AT-11 Automatic Antenna Tuner

Assembly Manual Ver 2.5

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Introduction: The AT-11 is a full featured auto or semi automatic antenna tuner designed for HF (1.8 to 30 MHz) transceivers using 5 to 150 watts. The tuner uses a switched "L" configuration with 256 capacitor, 256 inductor and Hi/Lo-Z settings to provide over one hundred and thirty thousand tuning combinations. The "L" network works great with just about any coax fed antenna (dipole, vertical, beam, etc). Users with long wires can install a balun between the tuner and the antenna. Tuning time is between 0.1 and 5.0 seconds with the average being about 2.5 seconds.

Operation of the tuner is auto or semi automatic. In auto mode, the tuner will seek a 1.5 match (or better) anytime the SWR is above 3.0. In semi mode, the tuner will seek a match only when the tune push button is pressed. Both modes require that more than 5 watts of RF power be present. Up and down buttons are used for fine tuning the inductors and capacitors and can be used in either mode. Three LEDs provide an indication of SWR. Green indicates SWR of less than 1.5, Green/Yellow is 1.5-2.0, Yellow is 2.0-2.5, Yellow/Red is 2.5-3.0 and Red indicates more than 3.0. The fourth LED is a tuning indicator. It is lit only when the tuner is trying to find a match.

The AT-11 is a small to medium sized project. It should take the average builder an evening or two to complete (the average is 6 to 8 hours). Besides the normal building tools needed (soldering iron or soldering pencil, wire cutters, screw drivers, etc), the only test equipment needed is an HF transceiver, dummy load (or resonant antenna) and voltmeter. You will need to provide the power supply once the project is finished. The maximum current consumption is 500 mA and the voltage requirements are 11 - 15 volts.

Building the Kit: Before getting the soldering iron out, go through all of the parts in the kit and familiarize yourself with each component and its placement. Most of the parts are common, but a few of them may be new to some builders. There are just over 100 parts and 300 solder connections, so take your time.

You will first wind the inductors on the eight T-106 toroids (they are red and just over an inch in diameter). Take care not to drop them; they will break. Using the #18 wire provided, you will wind eight of them. Save the left over wire for later. It is used for connections on the SO-239s.

Refer to figure 1 for winding methods, and to the winding chart for lengths of wire and number of turns. For consistency, we count one turn when the wire passes through the center of the toroid.

Winding Chart

Inductor	uH	Turns	Inches needed
L8	10.0	26	42
L7	5.0	18	32
L6	2.5	13	23
L5	1.25	9	18
L4	.59	6	12
L3	.39	4	9
L2	.22	2 bottom	4
L1	.11	1 bottom	2

Figure 1 L2 Example L3 - L8 Example

___ Using the winding chart, cut a 42 inch length of wire for L8. Hold about one inch in one hand with the toroid and wind the wire around the toroid as shown in figure 1 for 26 turns. You should space the wires evenly around the toroid as you wind them. Once you have completed winding L8, trim both ends to one half inch and scrape away the insulation from them. Do not install L8 until later.

___ In a similar manner, wind L7 through L3, using the winding chart for lengths and turns. Trim and scrape thermaleze coating from #18 wire. The thermaleze wire cannot be soldered unless the thermaleze coating is scraped off.

___ Wind L2 as shown in figure 1.

___ Wind L1 by just passing the wire through the toroid and bending it down on each side.

___ Wind T1 with 10 turns using the red and green #28 gauge wire. T1 is the small, black toroid just under one half inch in diameter. See figure 2 and wind this in bifiliar fashion by using two lengths of wire and winding them at the same time. It doesn't matter if you twist them or wind them side by side. Note: you must wind this in the direction shown in figure 2.

___ After scraping the insulation from the ends of all four wires, connect the green 1 wire to the red 2 wire and twist together. You will now have three leads: the red wire on the left, the twisted pair, and the green wire on the right. Do not install T1 yet.

