

# **AT-11 Automatic Antenna Tuner**

**Assembly Manual** Ver 2.4a



## **LDG Electronics**

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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 2 to 100 watts. The tuner uses a switched "L" configuration with 256 capacitor, 256 inductor and Hi/Lo-Z settings to provide over a quarter-million tuning combinations (figure 1)(figures appear at the end of text). The "L" network works great with just about any coax fed antenna (dipole, vertical, beam, ect). Tuning time is between 0.1 and 6.2 seconds.

Operation of the tuner is auto or semi automatic. In auto mode, the tuner will seek a 1.5 match anytime the SWR is above 3.0. In semi mode, the tuner will seek a match when the tune push button is pressed. Both modes require that more than 2 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 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 (we averaged 6 hours on the prototypes). Besides the normal building tools needed (soldering iron or soldering pencil, wire cutters, screw drivers, ect), the only test equipment needed is an HF transceiver, dummy load (or resonant antenna) and voltmeter.

Before starting, you may want to get a copy of the January 1996 QST article where the AT-11 first appeared. Although not needed for construction of the kit, it contains a little more theory about the AT-11 along with some pictures. If you don't have or can't find the article, a reprint may be available from QST, 225 Main St., Newington CT 06111.

**Hardware Changes:** A few changes were made since the article. Please use the instructions, schematics and figures included in this manual for building your kit. D20 was added to prevent damage from accidental reversing of the power and ground supply. More bypass capacitors were added to help prevent stray RF on the board. J3 was changed from a 10 pin to a 14 pin header. A coaxial power jack was added near the back of the PC board. Some of the tuning capacitors were upgraded to 1000 volt types to reduce drift due to component heating on the lower bands (80 and 160). The 4.433 MHz crystal was changed to a 8.0 MHz oscillator module.

Also notice that due to upgrades, the silk screen on the PC board may be incorrect for some components. Use the parts placement sheet at the end of this manual for correct parts placement.

**Software Changes:** Several months after the AT-11 was released, some users noticed spurious noise emitting from the chip. These "birdies" could be heard on a receiver at various places across the HF spectrum. The software was changed to allow the AT-11 to go into sleep mode and extinguish the birdies.

The new software changes some of the operating features. At power on and in Semi mode, if there is no RF, there is no noticeable difference. If there is RF, the tuner will tune to find a match. Once finished with tuning and RF is removed, the processor will shut down, go into sleep mode and the birdies are gone.

In the sleep mode, the LEDs are disabled. You will not get the SWR indication when RF is present. The Cap and Ind Up/Down buttons are also disabled while in sleep mode. Pressing the Tune switch with no RF applied will wake up the processor (the LEDs will flash once). The LEDs will then indicate SWR when RF is present and the Up / Down buttons will also function.

If you are in the Auto mode, the processor will not go to sleep because it has to monitor the SWR for 3.0 or higher to make another tune. Pressing both Down switches at the same time forces the processor into sleep from either, semi or automatic mode.

**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 200 parts and 500 solder connections, so take your time.

Once familiar with the parts, start with the eight T-106 toroids (they are red and just over an inch in diameter). Take care to not drop them, they will break. Use the number #18 gauge wire provided to wind L1-8. For consistency, we count one turn when the wire passes through the center of the toroid. L1 and L2 just loop at the bottom of the toroid (figure 2). L3-L8 are evenly spaced around (figure 3). Use the inductor table to cut the wire to length (figure 4). Wind each toroid in the same direction as shown. Trim the wire to about 1/2 inch and scrape away the insulation from the end. Don't solder them in until later.

Next, wind T1 with 10 turns (figure 5). It is the small, black toroid and just under 1/2 inch in diameter. The windings use the smaller #28 gauge wire and are made bifilar. This means to use two lengths of wire and wind them at the same time. It doesn't matter if you twist them or wind them side by side. Connecting Green 1 and Red 2 together forms the center tap of T1. Be sure to note that the wire on the left side come from under T1 and the wires on the right side come over the top side of T1. Trim the wire to about 1/2 inch and scrape away the insulation from the end. Do not install T1 until later.

