AT-7000
Automatic Antenna Tuner
For Icom Transceivers

Manual Version 1.1

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LDG AT-7000
Automatic Antenna Tuner
For ICOM IC-7000

Introduction

Congratulations on selecting the LDG AT-7000 tuner. The AT-7000 provides automatic antenna tuning for your Icom IC-7000 (and some other Icom radios that are AH-3 or AH-4 compatible) across the entire HF range plus 6 meters. It will tune dipoles, verticals, Yagis or virtually any coax-fed antenna. It will match an amazing range of antennas and impedances, far greater than some other tuners you may have considered. The AT-7000 uses little power while tuning, and with its latching relays, uses essentially no power in standby.

The AT-7000 represents a quantum leap in features and performance. Enhanced tuning algorithms provide much faster, precise and consistent tuning.

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.

Jumpstart, *or* "Real Hams Don't Read Manuals!"

Ok, but at least read this one section before you transmit:

1. **Connect the HF antenna jack on your transceiver to the "TX" jack on your AT-7000 tuner using the provided jumper cable.**
2. **Connect your 50 Ohm antenna coax lead to the "Ant" jack on the back of your AT-7000.**
3. **Connect the tuner's RADIO port to your IC-7000 transceiver's Tuner port using the provided cable.**
4. **Power up your transceiver and select the desired operating frequency and mode.**
5. **Press and hold the TUNER/CALL button on the radio for one second, then release.**
6. **Wait for the tuning cycle to end and for the TUNE icon to appear on the radio's display.**
7. **You're now ready to operate.**

Specifications

- 0.1 to 125 watts SSB and CW peak power, 100 watts digital
- 2,000 memories for instantaneous frequency or band changing
- Tuning time: 0.5 to 6 seconds full tune, < 0.1 second memory tune
- Built in frequency counter for memory operation
- Frequency coverage: 1.8 to 54.0 MHz.
- Tunes 4 to 800 ohm loads (16 to 150 ohms on 6M), 16 to 3200 ohms with optional 4:1 Balun (LDG RBA-4:1)
- For Dipoles, Verticals, Vs, Beams or and Coax Fed Antenna
- Optional external Balun allows tuning of random length, long wire or ladder line fed antennas
- Dedicated interface to the IC-7000 transceiver (and some other Icom radios)
- Power requirements: 11 to 16 volts DC at 250 mA max during tuning, < 8mA idle, provided by the Icom transceiver
- Enclosure: 6.5 x 6.5 x 1.5 inches
- Weight: 1.5 pounds

An Important Word About Power Levels

The AT-7000 is rated at 125 watts maximum power input *at most*. Many ham transmitters and transceivers, and virtually all amplifiers, output well over 125 watts. Power levels significantly exceeding specifications will definitely damage or destroy your AT-7000. If your tuner fails during overload, it could damage your transmitter or transceiver. Be sure to observe the specified power limitations.

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.

Getting To Know Your AT-7000

Your AT-7000 is a quality, precision instrument that will give you many years of outstanding service; take a few minutes to get to know it.

Your AT-7000 is designed specifically to work with the ICOM IC-7000 transceiver. It can also be used with other ICOM transceivers that are compatible with AH-3 and AH-4 antennas.

There are no controls or readouts on the AT-7000. All functions are controlled by the **TUNER/CALL** button on your IC-7000.

Your AT-7000 is powered directly by the radio; it needs no separate power supply. Your AT-7000 automatically powers up whenever you start a tuning cycle, and after tuning, automatically enters a “deep sleep” state in which it draws less than 8 mA. The tuner will automatically "wake up" the next time you start a tuning cycle. The latching relays hold the tuned configuration indefinitely, even while DC power is completely removed. Tuning memories are stored indefinitely in EEPROM memory.

The AT-7000 has 2,000 frequency memories. When you transmit on or near a previously tuned frequency, your AT-7000 automatically uses “Memory Tune” to reset the tuning parameters in only a fraction of a second. The process of storing tuning settings in memory is completely automatic; your AT-7000 literally “learns” as you use it, adapting itself to all of the bands and frequencies you use. If no memorized settings are available, the tuner runs a full tuning cycle, storing the parameters for memory recall on later tuning cycles on that frequency.