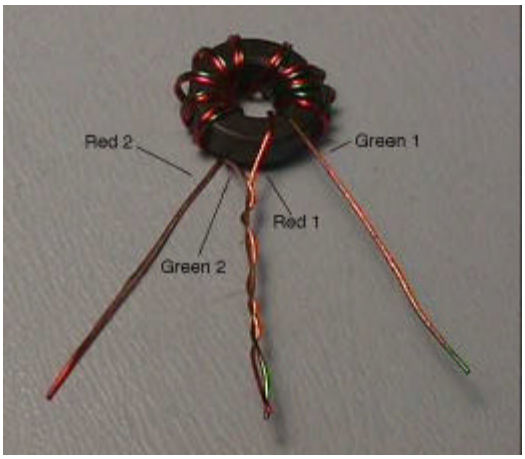

Figure 2 T1 Example

You will now install (locate, place, and solder in place) the parts on the PC board. Use the silk screen layout in the back of this manual to assist in locating where parts are to be installed. Parts are installed and soldered in order of height, from shortest to tallest.

___ Install all of the resistors, R1-8, 11. Be sure to check the values with the parts list. Most of the resistors are 1/8 watt and may be hard to read. Use an ohmmeter to verify the values if you have trouble identifying them.

___ Install the 1N4148 diodes, D1, 2, 4-9. Note the band polarity.

___ Install the larger 1N4001, D3. Note the band polarity.

___ Install the 10K 10 pin SIP resistor, SIP1. Be sure to note the orientation of the SIP resistor. A small line (or dot) on the side with writing marks pin 1.

___ Install T1. It lies flat against the PC board and the #18 wire from the SO-239 will pass through the center (you will install this later). You may wish to use a small amount of silicon RTV or hot glue to hold T1 in place, but wait until after the unit is tested before applying it in case there are problems.

___ Install the socket for U3, 28 pin DIP socket. Match the notch on the silk screen with the notch on the socket. Do not install the U3 (the UCN5812) until later.

___ Install the .01uf monolithic capacitors, C2-5, 10, 12, 14-15, 18-45, 50-53.

___ Install the ceramic capacitors, C11 .01uf ; C49, 52 100pf 1KV.

___ Install U2, the 78L05. Note the orientation.

___ Install the 2N3904 transistor, Q1. Note the correct orientation.

___ Install the variable resistors (100K pots), R9 and R10.

___ Install the trimmer capacitor C1. Note that C1 has two pins that are common (connected). They should line up with the two holes on the PC board that are connected together with a trace on the bottom.

___ Install the 8 MHz oscillator. Three of the corners are rounded and one corner is square on the oscillator. The square corner is pin 1.

___ Install the socket for U1. Note the orientation of the socket. The flattened corner goes in the upper left, toward the oscillator. Do not install U1 (the 68HC11) until later.

___ Install the tuning capacitors, C54 15pf, C55 30pf, C56 62pf, C57 120pf, C58 & 59 470pf, C60 & 61 1000pf, C62 & 63 2000pf, C64 & 65 3900pf.

___ Install the electrolytic capacitors, C46, 10 uf radial and C47, 1 uf radial. Note the polarity.

___ Install the power jack, J5.

___ Install the 14 pin header, J3. Solder the shorter ends of the pins to the PC board.

___ Install the 1 x 3 pin header, J4. Solder the shorter ends of the pins to the PC board.

___ Install the relays K1-K17. Be careful not to bend the pins over pushing them in.

___ Install inductors L1-L8 on the PC board. Note that the mounting holes are offset slightly on L3-L8 to help keep the inductors straight after installation. Make sure the insulation is scraped off the ends of the wires on each inductor. Push in each inductor until the windings touch the PC board. The #18 wire is stiff enough to support L3-L8, but RTV or hot melt glue may be needed for L1 and L2 to hold them in place. In you plan to use the unit in a mobile application, you should use the RTV or hot melt glue on all inductors.

___ Install a two inch length of left over #18 wire left over from winding the inductors through the hole in T1. Be sure to scrape the thermaleze coating off of the ends of the wire before soldering. Solder this from beneath the circuit board. Attach one SO-239 to the other end of this wire. Cut another two inch length of wire for the antenna connection. Solder one end to the pc board next to L8, then attach one SO-239 to the other end.

___ Using left over pieces of #18 wire, cut two pieces two inches long. Crimp the terminal lugs onto one end of each of the wire, and attach the other ends to the pc board at J1 & J2. Be sure to scrape the insulation off the wires so they can be soldered.

You are finished with the assembly of the main pc board. Proceed with the assembly of the front panel pc board.