Note that some of the silk screen may have been drilled away when it was fabricated. Use the parts placement layout in the back of this manual to assist in locating where parts are installed.

Parts are installed and soldered in order of height, from shortest to tallest. With the PC board blank, it is easiest to install all of the resistors first. 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.

Next, install the 1N4148 diodes. Then, the larger 1N4001 (D20). Be sure to note the band polarity on both types. Next, install the monolithic and ceramic caps. The SIP resistor can also be installed. Be sure to note the orientation of the SIP resistor. A small line (or dot) on the side with writing marks pin 1.

Next install U2, the 34064 (use the parts placement sheet for orientation). Then U3, the 78L05. Next, install Q1-17. Note the orientation. Then, the variable resistors VR39 and 40. Then the Variable capacitor C35.

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

Now 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 the 68HC11 until later. Then the 8 MHz oscillator. Three of the corners are rounded and one corner is square on the oscillator. The square corner is pin 1.

Next, install the tuning capacitors, C58-67. Be sure to match the values from the capacitor chart (figure 6). Then the electrolytic capacitor, C51, on the power input, note the polarity. Then the power jack. Now, relays K1-17 can be installed.

Lastly, inductors L1-8 can be installed on the PC board. Note that the mounting holes are offset slightly on L3-L8 to help keep the inductors straight after installation. The inductors can be pushed in until the windings touch the PC board. Don't forget to scrape some the insulation off the ends before trying to solder. 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. The RTV or hot melt glue should be used if you plan to use the unit in a mobile application.

The circuit should be "power on" tested once all the components except for U1 (the 68HC11 chip) have been installed. Apply 12 to 14 volts DC to the power input. Check for +5.0 volts on the output of the 78L05 (pin closest to U1). Current draw should be around 20 mA (anything less than 30.0 mA is acceptable). If the volts and amps look good, you can proceed to mount the unit in the case and begin wiring the user interface. Do not drill the mounting holes on the PC board to make them larger.

Just about any metal enclosure that is 5.5 inches deep by 8 across by 2.5 inches high will work. See the front panel layout for ideas (figure 7). LDG also has custom finished enclosures available for around \$30.

Use the stand offs to mount the PC board in the box. Use the four mounting holes provided on the PC board, do not drill the mounting holes on the PC board holes to make them larger.

Switch 1-7 and LED 1-4 mount on the front panel and J1 and 2 mount on the rear panel. The power switch, SW6 connects to the two wire holes near the power jack.

The mode switch, SW7 mounts next to the power switch. It connects to J3. Grounding the pin is Auto mode, letting it float is Semi. The 5 push buttons mount nearly in the center of the front panel and the LEDs just push through holes. Note the polarity of the LEDs. The flattened side (on the plastic part of the LED) should go to ground. You can see the flattened side by looking at the LED with the leads facing you. The flattened side will be right next to one of the leads. You may want to use some silicon RTV, hot melt glue or adhesive to help hold in the LEDs in place.

J3 is laid out on the board as a 14 pin header with 0.1 inch spacing (figure 8). A header and connector with ribbon wire is provided for wiring the front panel components. See figure 9 for the wire designations.

The wires from the SO-239 can be left over #18 gauge wire from L1-8. You should only need about 2 or 3 inches to make the connection (figure 10). Be sure to note that the #18 gauge wire on the radio side goes through the center of T1. Also, bring a ground wire from each SO-239 to the PC board. Be sure to scrape the insulation off the ends of the wire before soldering.

Once everything is mounted and wired, U1(the 68HC11) can be placed into the socket and power applied. Notice that U1 has a flattened corner that should match the socket. On power up, the AT-11 will flash all LEDs once to indicate that everything has initialized successfully. Current draw should be around 10 mA.

Each relay draws about 30 mA when energized. If a relay energizes on power up (a sign there is a problem), you will not be able to tell (by current draw) if the processor is working properly. No relays should energize when the unit is first powered on. The maximum current draw is about 500 mA with all the relays energized. Since it is rare that all relays are energized, the average current draw is about 200 mA.

