R121 AVIATION RECEIVER: INSTALLATION, OPERATION, AND MAINTENANCE

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GENERAL INFORMATION.

Functional Description.

The R121 Aviation Receiver is a tough, commercial-grade, receiver which answers the need for the most demanding applications. It has very good sensitivity and selectivity.

The R121 Receiver is ideal for operation at small airports to monitor or to provide pilot control of lighting. CAP and amateur radio groups will appreciate a high-quality, reasonably-priced ELT monitor to detect downed aircraft.

The R121 Aviation Receiver builds on proven frequency synthesized receiver technology Hamtronics® vhf and uhf fm repeater receivers have been noted for. It is tunable over a range of 118-137 MHz in 25kHz increments. It uses triple-tuned circuits in the front end and dual ceramic filters in the i-f with steep skirts for good adjacent channel selectivity. Low noise fet's in the front end provide good overload resistance and 0.2µV sensitivity. You won't need a preamp with this receiver!

Modes of Operation Available:

The R121 has one microcontroller which is responsible for watching the squelch to determine what is happening on the air. It can be programmed to perform several different tasks in response.

Pilot-controlled Lighting:

- Runway lights may be controlled in varying intensities by keying the microphone 3, 5, or 7 times in a 5-second period.
- Lights remain on for a programmable period of time, usually 15 minutes.
- Various programming options allow for change in intensity after initial turn-on and flashing lights to warn of turnoff.
- Front panel LED indicates when lights have been activated at any intensity.

ELT Detection:

- Alarm automatically triggers after carrier has been detected a programmable length of time.
- Alarm outputs:
  Two open-collector switching transistors able to sink up to 50 mA to ground on circuits up to 15Vdc.
  - Can be used to trigger an alarm circuit

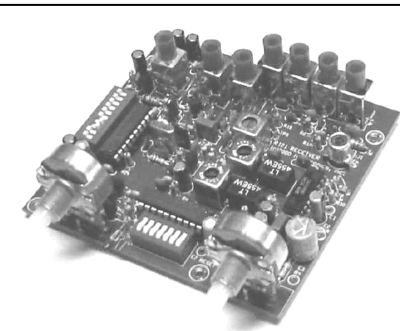


Figure 1. R121 Receiver Module

- Can trip alarm feature on an fm repeater such as our REP-200; audio can be fed to aux rcvr input on repeater. One normally grounded transistor may be used to unmute receiver automatically
- Automatic reset when ELT signal disappears
- LED indicates when ELT detector is tripped.
- Attaching an external S-meter allows receiver to be used to track downed aircraft.

Monitor mode:

Microcontroller turned off to save power.

Test mode:

LED blinks in one second intervals to check operation.

INSTALLATION.

General.

Some aspects of installation are similar for all applications, such as mounting and power requirements. Others, such as ELT detection and Pilot Control of runway Lighting (PCL), require different connections and are therefore treated as separate subjects.

Mounting.

If you purchased the receiver module to install in your own cabinet, some form of support should be provided under the pc board, generally mounting the board with spacers to a chassis. 3/8-inch holes should be provided in a front panel for the bushings of the SQUELCH and VOLUME controls. After sliding bushings through panel, washers and nuts can be installed on the outside of the panel. Be sure to provide support for the board; do not rely on the controls to support the board, since that could cause a break in the pcb solder connections.

The receiver board relies on the mounting hardware to provide the dc and speaker ground connections to the ground plane on the board; so metal standoffs and screws should be used for mounting.

If you purchased the unit in the enclosure, it can be mounted against any vertical or horizontal surface with screws through the mounting flanges. If you want to use a simple whip antenna for localized operation, mounting the unit with the connectors up will allow you to simply screw a whip antenna on the connector. If you need to remove the cover, remove the four screws on the ***side*** of the cover, and slide it off.

Table 1. Quick Reference

Frequency range: 118-137 MHz
Channel Spacing: 25 kHz. Frequency set with dip switch; (repeaking coils required for freq change more than 2 MHz - use A28 tool)
Sensitivity (10dB S/N): 0.2μV
Squelch Sensitivity: adjustable 0.2μV to 5.0μV
Adjacent Channel Selectivity: 80 dB
Temp stability: ±10ppm +20 to +30° C; ±20ppm -30 to +50deg C.
Audio Output: 2 Watts (8 ohms)
S-meter output: will drive external 1mA meter
Front panel controls: volume, squelch, LED.
Control outputs: three separately controlled open-collector switching transistors able to sink up to 50 mA to ground on circuits up to 15Vdc. External relays can be controlled for high current loads.
Antenna connector: RCA jack on pcb (50Ω). BNC jack if installed in cabinet.
Power, audio, s-meter, control connections: solder terminals on pc board
Size: 4 in wide, 3.8 in deep, 1.5 in high.
Operating Power: +13.6Vdc +-10% at 75-200 mA, depending on audio level.