___ Install the 14 pin header with 0.1 inch spacing to the side of the front panel that has the white silk screen. Solder the shorter ends of the pins to the PC board.

___ Install the resistors on the opposite side of the pc board as the header. R1, 2 470 ohm 1/8 watt, and R3, 4 100 ohm 1/8 watt.

___ Unwrap the chassis (beige part of the enclosure) and put the 4 rubber feet on the bottom.

___ Install the 2 SPST toggle switches (S1 & S2) in the chassis in the power and the auto/semi positions. Remove the nut and one washer from the switch. Place the switch in the hole with the

2 prongs toward the bottom. Then replace the lock washer and nut on the switch. You may need to re-align the switches later, so don't tighten yet.

___ Install the 5 push button switches (S3-S7) in the chassis in inductor up/down, the cap up/down and tune positions. Remove the nut and washer from the switch. Place the switch in the hole and replace the washer and nut on the switch. Be sure the solder terminals of the switches are aligned one on top of the other. You may need to realign the switches later, so don't tighten yet.

___ Place the LEDs in the front panel board, D1 Green, D2 Yellow, D3 & 4 Red. Be sure to place ground side down. The ground leg of the LED is the one with the notched plastic next to it. Do not solder them at this time.

___ Install the front panel pc board on the switches. The side without the white silkscreen will be placed on the solder terminals of the switches. Gently push the pc board onto the switches. The LEDs should slide into the holes in the chassis. They should be in this order -- Tune Switch, Green, Yellow, Red and Red. Once you have checked the alignment, then solder the switches to the pc board. Tighten nuts on switches at this time. Next, slide the LEDs into the chassis and solder the legs to the pc board. Then clip the legs of the LEDs. See figure 3.

You are now ready to mount the AT-11 pc board in the chassis.

___ Install the AT-11 PC board in the chassis using four screws, nylon spacers, washers and nuts. Do not drill out the holes in the PC board.

___ Install the SO-239s in the holes on the back panel of the chassis. Attach the terminal lugs to the bottom mounting screws of both the SO-239s.

___ Install U1 (the 68HC11) by carefully pressing it into place in its socket. Note that U1 has a flattened corner that should match the socket.

___ Install U3 (the UCN5812) by carefully pressing it into place in its socket. Note that U3 has a notch that should match the socket.

___ Install the ribbon cable with the red stripe connecting pin 1 of J3 to pin 1 on the 2 x 7 header on the front panel. See Figure 4.

___ Plug in the power and turn the unit on. The LEDs should all flash once simultaneously.

___ Apply 11 to 14 volts DC to the power input. The center pin is positive.

___ Check for +5.0 volts on the output of U2 (the 78L05). The output is the pin closest to the oscillator.

___ Current draw should be around 8 mA (anything from 5 to 10 mA is acceptable).

Figure 3 Front panel pc board

___ Set R9 and R10 to the center position. See Figure 4 below.

___ With a voltmeter on test point REV (to the left of R9), and about 10 watts applied and a dummy load or resonant antenna on the output, tune C1 for minimum DC voltage. The voltage should be just about 0.0 volts (0.1 is OK). You MUST use a 50 ohm load (either dummy or resonant antenna) to properly do the alignment.

___ Raise the power to 100 watts and with your voltmeter on test point FWD (to the right of R10), adjust R10 for 4.5 volts (4.2 to 4.8 is OK). This is a fairly course adjustment, so you do not need to be exact.