**Alignment:** The AT-11 can be powered on or off during alignment. We recommend to leave it off so that other components that may have problems will not interfere. If you leave it on during alignment, be sure to place the semi/auto switch in the semi position. Otherwise, it will start tuning while you are making adjustments. Set VR39 and 40 to the center position. With a voltmeter on test point REV (to the left of VR39) and about 10 watts applied and a dummy load or resonant antenna on the output, tune C35 for minimum DC voltage. It should dip to just about 0.0 volts (0.1 is Ok). You MUST use a 50 ohm load (either dummy or antenna) to properly do the alignment.

Then, apply 100 watts to the input. Adjust VR40 for 4.5 (4.2 to 4.8 is Ok) volts on test point FWD (to the right of VR40). The adjustment is fairly coarse, so you do not need to be exact. Move the dummy load to the input and apply 100 watts to the output. Adjust VR39 for 4.5 volts on test point REV.

If you can't get 100 watts out of your radio, use 10 watts and adjust for 1.5 volts. That's it, the AT-11 is now ready to be placed on the air.

**Operation Notes:** In general, the tuner operation is straight forward and works as described in the introduction of this manual.

Although rated for 100 watts continuous (the actual max power is about 150 watts at 50% duty cycle), 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 2 watts of forward power. If you press the tune button and there is less than 2 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 6 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 after about 2 seconds. 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 that didn't make it into the article. We modified the SWR sensor in one of the prototypes and reduced the power to way below 100 milliwatts to check everything from 1.6 to 30 MHz.

A 40 meter dipole (at 30 feet) would tune 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, then we had to use the manual switches to get below 1.5.

Next, an Antron-99 (at 40 feet) would tune 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 when ever the SWR went over 3.0.

Then we tried out the unit on a friends 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, ect.) 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 8 ohms to about 650 ohms. This corresponds to an SWR of about 8:1 for Low-Z and 10:1 for Hi-Z.

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:** The AT-11 goes together very easy and the dozens of units that we have built have all worked on the first try. 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 U2 is installed correctly. Check D20 for polarity. Check the SIP resistor for proper orientation.

One or more relays energizes on power up: Check for correct positioning of all transistors. If a transistor is found to be bad, just about any 2N3904 type or equivalent will work. Check solder joints.

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 side of the LEDs should go to ground.

LEDs work, but won't tune: Check Q1-17 and D1-17 for polarity.

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 6 to 9 pm Eastern Standard Time. Replies by FAX (410-586-8475) are welcome, e-mail (ldg@radix.net) is also answered on a daily basis.

**Last Resort:** As a last resort only, LDG Electronics will attempt to repair any problems. As much as we would like to do it for free, we just can't. 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. The 34064 is \$5. Relays are \$4 each. The 78L05 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.

**Upgrades:** We are continually trying to put more features in the software of the AT-11. The software was locked in with version 1.7 at the time of the QST article. There were only seven bytes (out of 512) of code

space left. The new 2.0 code has zero bytes left over.

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. We can mention now that we do not have enough code space to implement tuning from memory or adding an LCD display (but we're working on it). 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.

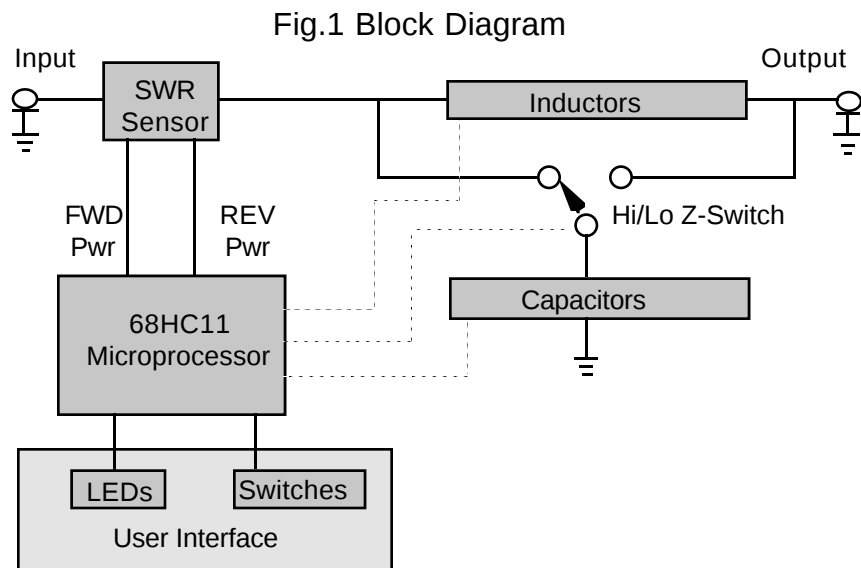


Fig. 2 L1-2. L2 Shown.