Electrical Connections.

The antenna connection is made with a coaxial connector. All other connections are made at solder terminals on the pc board or with a DB9 connector if purchased in a cabinet. Table 2 identifies the terminals used for these connections. Figure 2 shows identifies the terminals on the DB9 connector and figure 5 identifies the solder terminals on the pcb module.

Power, audio, and control signals should be connected to the unit with #22 solid hookup wire. Be careful not to route the wiring near the components on the left hand side of the pc board, which contains sensitive loop filter and vco circuits which could pick up noise from the wiring.

Be sure to solder wires on the bottom of the board. There is no pad on the top, although the clearance in the solder mask makes it look as though there might be.

Antenna Connections.

The antenna connection should be made to the receiver module with an RCA plug of the low-loss type made for rf. We have good plugs with cable clamps available (model A5). If you want to extend the antenna connection to a panel connector, we recommend using a short length of RG-174/u coax. For longer runs, low loss coax should be used.

We do not recommend trying to use direct coax soldered to board or another type of connector. The method designed into the board results in lowest loss practical. When soldering the cable, keep the stripped ends as short as possible; any pigtails are lossy.

Power Connections.

The receiver operates on +13.6 Vdc at about 200 mA peak with full audio. Current drain with no audio is only about 75 mA. A well regulated power supply should be used.

Be sure that the power source does not carry high voltage or reverse polarity transients on the line, since semiconductors in the receiver can be damaged. The positive power supply lead should be connected to the receiver at terminal E3, and the negative power lead should be connected to the ground plane of the board through the mounting hardware. Be sure to observe polarity!

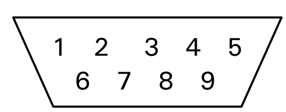
If the unit was supplied mounted in a cabinet, connect the power supply as per Table 2. Two ground pins are provided so you can use one just for the power supply negative lead.

Optional 12Vdc Power Adapter.

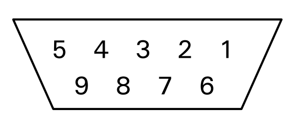
The A40 adapter is rated for 12Vdc at 200 mA load. It is a filtered dc power source but is not regulated. Since there is a voltage regulator on the receiver board, a regulated power supply is not necessary, as long as it is a well-filtered supply.

The adapter actually puts out close to 18Vdc with no load and drops to about 15-16Vdc with the load a receiver presents. The audio amplifier ic on the receiver module is made to operate at these voltages, and the other circuitry is run from an 8Vdc regulator ic on the receiver module; so the unregulated voltage from the adapter is ok.

To install the adapter, clip the



Wiring side of DB-9 female jack used on chassis



Wiring side of DB-9 male plug used on cable

Figure 2. Connector Pinout.

ends of the leads off and strip them about ¼ inch. The lead with the small grooves molded into it is positive, and the smoother lead is negative.

The stripped leads can be soldered to the + power input and ground terminals of the DB9 plug. *Be sure to observe polarity to avoid damaging the receiver module. Because it is difficult to tell the ribbed lead from the smooth lead, double check before applying power to the radio.*

Speaker.

An 8-ohm loudspeaker should be connected to E2 with ground return through the mounting hardware. Use of lower impedance speaker or shorting of speaker terminal can result in ic damage. The receiver can also drive higher impedances, such as the auxiliary audio input of repeater controller boards.

S-meter Output.

To allow the receiver to be used to search for downed aircraft, a signal strength meter output has been provided on the pc board. It is not wired to the rear panel connector, but you can add a connection if you want to use it. The s-meter output is capable of driving a 1mA meter movement. It can also be used with more sensitive meters, such as a 100µA meter, if a shunt resistor is connected across the meter. The value of the resistor depends on the meter movement and must be determined by trial and error. Start with a very low resistor (about 10Ω), and increase it until the meter doesn't peg on very strong signals.

Control Outputs.

The R121 has three output transistors used for various functions, depending on the mode, either ELT or PCL. These are called Output A, Output B, and Output C. Each transistor can sink as much as 50mA at voltages up to +15Vdc. In other words, the transistors switch ground on and off and can be used to ground one end of a circuit. The common use is to ground one side of a relay coil to energize a relay. However, the transistors can also be used to provide audio muting or to trip an alarm. Following is information on various applications.