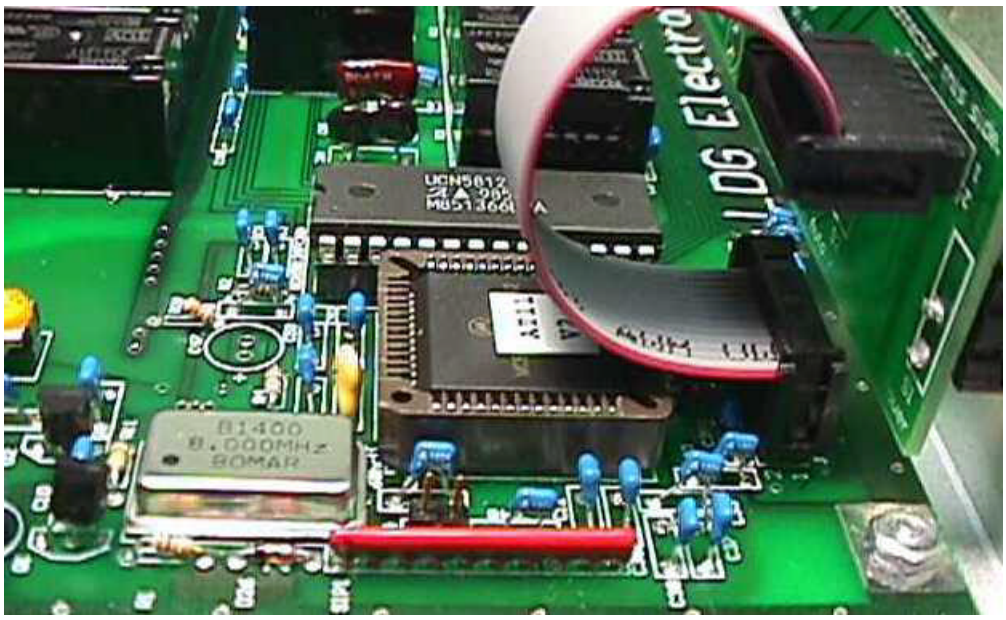

Figure 4 Ribbon cable and U1

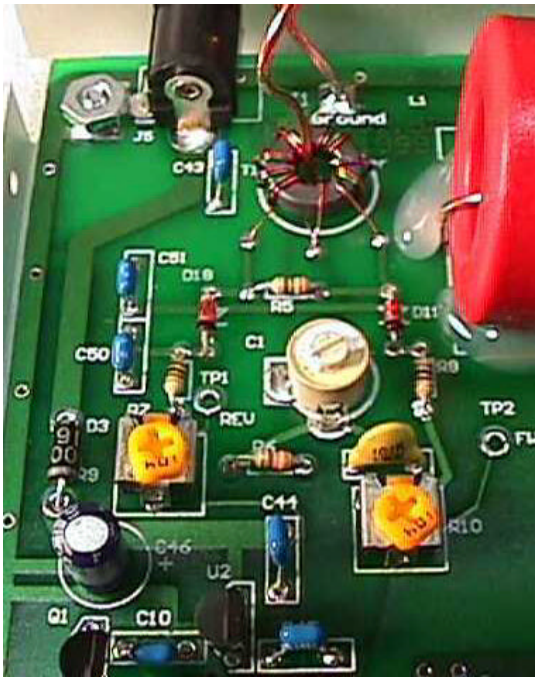

Figure 5 T1 and Variable Capacitor C1

___ Reverse the two coax lines so the transmitter output is applied to the ANTENNA jack of the unit and the TRANSMITTER jack is connected to the 50 ohm load. Apply 100 watts and adjust R9 for 4.5 volts on test point REV.

Note: if you can't get 100 watts out of your radio, use 10 watts and adjust R9 and R10 as shown above for 1.5 volts.

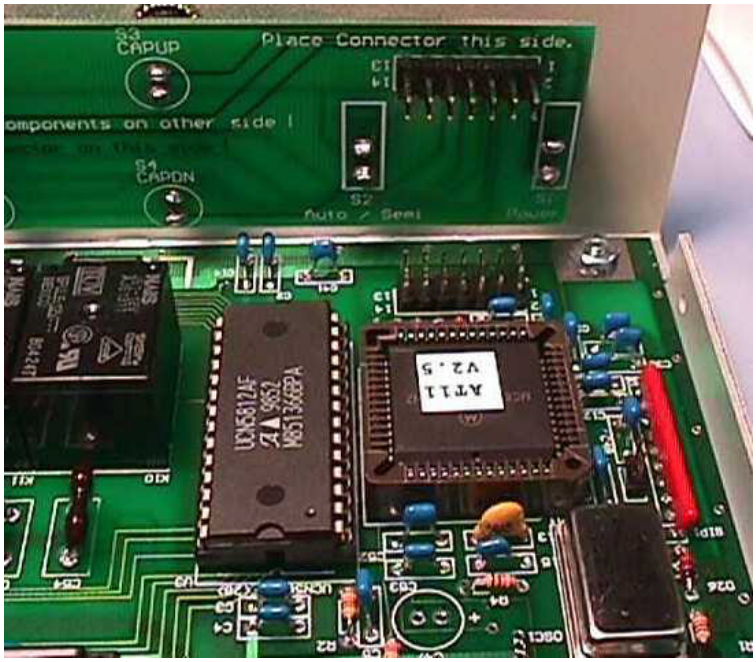

Figure 6 U1 nad U3

Congratulations! The AT-11 is now ready to be put on the air.