On the back panel, there are four connectors:

- RF input (marked “**TX**”, standard SO-239 socket)
- Antenna connector (marked "**Ant**", standard SO-239 socket)
- Interface jack (marked "**Radio**") for connecting the control cable to the IC-7000 or other compatible transceiver
- Ground connector (wing nut)

Installation

Your AT-7000 tuner is intended for indoor use only; it is not water resistant. If you use it outdoors (Field Day, for example) you must protect it from rain. The AT-7000 is designed for use with coax-fed antennas. If you wish to use it with longwires or antennas fed with a balanced transmission line (e.g., ladder line), an external balun is required; either the LDG RBA-4:1 or RBA-1:1 is ideal, depending on the antenna and transmission line used.

Always turn your radio off before plugging or unplugging anything. Your radio may be damaged if you connect or disconnect a cable with the unit powered up.

Connect the HF antenna jack on your IC-7000 to the **TX** jack on the back of your AT-7000 tuner using the provided coax jumper cable. Attach your antenna lead-in coax to the **Ant** jack on the back of your AT-7000 tuner.

Connect the tuner's **RADIO** jack to the **TUNER** jack on the radio using the provided data cable.

The AT-7000 can also be used with any Icom radio that is compatible with the AH-3 or AH-4 antennas. Please check your radio's instruction manual for compatibility (select AH-4 for IC-718). This includes, but is not limited to:

- IC-7000
- IC-706 (all variations)
- IC-703Plus
- IC-718 (select AH-4)
- IC-746
- IC-756 (all variations)

Grounding your tuner will enhance its performance and safety. LDG recommends that you connect your tuner to a suitable ground; a dedicated ground rod connected to buried radials is preferred, but a single ground rod or a cold water pipe can provide a serviceable ground. LDG strongly recommends that you use a properly installed, high quality lightning arrestor on each antenna cable.

Operation

Your AT-7000 is controlled entirely through the **TUNER/CALL** button on the IC-7000 transceiver. Feedback on tuner operation is provided by the **TUNE** icon in the upper left of the radio's display. When you power up the radio, the AT-7000 powers up and automatically resets to a bypassed condition. The **TUNE** icon will be off.

To run a tuning cycle, simply press and hold the **TUNER/CALL** button on the radio for 1 second, then release. The radio will transmit a CW carrier of about 10 watts, a tuning cycle will run to completion (using stored memory parameters if available), then automatically end. The radio will return to receive mode, with RF power reset to its previous operating level.

During the tune process, the **TUNE** icon will flash, showing that the tuner is in the process of tuning. Do not attempt to use the radio during the tuning process.

Once the tuning process is complete, the **TUNE** icon will show the status of the tuned state. The **TUNE** icon will be on when the tuner was successful in obtaining a match of about 1.5 or less. On rare occasions, your AT-7000 may not be about to achieve a satisfactory match. This is usually due to a highly reactive antenna that is far from resonance. In this case, the tuner will go into bypass mode at the end of the tuning cycle, and the **TUNE** icon on the radio will be off. Adjust the antenna as necessary, and tune again.

Note: The IC-7000 does not display the SWR during the tuning process. To display the SWR after a tune, select the SWR indicator scale from the radio's menu, and transmit a carrier (AM, FM, CW). The SWR will then be displayed on the SWR scale.

To place your AT-7000 tuner in bypass mode, press the **TUNER/CALL** button on the radio for less than one-half second, then release. The **TUNE** icon will go off. In Bypass mode, RF from your transmitter goes directly to the antenna with no matching. To return the tuner to operation, simply press the **TUNER/CALL** button for one second and release to start a new memory tuning cycle.