CAUTION: Be careful not to exceed the voltage or current capabilities of the transistors. Also, be very careful about transients generated by inductive loads, such as relays. All relay coils must have a diode connected across the coil to absorb transients from inductive kickback, which can reach several hundred volts when the coil is switched off. See application diagrams, which follow, for examples of how to connect the diode, which basically must conduct any energy of reverse polarity; so the diode is connected backwards from regular polarity of the power source. Therefore, the diode does not conduct unless there is a reverse voltage.

The relay should be mounted in an electrical cabinet for safety. If you use a solid state relay, it should be mounted on a metal surface for proper heatsinking. For instance, our A95 relay may be operated with a load up to 4Amp at room temperature with no heatsink. For operation at elevated temperatures or for load currents over 4 Amp, the relay needs to be heat sunk to a large metal surface, and a good size electrical cabinet should provide ample surface for that.

To provide heatsinking for the relay, it must be mounted on a bare metal surface. If necessary, an aluminum plate can be installed in the cabinet to provide bare metal for heatsinking. Before screwing the relay to the heatsink surface, spread a very thin layer of heatsink compound on the metal relay base to transfer the heat to the heatsink.

CAUTION: Installer is responsible to ensure that proper heatsinking is provided. Warranty does not cover damage to relay which might result from improper installation.

Application #1: Runway Light Operation. To allow pilot control of runway lights (PCL), the three output transistors are turned on by clicking the microphone button in the aircraft, as explained later under Operation. Three clicks in five seconds turns on Output A, five clicks turns on Output B, and seven clicks turns on Output C. Only one can be on at one time. The outputs can be used to control relays to turn on the ac power for the lights. Think about how you want the lights to operate before wiring the outputs. There are ways to provide different options, depending on the wiring. The three outputs can be used to control relays for three levels of lighting. If you use fewer levels of lighting, any relays not wired will allow someone to turn off the lights. Therefore, you may want to parallel unused outputs with others to limit the options the pilot has and perhaps prevent undesired consequences, such as locking the lights off for 15 minutes or turning off the lights accidentally. See more information in Operation section.

Figure 3 shows two ways to turn on large ac loads with the receiver. The preferred method is to use a modern solid state relay which can be controlled with a small dc current and switch large ac loads. Solid state relays can be obtained from Hamtronics as an accessory. Figure 3A shows how to wire a solid state relay, with the negative side of the control input switched by the output of the receiver.

The older method of switching large loads is to use a small dc relay to turn on a large ac power contactor. This method is shown in figure 3B. Make sure that the smaller relay can be operated with less than 50mA of current, and be sure to place a reverse polarity diode across the coil to prevent inductive kickback from damaging the receiver. This diode can be almost any type, including 1N4148, 1N914, 1N4001.

Application #2: ELT Detection. In the ELT mode, Output A and Output B are normally off, and Output C is normally on. This gives you two

Table 2. Power, Audio, and Control Connections		
Function	Module Pin	DB9 Pin
Ground	screws	6&7
+12Vdc	E3	1&2
Speaker	E2	8
Output A	E4	3
Output B	E5	4
Output C	E6	5

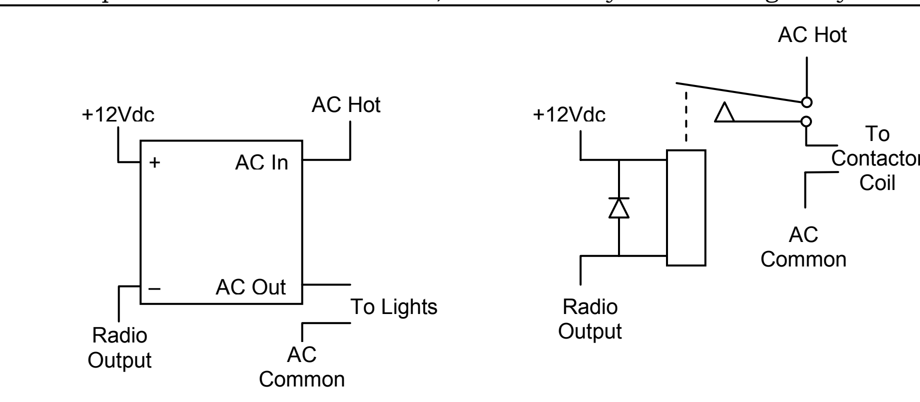


Figure 3A. Solid State Relay Wiring.

Figure 3B. Small Relay Switching Power Contactor.

outputs to use to turn on something if a downed aircraft is detected. Output C turns off upon detection of an ELT signal, allowing it to be used for muting the audio until detection occurs. There may also be other applications. Here are several ideas for how to use these outputs.