Operation: Turning the unit will initialize the microprocessor. All four LEDs will flash once to indicate the power up process was initiated. The unit can be turned off with the front panel power switch, but the LEDs will not show the initialization process again. Turning the unit off by the front panel power switch places the tuner in a standby mode. All relays are de-energized and the unit is in bypass. Turning the unit back on will return the tuner to the tuning position previously held.

The semi/auto switch controls how the tuning process will be envoked. When the semi/auto switch is in semi, the tuning process will only be started when there is RF present and the Tune push button is pressed. When the semi/auto switch is in auto, the tuning process will be started if there is RF and the SWR is over 3 to 1. The Tune push button is enabled when in the auto mode.

Placing the unit in the semi mode allows more control over the tuner. It will not start tuning if the SWR temporarily goes over 3 to 1. In the auto mode, the tuner may start tuning while transmitting even if the SWR temporarily goes over 3 to 1.

The Cap and Ind up and down push buttons are for manually fine tuning. Even though the tuning algorithm will find a match that is 1.5 to 1 or better, the user may want to find a better match that approaches 1.1 to 1. While transmitting, the up and down push buttons can be used to fine tune the SWR. An external SWR meter may be needed to assist in the fine tuning. Note that if the unit is in auto mode, the unit will start tuning if the fine tuning push buttons cause an SWR of over 3 to 1.

Besides envoking the tuning process, the Tune push button has some other functions. Pressing the Tune and Cap Up push buttons at the same time will cause the Hi/Lo-Z relay to move to the Hi-Z position. The Tuning LED (red) will flash to indicate the change. Pressing the Tune and Cap Down push buttons at the same time will cause the Hi/Lo-Z relay to move to the Lo-Z position. The 1.5 SWR LED (green) will flash to indicate the change. Pressing the Tune and Ind Up push buttons at the same time will reset all relays to bypass. Pressing the Tune and Ind Down Push buttons at the same time will toggle the sound on and off. When on, the >3.0 LED (red) will light. When off, the 2.0 SWR LED (yellow) will light.

The sound option allows the user to receive an audio feedback of the SWR condition after a tun has been completed. When enabled, the speaker will emit a series of beeps that correspond to the SWR condition. One beep will mean the SWR is below 1.5 to 1. Five beeps will mean the SWR is above 3 to 1. Two, three and four beeps corresponds to increasing SWR. If the sound is turned on, but no sound module is installed, the user will notice a delay after each tune. The sound will also be sent when one of the Cap or Ind up or down push buttons have been pressed.

The SWR/Status LEDs indicate the SWR and the tuning status. The Tuning LED (red) only lights when the tuner is processing the tuning algorithm. The other three LEDs give an indication of the SWR when there is RF present. The Green alone LED means SWR below 1.5. The Green and Yellow means 1.5 to 2.0 SWR. The Yellow alone means 2.0 to 2.5 SWR. The Yellow and Red means 2.5 to 3.0 SWR. The Red alone means above 3.0 SWR.

Operation Notes: Although rated for 150 watts, try to do the tuning with only 10 watts of power (especially if using a tube rig). This will reduce stray RF and reduce stress on the relays. Solid state radios that automatically fold back the power during high SWR periods will have no problems. With tube radios, the AT-11 tunes best with 10 watts.

The LEDs will indicate SWR whenever there is more than 5 watts of forward power. If you press the tune button and there is less than 5 watts of forward power, it will not go to the tune algorithm, but all LEDs will flash once.

You can use SSB to provide the power for tuning. Just press your mic and say something (like "Ahhhhhh") until the AT-11 stops tuning (somewhere between .1 and 3.5 seconds). If the tuner has a hard time finding a match or doesn't find 1.5, try using a CW or AM carrier at 10 watts.

If you reach the upper or lower limit of the inductors or capacitors with the manual push buttons, the LEDs will flash while the button is pressed.
When in the auto mode, if the tuner can not find a better than 3.0 to 1 match, the tuning algorithm will be repeated until power (either RF or +12) is removed or the mode switch is placed in the semi position.