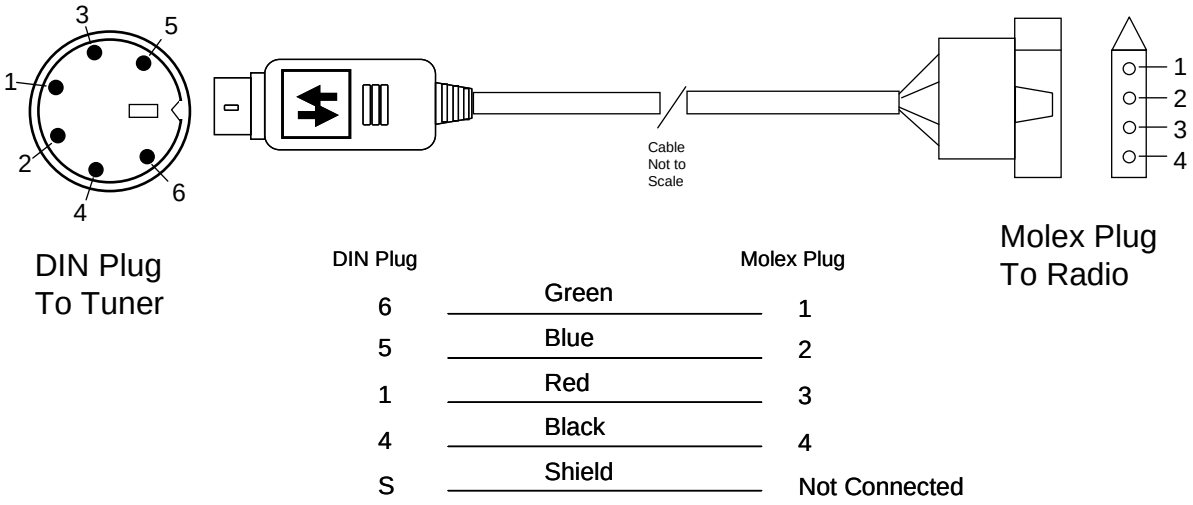
Important Note: The IC-7000 does not adjust the tuner when you change bands; your AT-7000 does not "know" when you change bands. Thus, the tuner may be matched for one band, with the radio changed to a different band. In this case, the **TUNE** icon will still be on, even though the tuner is not matched to the new band. Always re-tune after you change bands.

Your AT-7000 has 2,000 frequency memories. These are "Continuous Q Matched" memories from 1.8 MHz to 54 MHz; there are more memories on lower frequencies where antenna Q is usually higher, and fewer memories on higher frequencies). When you tune on or near a memorized frequency again, the tuner sets those parameters in a fraction of a second, much faster than a full tuning cycle.

Application Notes

Fixed Station Operation

Your AT-7000 operates well as a base-station tuner. You can position it on top of, or under the radio. Placing it elsewhere on your operating desk is possible, but you would need to "homebrew" a longer control cable; LDG does not provide a longer cable. Here is the control cable pinout information if you desire to make your own interface cable:



Expert Button

Your AT-7000 has a control button and LED inside the case that may prove useful in certain situations. To access this "expert" control, carefully remove the top of the case by unscrewing the four screws that hold it on. The button and LED are located on the PC board near the front panel on the left. Use caution when transmitting with the cover removed; high RF voltages may be present. LDG recommends that you use an insulated rod to press the button.

The following functions are available:

Full reset: press and hold the button while powering on the radio and tuner. Hold for at least ½ second after powering up. The LED will light for about 6 seconds, go off for ½ second, then flash back on for about ½ second before going off. All memories will be cleared.

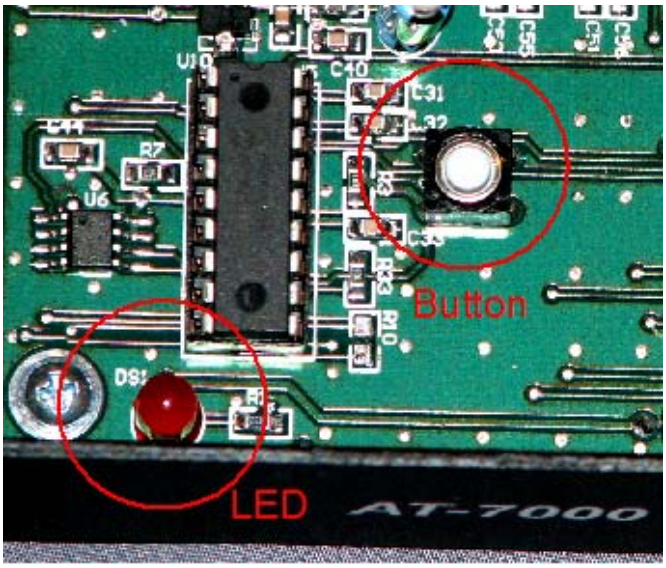
Manual Bypass: Press the button for less than ½ second, then release to put tuner in bypass mode. The LED will blink once.