Output A or B can be used to trip some sort of alarm when a downed aircraft is detected. It can also be used in conjunction with one of our REP-200 Repeaters to set off the alarm tones on the repeater and notify hams in a search and rescue squad, for instance. Any alarm circuit can be tripped by sinking current to ground within the limits outlined earlier.

The R121 Receiver normally is muted when no signal is present and unsquelched when a signal is on the air. However, you may have an application where you don't want to listen to any signal until an ELT has been on the air long enough to signify an alert. In such a case, you can wire Output C to the input of the Volume control (right hand lug) with a short hookup wire to mute the audio until the alarm is tripped. If you want to monitor sometimes and not wait for an alert, you can install a switch inline with this wire to the Volume control so it only grounds the Volume control when you want that feature in effect.

Some customers have expressed the desired to link the audio from the R121 to one of our repeaters so they can hear the ELT signal on the repeater. To do that, simply install the muting wire from Output C to the Volume control as previously described, and then wire the speaker output of the R121 to the auxiliary audio input on the control board of the repeater. With Output A or B connected to the auxiliary COS input of the repeater controller and the audio connection just described, the R121 will key up the repeater and allow you to hear the ELT on the repeater after the alert occurs. If you provide this type of operation, you should also provide a way to reset the R121 remotely so the repeater doesn't stay on the air until it times out.

Reset Provisions.

In some installations, it may be desirable to reset the microcontroller used for PCL and ELT operation. For instance, you might want to have a switch on the unit to turn off runway lights manually or you might want to reset the ELT alarm manually. In such a case, simply wire a pushbutton switch from ground to External Reset terminal E7 on the pc board. When you press the button, it will cause the microcontroller to reboot from scratch and reset everything to the starting condition.

Any device which can generate a momentary ground (connected to ground plane on pc board) can be used to do the reset. For instance, a touch tone controller, like our TD-2, can be used to momentarily ground E7 to reset the micro. Such a setup would be handy if the R121 is connected to a repeater, and there probably are other cases where this feature would be useful.

OPERATION.

General.

The R121 has one microcontroller which is responsible for watching the squelch to determine what is happening on the air. It can be programmed to perform several different tasks in response. It can also be programmed for no special features so the receiver can be used just to monitor a channel, for example, at a small airport or at a pilot's home.

Basic operation is rather obvious. The Volume control, on the right side of the pc board, sets the listening level. The Squelch control, on the left, sets the threshold at which signals will be heard and quiets background noise in between transmissions. The LED is used to indicate various conditions as explained for each mode below.

Mode Switch.

Seven position dip switch S2 is used to program the microcontroller which provides special features. In the discussion below, "1" indicates that a particular switch is ON or closed and "0" indicates that a switch is OFF or open.

Positions 1 and 2 set the mode of operation. The four possible modes are as follows:

0 0 = monitor mode
0 1 = test mode
1 0 = ELT mode
1 1 = PCL mode

Position 3 is set to allow an option in the basic operation as follows:

In ELT mode, turning on this switch allows the ELT alarm to automatically reset.

In PCL mode, turning on this switch allows changes to be made by the pilot after initially turning on lights.

Position 4 is an optional setting for the PCL mode. It controls how the output responds during the last minute runway lights are on. (It has no function for other modes, such as ELT mode.) If switch position 4 is turned on, the runway lights will flash during the last minute they are on to warn pilots that the lights are about to go out. If the switch is off, no flashing will occur; lights will simply turn off at the end of the timer period.

Positions 5 through 7 set the time delay for ELT and PCL modes in 5 minute increments. The switches set a four digit binary number which, multiplied by 5, is the time delay in minutes. Following are example settings:

000 = 1 min	100 = 20 min
001 = 5 min	101 = 25 min
010 = 10 min	110 = 30 min
011 = 15 min	111 = 35 min

Note that 000 sets it for one minute, an exception, handy for testing.

Monitor Mode.

To use the receiver as a basic monitor receiver without the ELT or PCL modes, turn off switch sections 1 and 2. This tells the microcontroller to turn off, thus saving power.

Test Mode.

Turning on switch section 2 with section 1 turned off sets the microcontroller for a special test mode in which the LED blinks on and off one cycle every two seconds. This allows a technician to check the controller clock accuracy, as there should be about 30 flashes per minute. Note that the controller clock is not as precise as a regular clock; so there may be a small variation in timing. This is normal. The purpose of the test is simply to see if the controller is running properly and that the clock is roughly accurate. The blinking will stop if the squelch is opened.

Pilot Control of Lighting.

In the PCL mode, if a pilot clicks his push-to-talk button three, five, or seven times within five seconds, runway lights can be activated with Outputs A, B, and C, respectively. Depending on wiring, this can turn on runway lights at up to 3 intensity levels.