In either mode, if power (either RF or +12) is removed after the tuning cycle starts, but before it finishes, the LEDs will go out and the tuning will stop. The resultant tune will be undetermined, it may or may not be a match.

In worse case scenarios where the tuner just barely finds a match, the LEDs may flash with improper values. This is due to the high stray RF levels on the board. You may want to switch to the semi mode if this occurs with your antenna system. This will stop the auto function from continually going into the tune algorithm.

Performance: The actual performance from the small package will surprise you. It really tunes a lot of antennas to a lot of places! Here are some of the actual test results.

A 40 meter dipole (at 30 feet) would tune just about anywhere from 3.1 to 30 MHz! We had some problems at 19 and 28 MHz finding a 1.5 match. The AT-11 usually found a 2.0, and then we had to use the manual switches to get below 1.5.

Next, an Antron-99 (at 40 feet) would again tune just about anywhere from 30 to 5 MHz. The auto mode worked great the whole time. We just dialed down the band and the AT-11 would kick in whenever the SWR went over 3.0.

Then we tried out the unit on a 3 element tri-band (20,15,10) at 70 feet. It would tune any of the ham bands (including WARC) except 160 and 80. We had some problems finding a match around 27.200 MHz, but got around it by moving to 27.000, letting the AT-11 find a match, then moving back to 27.200.

The 80 meter inverted Vee was next. It tuned everything from 3.1 to 30 MHz. We were hoping that it would tune all of 160 meters, but it only found good matches from 1.900 to 1.800 MHz.

We've tried many other antennas with similar good results. There may be a place or two that your antenna (dipole, inverted-Vee, vertical, beam, etc.) won't tune. Also, the farther away from resonance you try to tune, the harder time the tuner will have. The AT-11 will tune a 10 meter vertical to 80 meters, but your performance will not be that great (you can't get something for nothing).

For balanced lines and random wires, you may get better performance by using a 4 to 1 or 6 to 1 balun between the antenna and tuner.

We used the Autek RF-1 analyzer to give us more information about how well the AT-11 was working. We found that it would consistently tune impedances from about 6 ohms to about 650 ohms. This corresponds to an SWR of about 10:1.

The SWR bandwidth (usable bandwidth of 1.5 SWR without retuning) averaged about 200 kHz. On the lower frequencies it was smaller (about 75 kHz on 80 meters) and on the higher frequencies it was larger (about 400 KHz on 10), no surprises here.

Trouble Shooting: If there are any problems, first check all components for proper value, placement and polarity. Next look at the solder connections. Check for cold solder joints and solder bridges first, since they are the number one cause of problems with the kits.

Does nothing: Check for 12 volts getting to PC board. Check for 5.0 volts out of 78L05. Make sure the socket for U1 was installed correctly. Make sure U3 is installed correctly. Check D3 for polarity. Check the SIP resistor for proper orientation.

Can't get 4.5 volts on FWD: Make sure T1 was wound correctly. Make sure the wire from the SO-239 passes through the center of T1. Check polarity of D18 and D19. If you can't get 100 watts out of your radio, use 10 watts and set FWD and REV to 1.5 volts.

LEDs don't work: Check for polarity on LED1-4. The flattened (or notched) side of the LEDs should go to ground.

LEDs flash randomly at high power or relays chatter or unit locks up: Excessive stray RF on board or poor grounding. Try reducing power to 5 to 10 watts during tune to find match. AT-11 may also be outside of tuning range.

Tech Support: Telephone technical support at 410-586-2177 is available most days from 8 am to 9pm Eastern Standard Time. Replies by FAX (410-586-8475) are welcome, e-mail (ldg@ldgelectronics.com) is also answered on a daily basis.

Last Resort: As a last resort only, LDG Electronics will attempt to repair any problems. We have a flat fee of $50 plus parts to repair an AT-11 (most resistors and capacitors are included in that fee). The 68HC11 chip is the most expensive at $20. is $1.

We will not attempt to repair any unit that has been soldered with acid core. We reserve the right to refuse repair due to excessive problems or damage due to construction.