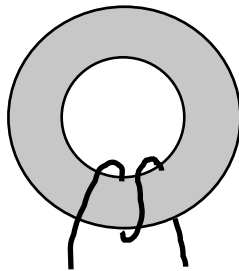


Fig. 3 L3-8. L4 Shown.

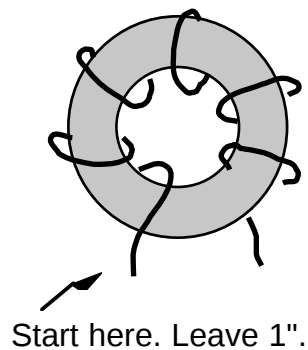


Fig. 4 Inductor Table

| <u>Inductor</u> | <u>uH</u> | <u>Turns</u> | <u>Inches needed</u> |
|-----------------|-----------|--------------|----------------------|
| 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                    |

Fig. 5 T1,10 turns #28

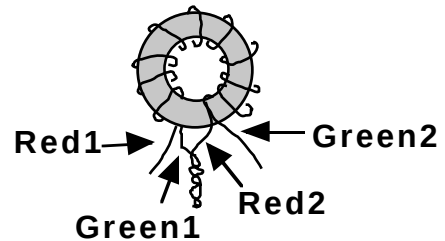


Fig. 6 Capacitor Table

| Capacitor | pF (+/-5%) | Combination | Voltage |
|-----------|------------|-------------|---------|
| C54       | 10         | 10          | 500     |
| C55+56    | 20         | 10+10       | 500     |
| C57       | 40         | 39          | 500     |
| C58       | 80         | 82          | 500     |
| C59       | 160        | 150         | 1 KV    |
| C60       | 320        | 330         | 1 KV    |
| C61       | 640        | 680         | 1 KV    |
| C62+63    | 1280       | 680+680     | 1 KV    |

Fig. 8 J3, Control Header

|        |   |   |   |           |
|--------|---|---|---|-----------|
| Cap Up | 1 | □ | ○ | Ind Up    |
| Cap Dn |   | ○ | ○ | Ind Dn    |
| Green  |   | ○ | ○ | Yellow    |
| Red1   |   | ○ | ○ | Red 2     |
| N/C    |   | ○ | ○ | Tune SW   |
| N/C    |   | ○ | ○ | Auto/Semi |
| GND    |   | ○ | ○ | GND       |

Fig. 7 Front Panel Wiring (inside view)