Memory Tune: Press the button for less than ½ to 2.5 seconds to start a memory tune cycle. As you hold the button down the LED will light to indicate you are in the proper time interval. Release the button while the LED is lit. The tuner will automatically default to a full tune cycle if no parameters are stored for the present frequency.

Full Tune: Press the button for more than 2.5 seconds to start a full tuning cycle, even if parameters are stored for that frequency. As you hold the button down, the LED will light, then go out; release the button after the LED goes out.

The LED will light during any tuning cycle. When a memory tuning cycle ends, the LED will simply go out if the tuning cycle was successful. After a full tuning cycle, the LED will simply go out if the achieved SWR was higher than the previously stored value. This indicates that new parameters were not stored. If the achieved SWR is lower than the saved value, the LED will blink three times fast to indicate that new parameters were saved. The LED will blink once if the SWR is the same as the stored value.

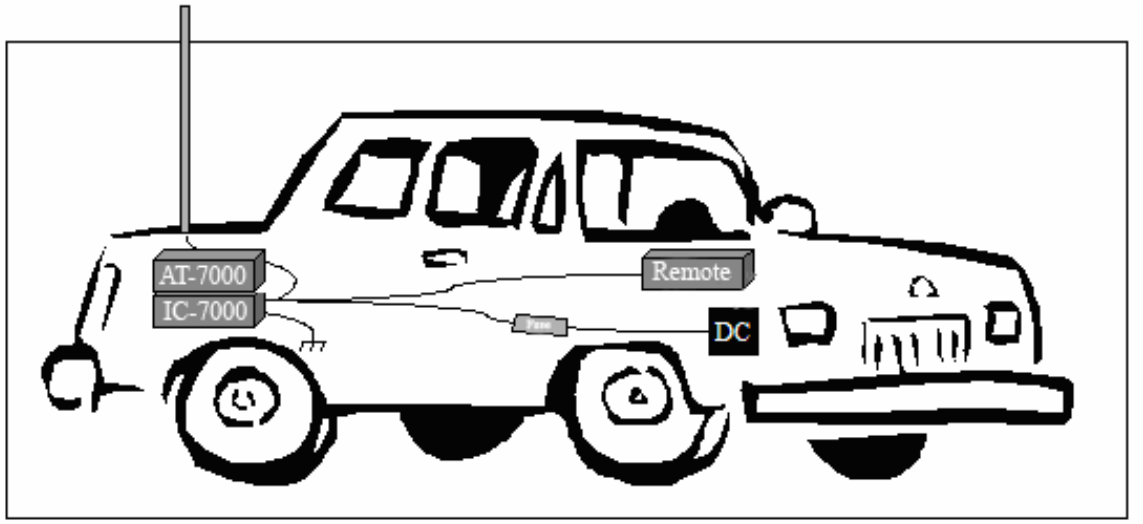
Three slow blinks indicates that RF power was lost during the tuning cycle. Adjust your transceiver as necessary and begin a new tuning cycle.



Mobile Operation

Your AT-7000 is perfectly suited to mobile operation. You can install it under the dash along with your transceiver, or remotely in the trunk if you are using the IC-7000's remote head capability.

To install the unit under the dash, you can "homebrew" a bracket (LDG does not provide one). You can also use Velcro tape, although the adhesive tends to soften in hot weather. In the trunk, Velcro works well to secure the units together, and to the trunk floor. Simply run the coax jumper from your transceiver to the tuner, run a DC line to the tuner and connect your mobile antenna. Press the **TUNER/CALL** button on the radio, and the tuner will operate as usual. Be sure to use a fused power line to the radio.



MARS/CAP Coverage

Your AT-7000 provides tuning continuously over its specified range, not just in the ham bands. This makes it useful for MARS or CAP operation, or any other legal HF operation.