As explained earlier, programming the dip switch for PCL mode requires that switch sections 1 and 2 both be turned on. Switch position 3 allows for the option of letting the pilot make a change in settings once the lights are initially activated. Once the lights are activated, they will stay on for the length of time programmed with switch sections 5 through 7. Note that the timing system isn't precise; so if the time is too short, simply increase the setting until you get the about the length of time you want. Position 4 controls whether or not the lights flash during the final minute as a warning that they are about to go out.

When you install the system, carefully plan how you want the lights to respond to any possible condition. With the proper combination of programming and wiring the outputs to relays, you can make the lighting system operate smoothly and safely. Following are factors to be considered.

Your system may have only one or two intensities. Any outputs which are not wired to one of the relays controlling the lights allows the pilot to turn off the lights. This may be undesirable from a safety standpoint, especially considering that someone may send the required command unintentionally, perhaps even someone trying to access lights at another nearby airport. Sending one of the three commands overrides the other two commands. You can prevent turnoff simply by wiring any unused outputs in parallel with another output so that accidental commands will turn on the lights.

The receiver has the option of allowing changes to the command after an initial command is executed. If the switch is on, subsequent commands will be carried out, otherwise, they will be ignored until the time delay is completed for turning off the lights. Allowing changes may be good, depending on the way the relays are wired. If you are sure there is no way to turn the lights off altogether, it allows a pilot to correct an erroneous command or to increase or decrease the intensity. If you do not allow changes and someone, even unintentionally, sends a command, they cannot carry out another command for 15 minutes or whatever the time delay is set for.

The red LED on the front of the receiver will illuminate anytime a command is in effect, that is, whenever one of the outputs is activated.

If you wish to have a way to turn off the lights manually, you can use a reset switch, as explained in the Installation section. Resetting the controller effectively starts everything from scratch with the lights off.

Turning the power to the receiver off momentarily will also reset the controller. Therefore, consider the safety aspect of providing backup power for your runway lighting system to prevent lights from being turned off by a momentary power outage. A simple way to prevent the receiver from losing power is to operate it from a battery with a trickle charger.

ELT Detection.

In ELT mode, if a signal is received and keeps the squelch open for a continuous period of time longer than the programmed delay, the ELT alarm will be tripped. The alarm causes Outputs A and B to be turned on and Output C to be turned off. There are many ways to use these output transistors to trigger an external alarm, activate a repeater, unmute the audio, etc., as discussed in the Installation section.

As explained earlier, programming the dip switch for ELT mode requires that switch section 1 be turned on and section 2 be turned off.

Switch sections 5 through 7 set the time delay required for triggering the alarm. In order for the alarm to be tripped, the squelch must remain open during the entire time delay you set. Since ELT testing is allowed by the FAA for periods not to exceed 5 minutes, the minimum practical setting for the delay time is 10 minutes.

If the signal disappears or gets weak enough for the squelch to close, the detector will be reset with the timer starting over. Therefore, setting the squelch threshold with the Squelch control determines how weak a signal you want to be able to trip the alarm.

Turning on switch section 3 provides the option of automatically resetting the ELT alarm if the carrier later goes off the air. If section 3 is turned off, the alarm condition remains in effect until the manual reset switch is operated or power to the receiver is turned off and on again. It is considered desirable to have a manual reset switch even if you allow automatic reset. The reset can even be done remotely by touch tone command, as explained in the Installation section.

The red LED on the front of the receiver will illuminate anytime an ELT alarm has occurred, and it remains on until the alarm circuit is reset.

Signal Strength Indicator.

The R121 Receiver has the capability of driving an external signal strength meter, as explained in the Installation section. By using the receiver in a portable setup with an S-meter, the R121 can be used to help find downed aircraft. Therefore, it may be desirable to have more than one receiver, including one set up as a permanent alarm monitor and others used to hunt.

FREQUENCY ADJUSTMENTS.

Opening Case.

If your receiver was supplied factory installed in a cabinet, remove the four screws on the ***side*** of the cabinet, and lift off the cover.

General Procedure.

The channel frequency is determined by frequency synthesizer circuits, which use dip switch S1 in conjunction with programming in microcontroller U1 to set the channel. The microcontroller reads the dip switch information and does mathematics, applying serial data to the synthesizer ic whenever power is applied. Following is a discussion of how to set the dip switch to the desired channel frequency.

☞ **NOTE:** *If the frequency is changed more than about 1 MHz, a complete alignment of the receiver should be performed, as described in later text. Optimum operation only occurs if the synthesizer is adjusted to match the frequency switch setting and all the tuned amplifier circuits are peaked for the desired frequency.*

To determine what channel frequency to use, the microcontroller adds the frequency information from the dip switch to the 118 MHz "base" frequency.