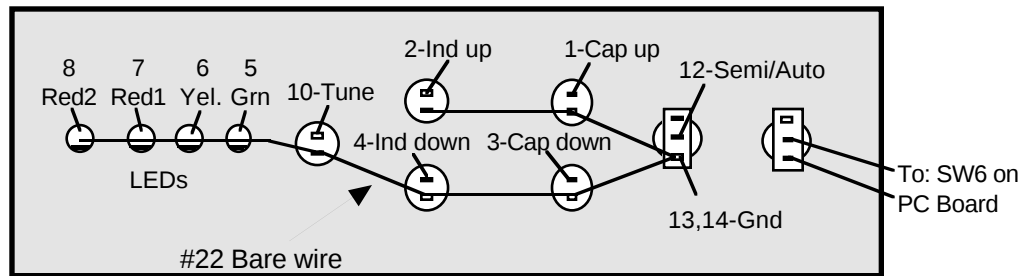


Fig. 9 Ribbon Cable Layout

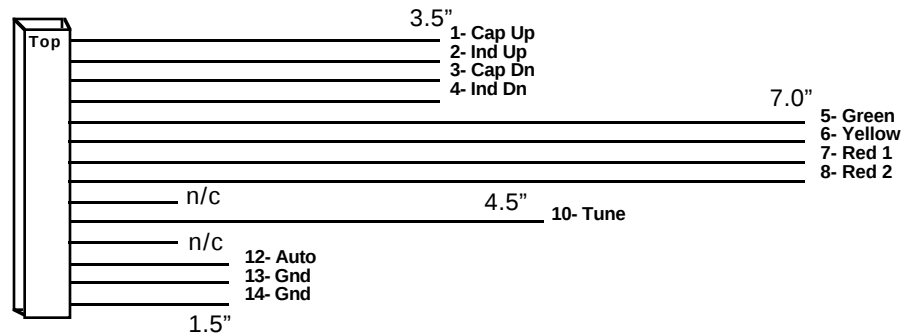
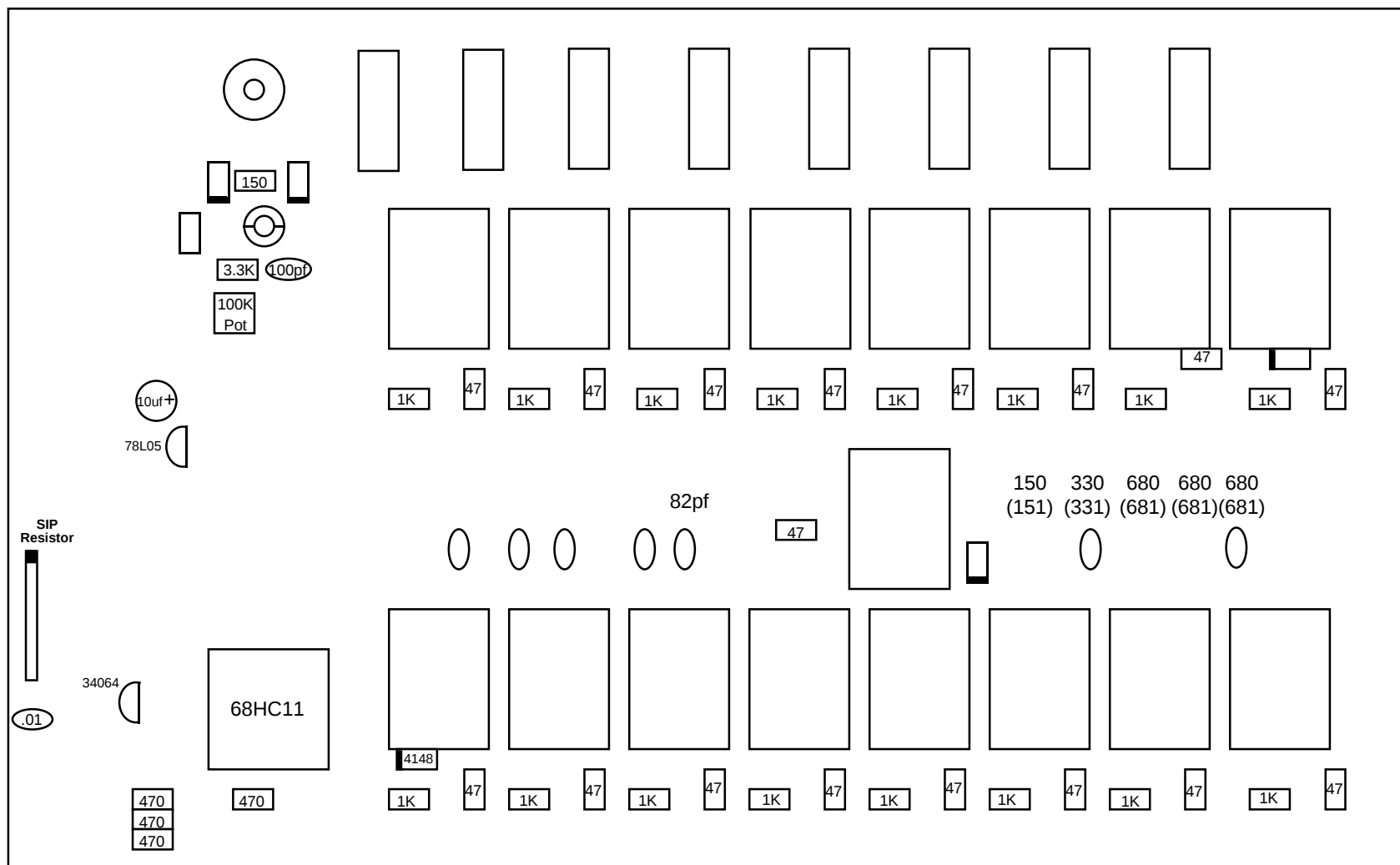