Theory Of Operation

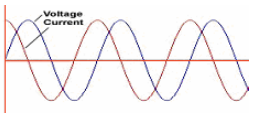
Some Basic Ideas About Impedance

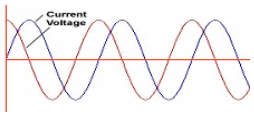
The theory underlying antennas and transmission lines is fairly complex, and in fact employs a mathematical notation called "complex numbers" that have "real" and "imaginary" parts. It is beyond the scope of this manual to present a tutorial on this subject[1], but a little background will help you understand what your AT-7000 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.

Capacitive Reactance





Inductive Reactance

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)

rises to 2, 3 or higher. As a general rule, modern solid state transmitters must operate with an SWR of 2 or less. Tube exciters 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.

$$SWR = \frac{1+\sqrt{R/F}}{1-\sqrt{R/F}}$$ 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-7000 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.

Reflected Power (Watts) \ Forward Power (Watts)	20	30	40	50	60	70	80	90	100
2	1.92	1.70	1.58	1.50	1.45	1.41	1.38	1.35	1.33
4	2.62	2.15	1.92	1.79	1.70	1.63	1.58	1.53	1.50
6	3.42	2.62	2.26	2.06	1.92	1.83	1.75	1.70	1.65
8	4.44	3.14	2.62	2.33	2.15	2.02	1.92	1.85	1.79
10	5.83	3.73	3.00	2.62	2.38	2.22	2.09	2.00	1.92
12	7.87	4.44	3.42	2.92	2.62	2.41	2.26	2.15	2.06
14	11.24	5.31	3.90	3.25	2.87	2.62	2.44	2.30	2.20
16	17.94	6.42	4.44	3.60	3.14	2.83	2.62	2.46	2.33
18	37.97	7.87	5.08	4.00	3.42	3.06	2.80	2.62	2.47
20	-	9.90	5.83	4.44	3.73	3.30	3.00	2.78	2.62
22	-	12.92	6.74	4.94	4.07	3.55	3.21	2.96	2.77
24	-	17.94	7.87	5.51	4.44	3.83	3.42	3.14	2.92
26	-	27.96	9.32	6.17	4.85	4.12	3.65	3.32	3.08
28	-	57.98	11.24	6.95	5.31	4.44	3.90	3.52	3.25
30	-	-	13.93	7.87	5.83	4.79	4.16	3.73	3.42
32	-	-	17.94	9.00	6.42	5.18	4.44	3.95	3.60
34	-	-	24.63	10.40	7.09	5.60	4.75	4.19	3.80
36	-	-	37.97	12.20	7.87	6.07	5.08	4.44	4.00
38	-	-	77.99	14.60	8.80	6.60	5.44	4.71	4.21
40	-	-	-	17.94	9.90	7.19	5.83	5.00	4.44
42	-	-	-	22.96	11.24	7.87	6.26	5.31	4.68
44	-	-	-	31.30	12.92	8.65	6.74	5.65	4.94
46	-	-	-	47.98	15.08	9.56	7.27	6.02	5.22
48	-	-	-	97.99	17.94	10.63	7.87	6.42	5.51
50	-	-	-	-	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-7000

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-7000 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. Resistors calibrate the FORWARD and REVERSE power levels. 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-7000 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 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 then 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.

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-7000's very short tuning cycle, often only a fraction of a second, minimizes the impact of your tuning transmissions.

Care and Maintenance

Your AT-7000 tuner is essentially maintenance-free; just be sure to observe the power limits discussed in this manual. The outer case may be cleaned as needed with a soft cloth slightly dampened in household cleaning solution. As with any modern electronic device, your AT-7000 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 product. For detailed tech support, submit our Tech Support form on our web site under Support/Manuals, then Tech Support. You can find us at **www.ldgelectronics.com**.

Warranty and Service

Your product 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. Please fill out and print the return form from our web site under Support/Manual, then Tech Support-Warranty.

If you need to return your unit to us for service, package it carefully, keeping in mind that we will re-use your packaging to return the unit to you. Include a full description of the problem, along with your name, address and a phone number or e-mail address on the web form. Repairs average about 3 to 6 weeks.

We will be glad to service your unit 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-7000, refining operation and adding features. Your AT-7000 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.

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