Dip switch settings are binary, which means each switch section has a different weighting, twice as great as the next lower section. Sections have weights such as 25 kHz, 50 kHz, etc., all the way up to 12.800 MHz. *(See Table 3 or the schematic diagram for switch values. Also see the shortcuts and tricks which follow this discussion.)*

The system sounds cumbersome, but it really is fairly simple, and you don't need to do this frequently. A piece of paper or a small calculator is handy to aid in determining which sections of the switch to turn on. When done, you might want to record the switch settings in table 4 for future reference.

Begin by subtracting the base frequency, 118.000, from the desired frequency to determine the total value of all the switch sections required to be turned on.

If the difference is greater than 12.800 MHz, turn on switch #1, and subtract 12.800 from the difference frequency to determine the remainder. Otherwise, turn off switch #1.

Do the same for each of the other sections, from highest to lowest weighting, in sequence. Each time you consider the remainder, turn on the switch section with the highest weighting which will fit within the remainder without exceeding it. Each time it is found necessary to turn on a switch section, subtract the value of that section from the remainder to get the new remainder.

As an example, let us consider how to set the receiver for 127.325 MHz. The following discussion is broken down into steps so you can visualize the process easier.

a. 127.325 - 118.000 base freq. = 9.325 MHz remainder. Turn on switch #2, which represents the largest increment to fit remainder. Turn off switch #1 because its value is larger than 9.325.

b. 9.325 - 6.400 value of switch #2 = 2.925 MHz. Turn off switch #3, which is too large a value. Turn on #4, which is 1.600 MHz, the largest increment to fit the remainder.

c. 2.925 - 1.600 = 1.325 MHz remainder. Turn on switch #5, which has a value of 0.800 MHz (800 kHz).

d. 1.325 - 0.800 = 0.525 MHz (525 kHz) remainder. Turn on switch #6, which has a value of 400 kHz.

e. 525 - 400 = 125 kHz remainder. Now it is easy. Looking at the weightings of the switches, you can see that turning on switches 8 and 10 gives 125 kHz. Turn off switches 7 and 9, which are not needed.

f. When we finished, we had turned on switch sections 2, 4, 5, 6, 8, and 10. We turned off all the others. This can also be expressed as the binary number 0101110101.

Note: Dip switch information is read by the synthesizer only when power is first applied. If switch settings are changed, turn the power off and on again.

Shortcut.

If you have access to the internet, our website has a long table of numbers which gives the equivalent binary number settings for every possible frequency. We couldn't print it here because it takes many printed pages of space. Surf to our website at www.hamtronics.com and look for Dip Switch Freq Programming for R121 Aviation Rcvr near the bottom of the Table of Contents.

Look up the frequency, and it will give you all the binary switch settings. The address is case sensitive, and you must enter the address carefully, exactly as shown.

Table 3. Frequency Settings

Device	Frequency Weight
Switch #1	12.800 MHz
Switch #2	6.400 MHz
Switch #3	3.200 MHz
Switch #4	1.600 MHz
Switch #5	800 kHz
Switch #6	400 kHz
Switch #7	200 kHz
Switch #8	100 kHz
Switch #9	50 kHz
Switch #10	25 kHz

Another Trick.

If you have a computer, but no internet access, you can use the calculator program to quickly determine the binary settings for the dip switch. Use this procedure.

a. Start the calculator program, by going to Run under the Start menu, and type CALC.EXE.

b. In the calculator menu, select View - Scientific.

c. Enter the frequency you want to operate on, example 127.325.

d. Subtract the base frequency of 118.000, which gives a remainder of 9.325 MHz in our example.

e. Divide by 25 because the receiver tunes in 25 kHz increments. This gives the answer 0.373 MHz.

f. Multiply by 1000 to convert to kHz. This gives you 373 in our example.

g. Convert this decimal number to binary by clicking on BIN on the toolbar. This reads out as "101110101".

h. The calculator drops any leading zeros. However, we need a ten digit binary number; so add leading zeros (left side of number) to make a total of ten digits. In this case, add one zero to make it "0101110101". This is the binary number to set in the switches. One = ON and zero = OFF.

ALIGNMENT.

General Information.

Following are three alignment procedures. The first is alignment of the frequency synthesizer and receiver front end (rf amplifier and mixer). This must be done whenever the channel frequency is changed by more than 1 MHz. The R121 is a high performance receiver and is designed to be very selective. Therefore, retuning is necessary for optimum performance. The second procedure is alignment of the i-f stages, which normally is only necessary if some parts are replaced. The third procedure is trimming the crystal oscillator to exact frequency, which should be done once each year or two to compensate for crystal aging.