Before any unit is sent to us, you must first call to get return authorization. All units sent back must be prepaid, either by check, money order or Credit Card unless other arrangements are made. Package the unit carefully and keep in mind that we will use your packaging to return the unit back to you. Include a description of what problem you are having along with your name, address and a phone number that you can be reached at in case we have questions. Repairs average about 4 to 6 weeks, depending on the particular problem.

If you have an idea of how the unit can be made better (in software or hardware), please send a description of your upgrade. If we use it for the AT-11, we'll send you a free upgrade. Future upgrades will be available for about $10 with 68HC11 chip trade in. If you purchased the kit from LDG, we will notify you when future upgrades and modifications are available through the AT-11 Newsletter. If you purchased the AT-11 through a distributor and would like to be added to our mailing list, just drop us a note by mail, fax or e-mail.

Feedback: We encourage everyone who builds the AT-11 kit to drop us a note (card, letter or e-mail preferred) to let us know how well it works for you. We're also always on the lookout for photographs of the AT-11 in use. We frequently place pictures that we receive into the AT-11 Newsletter or on our Web site (www.ldgelectronics.com).

	List #	Part Description	Qty
[ ]	L1-8	Iron Toroid T106-2	8
[ ]	T1	Ferrite Toroid FT37-43	1
[ ]	Wire	#18 Thermeleze	12'
[ ]	Wire	#28 Red	8"
[ ]	Wire	#28 Green	8"
[ ]	U1	68HC811E2FN	1
[ ]	U2	78L05	1
[ ]	U3	UCN5812	1
[ ]	OSC1	8.0 Mhz Oscillator	1
[ ]	Socket 1	52 Pin PLCC	1
[ ]	Socket 2	28 Pin PLCC	1
[ ]	D1-2, 4-9	1N4148	8
[ ]	D3	1N4001 1A/50V	1
[ ]	Q1	2N3904	1
[ ]	K1-17	JS1-12V Relay	17
[ ]	SIP1	10K 10 pin SIP	1
[ ]	R5	150 1/8w resistor brown-green-brown	1
[ ]	R6,3	3.3K 1/8w resistor orange-orange-red	2
[ ]	R7,8	100 1/8w resistor brown-black-brown	2
[ ]	R1,2,4,11	10K 1/8w resistor brown-black-orange	4
[ ]	R9, R10	100K pots	2
[ ]	C2-5,10,12,14,15,18-45,50-53	0.01 uf 50V Mono capacitor	41
[ ]	C13, 49	100pf 1KV capacitor	2
[ ]	C46	10 uf 50V radial capacitor	1
[ ]	C47	1 uf 50V Mono capacitor	1
[ ]	C54	15pf, SM capacitor	1
[ ]	C55	30pf, SM capacitor	1
[ ]	C56	62pf, SM capacitor	1
[ ]	C57	120pf, SM capacitor	1
[ ]	C58, 59	470pf, SM capacitor	2
[ ]	C60, 61	1000pf, SM capacitor	2
[ ]	C62, 63	2000pf, SM capacitor	2
[ ]	C64, 65	3900pf, SM capacitor	2
[ ]	C11	.01 uf 1000v capacitor (green)	1
[ ]	C1	3.5-13pf Trimmer Capacitor	1
[ ]	J1, 2	SO-239	2
[ ]	J3	2 x 7 Header	1
[ ]	J4	1 x 3 Header	1
[ ]	J5	Male Power Jack	1
[ ]	P1	Female Power Plug	1
[ ]	Ribbon Cable	Ribbon Cable	1
[ ]	Spacers	.25 Spacers	4
[ ]	Nuts	Hex Nuts	8
[ ]	Bolts	Screw, Phillip Head	8
[ ]	Star Washers	Lock Washer	8
[ ]	Terminal Lug	Terminal Lug	2
[ ]	V2.5 PCB	PC Board	1
[ ]	FP R1, 2	470 1/8w resistor yellow-violet-violet	2
[ ]	FP R3, 4	100 1/8w resistor brown-black-brown	2
[ ]	S1, 2	SPST Switch	2
[ ]	S3-7	Push switch	5
[ ]	D1	Green LED 5mm	1
[ ]	D2	Yellow LED 5mm	1
[ ]	D3, 4	Red LED 5mm	2
[ ]	J1	2 x 7 Header	1
[ ]	V2.5FP PCB	Front Panel PC Board	1
[ ]	V2.5 Manual	Manual	1