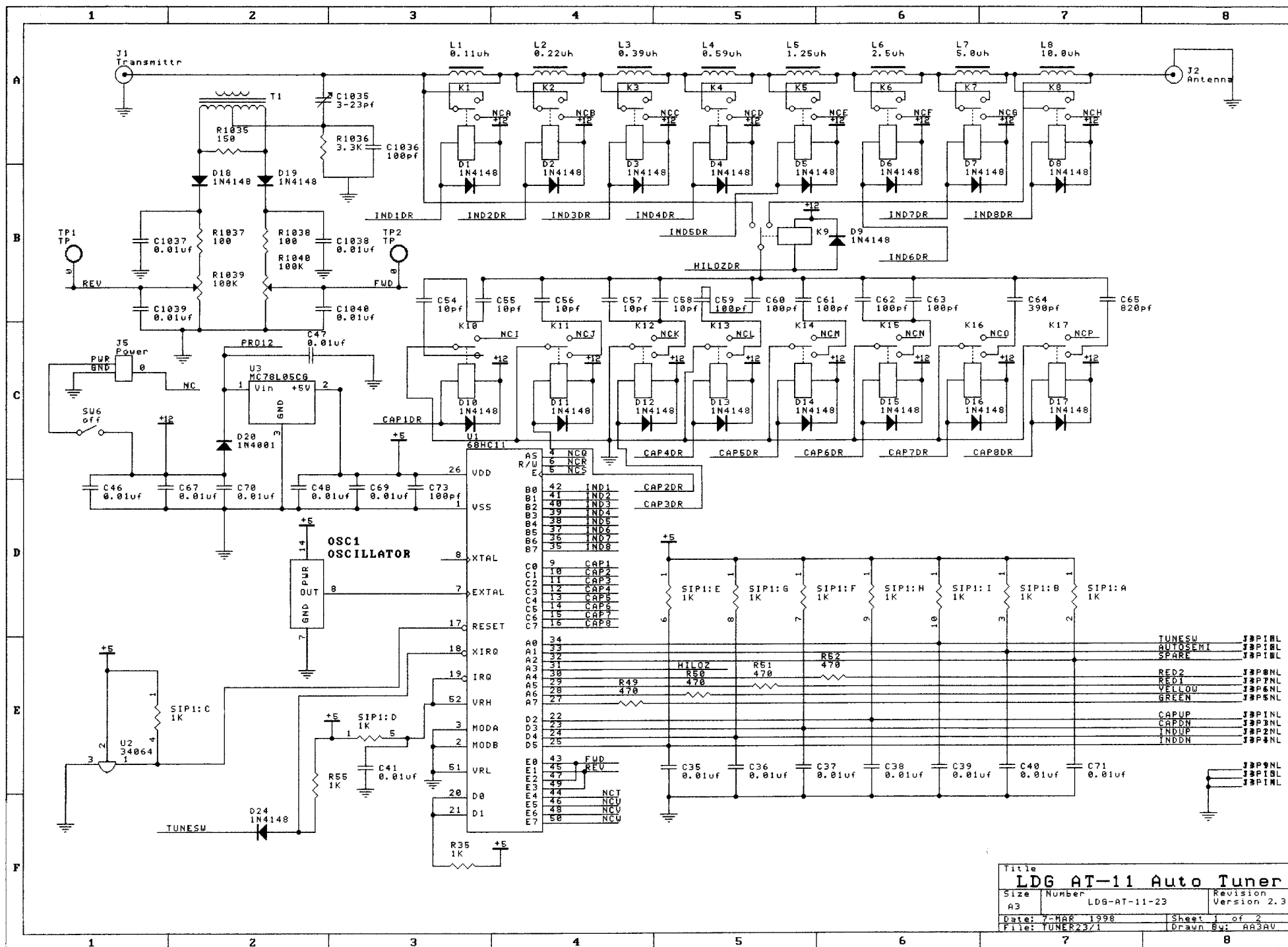
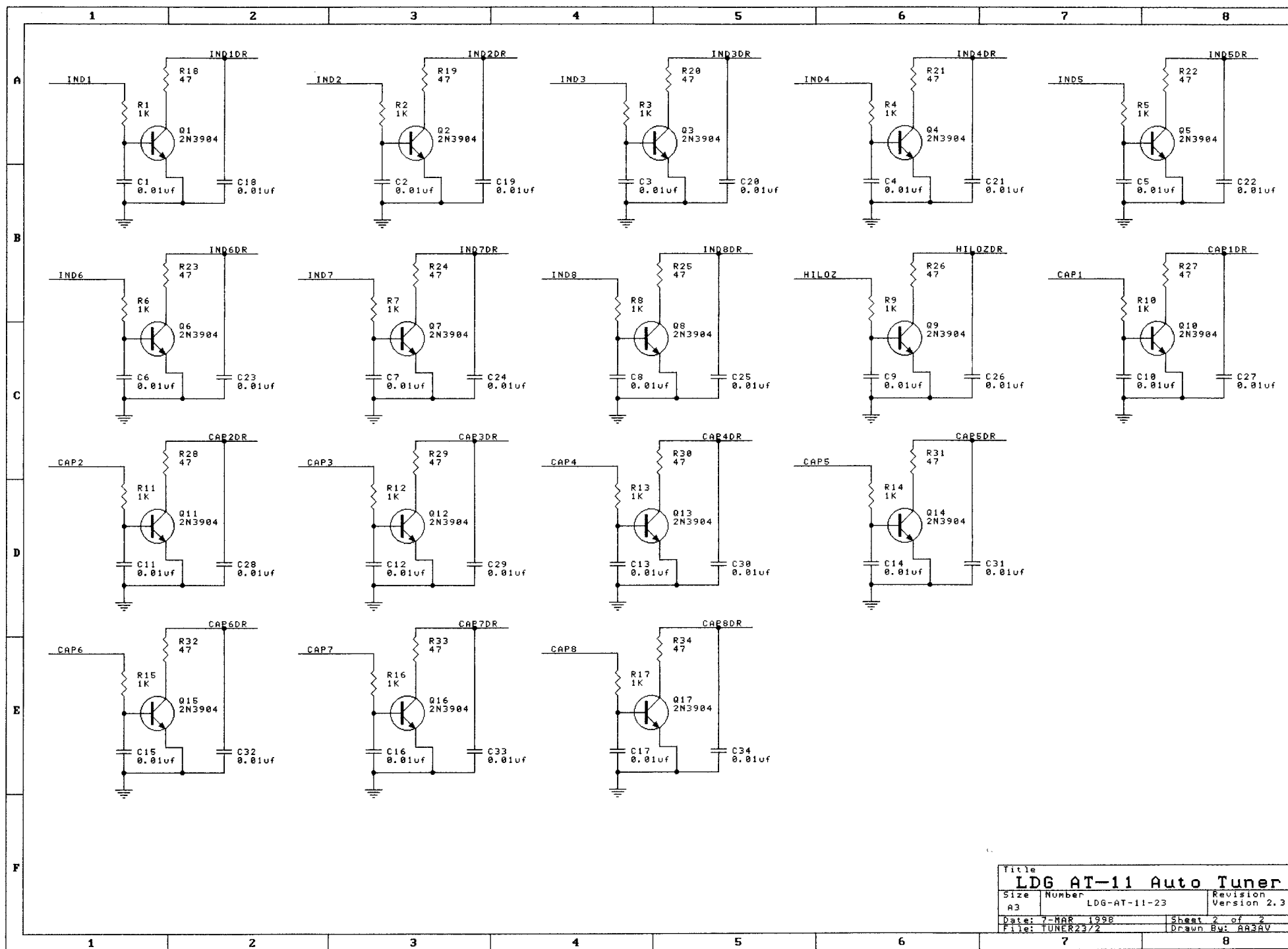