Equipment Needed.

Equipment needed for alignment is a sensitive dc voltmeter and a stable and accurate signal generator for the channel frequency. To adjust the crystal oscillator, a frequency counter is required.

The slug tuned coils in the receiver should be adjusted with the proper .062" square tuning tool to avoid cracking the powdered iron slugs. Variable capacitors and i-f transformers should be adjusted with a plastic tool having a small metal bit. (See A28 and A2 tools in catalog.)

Opening Case.

If your receiver was supplied factory installed in a cabinet, remove the four screws on the ***side*** of the cabinet, and lift off the cover.

Channel Frequency Alignment.

Alignment is needed whenever the frequency is changed by more than about 1 MHz. Alignment ensures that the frequency synthesizer is optimized at the center of the vco range and that all stages are tuned to resonance.

a. Set dip switches for desired frequency.

b. Set the SQUELCH control fully counterclockwise and the VOLUME control just a little clockwise.

c. Connect speaker and power. You should hear white noise.

d. Connect voltmeter to V-tune test point TP1 (top lead of R6). Adjust vco coil L1 for +4Vdc. (Although the vco will operate over a wide range of tuning voltages from about 1V to 7V, operation is optimum if the vco is adjusted to 4V.)

e. Connect voltmeter to buffer TP2 (top lead of R16). Adjust buffer coil L3 for a peak, typically about +0.5V to +0.9V.

f. Connect an accurate signal generator to J1 using a coax cable with RCA plug. Adjust signal generator to exact channel frequency, and turn output level up fairly high (about 1000µV).

g. Connect voltmeter to AGC TP4 (top lead of R30).

h. Adjust L4, L5, L6, L7, and L8 for minimum voltage. (Voltage goes down, not up, with increased signal level.)

Alignment of I-F Stages.

a. Connect an accurate signal generator to test point TP3 (top lead of R19), using coax cable with clip leads.

b. Connect voltmeter to AGC TP4

Table 4. My Switch Settings

Frequency:________________________ MHz

Switch Sections Turned On: (circle)

1 2 3 4 5 6 7 8 9 10

(top lead of R30).

c. Set generator to exactly 10.695 MHz. Use a frequency counter or a synthesized signal generator. Set level just high enough to reduce the meter reading to about 3Vdc (about 200µV).

d. Adjust T1, T2, and T3 for minimum dc voltage. Note that the transformers are fairly close from the factory and usually only require less than 1 turn in either direction.

☛ *Be careful not to turn the slug tight against either the top or bottom because the winding of the transformer can be broken.*

Oscillator Trimming.

Once each year, the crystal oscillator should be checked and adjusted back on frequency. Crystals normally age a little every year, with most of the aging change occurring in the first year.

To make this adjustment, connect an accurate frequency counter to TP3 with a coax cable clip lead, and adjust C6 with an insulated tool (like our model A2 tool). The frequency should be 10.695 MHz above the channel frequency.

The adjustment can theoretically also be done by monitoring the 10.240 oscillator frequency, but it is difficult to pick up the signal from the oscillator without loading the oscillator down. Monitoring at TP3 provides buffering and allows finer resolution because it is at the higher frequency.

THEORY OF OPERATION.

The R121 is a frequency synthesized vhf am receiver. Refer to the schematic diagram for the following discussion.

Low noise dual-gate mos fet's are used for the RF amplifier and mixer stages. The output of first mixer Q5 Is coupled through 10.695 MHz transformer T1 to the second mixer.

U4 provides IF amplification, a 2nd mixer to convert to 455 kHz, a detector, if agc, rf agc and squelch. Ceramic filters FL1 and FL2 provides adjacent channel selectivity at 455 kHz. T2 and T3 provide impedance matching for the filters. U4c is an envelope detector. It also provides agc for the if stages within U4 and delayed rf agc for gate2 of Q4. TP4 allows monitoring of the agc voltage as an indication of signal strength to use for alignment. U4c pin 12 provides a current source to drive an external S-meter based on the agc signal level.

Detected audio is applied through volume control R31 to audio amplifier U6. Squelch transistor Q8 mutes this audio when no signal is present. Q8 is driven through squelch amplifiers U4d and Q7. Squelch control R34 sets the threshold at which the squelch opens. C57 provides a slight delay to eliminate switching clicks when the audio is turned on and off.

The injection frequency for the first mixer is generated by vco (voltage controlled oscillator) Q1. The injection frequency is 10.695 MHz above the receive channel frequency. The output of the vco is buffered by Q2 to minimize effects of loading and voltage variations of following stages from modulating the carrier frequency. The buffer output is applied through a double tuned circuit to gate 2 of mixer Q5.

