes the capacitors and inductors. The program checks LC combination to see if a 1.5 or lower SWR can be obtained, and stops when it finds a good match.

The microprocessor runs a fine tune routine just after the tuner finds a match at an SWR of 1.5 or less. This routine tries to get the SWR as low as possible (not just 1.5); it takes about a half

second to run. There is also a quick tune mode. If the SWR is below 2.0 when you press the tune button to start a tuning cycle, the tuner will first try a memory tune routine to see if it can achieve a low SWR without a complete re-tune. This also takes about a half second to run. If it does not find a good match, then it runs a full tuning routine.

A Word About Tuning Etiquette

Be sure to use a vacant frequency to tune. With today's crowded ham bands, this is often difficult. However, do your best to avoid interfering with other hams as you tune. Your AT-100AMP's very short tuning cycle, often only a fraction of a second, minimizes the impact of your tuning transmissions. Tune at reduced power whenever possible; one or two watts is plenty.

Care and Maintenance

Your AT-100AMP tuner is maintenance-free. As with any modern electronic device, your AT-100AMP can be damaged by temperature extremes, water, impact or static discharge. LDG strongly recommends that you use a good quality, properly installed lightning arrestor in the antenna lead.

Technical Support

We are happy to help you with your AT-100AMP. Telephone technical support is available at 410-586-2177 weekdays from 9 am to 5pm Eastern Time. Inquiries by Fax at 410-586-8475 are welcome, and prompt e-mail support is available at ldg@ldgelectronics.com.

Warranty and Service

Your AT-100AMP is warranted against defects in parts or workmanship for two years from purchase. The warranty does not cover damage due to abuse or exceeding specifications. This warranty applies to the original purchaser only; it is not transferable. A copy of the receipt showing the purchaser's name and the date of purchase must accompany units returned for warranty service. All returns must be shipped to us pre-paid; we will not accept units with postage due. A return form is provided on our web site for your convenience.

If you need to return your AT-100AMP to us for service, package it carefully, keeping in mind that we will re-use your packaging to return the unit to you. Download the return form from our web site (ldg@ldgelectronics.com), fill it out and return it with your tuner. A self-addressed return-shipping label, while not required, will help insure speedy and accurate delivery of your repaired unit. Include a full description of the problem, along with your name, address and a phone number or e-mail address where we can reach you with any questions. Repairs average about 3 to 6 weeks.

We will be glad to service your AT-100AMP after the warranty period has ended. We will notify you of repair charges by phone or e-mail, and bill you after repairs are completed.

Firmware Upgrades

From time to time LDG may release upgraded firmware for the AT-100AMP, refining operation and adding features. Your AT-100AMP is not field programmable; you will have to remove the present chip and replace it with the upgrade chip. Upgrades are expected to cost about \$10-\$20, and will be announced on our web site when available.

Feedback

If you have an idea to improve our software or hardware, please send us a description. If we incorporate your idea in the AT-100AMP, we'll send you a free upgrade as a "thank you".

We encourage everyone who uses the AT-100AMP to contact us (card, letter or e-mail preferred) telling us how well it works for you. We are also always looking for photographs of our products in use; we frequently place such pictures on our Web site (www.ldgelectronics.com).