Fig. 10 Connection between SO-239 and Chassis









|                                      |                        |                         |
|--------------------------------------|------------------------|-------------------------|
| Title<br><b>LDG AT-11 Auto Tuner</b> |                        |                         |
| Size<br>A3                           | Number<br>LDG-AT-11-23 | Revision<br>Version 2.3 |
| Date: 7-MAR-1998                     | Sheet 2 of 2           |                         |
| File: TUNER23/2                      | Drawn By: AA3AV        |                         |

# AT-11 Parts List V2.4

|     | <u>List #</u>        | <u>Part Description</u> | <u>Qty</u> |
|-----|----------------------|-------------------------|------------|
| [ ] | L1-8                 | Iron Toroid T106-2      | 8          |
| [ ] | T1                   | Ferrite Toroid FT-37-77 | 1          |
| [ ] | Wire                 | #18 Thermeleze          | 12'        |
| [ ] | Wire                 | #28 Red                 | 8"         |
| [ ] | Wire                 | #28 Green               | 8"         |
| [ ] | Wire                 | #22 Bare                | 8"         |
| [ ] | U1                   | 68HC11A1FN              | 1          |
| [ ] | U2                   | 34064                   | 1          |
| [ ] | U3                   | 78L05                   | 1          |
| [ ] | X1                   | 8.0 Mhz Oscillator      | 1          |
| [ ] | Socket1              | 52 Pin PLCC             | 1          |
| [ ] | D1-19,21             | 1N4148                  | 20         |
| [ ] | D20                  | 1N4001 1A/100V          | 1          |
| [ ] | Q1-17                | 2N3904                  | 17         |
| [ ] | SW1-5                | Push switch             | 5          |
| [ ] | SW6,7                | SPST Switch             | 2          |
| [ ] | LED1                 | Green 5mm               | 1          |
| [ ] | LED2                 | Yellow 5mm              | 1          |
| [ ] | LED3-4               | Red 5mm                 | 2          |
| [ ] | K1-17                | SPDT Relay              | 17         |
| [ ] | SIP1                 | 10 pin SIP              | 1          |
| [ ] | R1-17                | 1K 1/8w                 | 17         |
| [ ] | R18-34               | 47 1/8w                 | 17         |
| [ ] | R35                  | 150 1/8w                | 1          |
| [ ] | R36,45               | 3.3K 1/8w               | 2          |
| [ ] | R37,38               | 100 1/8w                | 2          |
| [ ] | R39,40               | 10K 1/8w                | 2          |
| [ ] | R41-44               | 470 1/8w                | 4          |
| [ ] | VR39,40              | 100K pots               | 2          |
| [ ] | C1-34,37-50,52,53,64 | 0.01 uf 50V Mono        | 51         |
| [ ] | C36,65               | 100pf 500V or 1KV       | 2          |
| [ ] | C51                  | 10 uf 25V or 50V        | 1          |
| [ ] | C54,55,56            | 10 pf 500V              | 3          |
| [ ] | C57                  | 39 pf 500V              | 1          |
| [ ] | C58                  | 82 pf 500V              | 1          |
| [ ] | C59                  | 150pf 1000V             | 1          |
| [ ] | C60                  | 330pf 1000V             | 1          |
| [ ] | C61-63               | 680pf 1000V             | 3          |
| [ ] | C35                  | 3-23 pf Trimmer         | 1          |
| [ ] | J1, 2                | SO-239                  | 2          |
| [ ] | J3                   | 2 x 7 Header Pin        | 1          |
| [ ] | J4                   | Male Power Jack         | 1          |
| [ ] | P1                   | Female Power Plug       | 1          |
| [ ] | Ribbon Cable         | Ribbon Cable            | 1          |
| [ ] | Spacers              | .25 Spacers             | 4          |
| [ ] | Nuts                 | Hex Nuts                | 8          |
| [ ] | Bolts                | Mach Screw Phillips     | 8          |