The frequency of the vco stage is controlled by phase locked loop synthesizer U2. A sample of the vco output is applied through the buffer stage and R1 to a prescaler in U2. The prescaler and other dividers in the synthesizer divide the sample down to 5kHz.

A reference frequency of 10.240 MHz is generated by a crystal oscillator. The reference is divided down to 5 kHz.

The two 5kHz signals are compared to determine what error exists between them. The result is a slowly varying dc tuning voltage used to phase lock the vco precisely onto the desired channel frequency.

The tuning voltage is applied to carrier tune varactor diode D1, which varies its capacitance to tune the tank circuit formed by L1/C20/C21. C16 limits the tuning range of D1. The tuning voltage is applied to D1 through a third order low pass loop filter, which removes the 5kHz reference frequency from the tuning voltage to avoid whine.

Serial data to indicate the desired channel frequency and other operational characteristics of the synthesizer are applied to synthesizer U2 by microcontroller U1. Everything the synthesizer ic needs to know about the band, division schemes, reference frequency, and oscillator options is generated by the controller. Information about the base frequency of the band the receiver is to operate on and the channel within that band is calculated in the controller based on information programmed in the eprom on the controller and on channel settings done on dip switch S1. Whenever the microcontroller boots at power up, the microcontroller sends several bytes of serial data to the synthesizer, using the data, clock, and /enable lines running between the two ic's.

Some of the 10.240MHz signal generated in U2 is used for the injection to second mixer U4a. Q9 provides buffering for this injection signal.

Microcontroller U5 provides the intelligence to control runway lights and detect downed aircraft ELT signals. It senses squelch openings at interrupt pin 19, and its three outputs drive switching transistors Q10, Q11, and Q12. These transistors are capable of driving external relays and may be used in other ways as described in the Installation section. Care must be used to avoid reverse polarity, over-voltage, and transients, all which can damage the transistors.

+13.6Vdc power for the receiver is applied at E3. Audio output amplifier U6 is powered directly by the +13.6Vdc. All the other stages are powered through voltage regulators for stability and to eliminate noise. U3 is an 8Vdc regulator to power if amplifier U4, RF amplifier Q4, mixer Q5, and the vco, buffer, and phase detector in the synthesizer. Additional filtering for the vco and buffer stages is provided by capacitance amplifier Q3, which uses the characteristics of an emitter follower to provide a very stiff supply, eliminating any possible noise on the power supply line. Q6 provides a stiff +5Vdc supply for the frequency synthesizer and microcontrollers, which are low current CMOS devices.

TROUBLESHOOTING.

General.

The usual troubleshooting techniques of checking dc voltages and signal tracing with an RF voltmeter probe and oscilloscope will work well in troubleshooting the R121. DC voltage charts and a list of typical audio levels are given to act as a guide to troubleshooting. Although voltages may vary widely from set to set and under various operating and measurement conditions, the indications may be helpful when used in a logical troubleshooting procedure.

Current Drain.

Power line current drain normally is about 75 mA with volume turned down or squelched and up to 200 mA with full audio output.

If the current drain is approximately 100 mA with no audio output, check to see if voltage regulator U3 is hot. If so, and the voltage on the 8V line is low, there is a short circuit on the +8Vdc line somewhere. U3 limits the short circuit current to 100mA to protect the receiver from damage. If you clear the short circuit, the voltage should rise again. U3 should not be damaged by short circuits on its output line; however, it may be damaged by reverse voltage or high transient voltages.

A good way to isolate short circuits and other overloads on the 8V or 5V lines is to disconnect components in series with the path, for instance, ferrite beads or Q6. With so many things connected to the B+ lines, it is difficult to find the problem without eliminating large portions of the load that way.

Audio Output Stage.

Note that audio output ic U6 is designed to be heatsunk to the pc board through the many ground pins on the ic. When running moderately low audio levels as most applications require, it is no problem to use an ic socket; so we have provided one for your convenience. If you will be running high audio levels, check to see if the ic is getting hot. If so, you should remove the ic socket, and solder the LM-380N-8 ic directly to the board for better heatsinking.

If audio is present at the volume control but not at the speaker, the audio ic may have been damaged by reverse polarity or a transient on the B+ line. This is fairly common with lightning damage.

If no audio is present on the volume control, the squelch circuit may not be operating properly. Check the dc voltages on U4d, Q7, and Q8.

RF Signal Tracing.

If the receiver is completely dead, try a 10.695 MHz signal applied to TP-3 (the top lead of R19), using coax clip lead. Connect coax shield to pcb ground. Set level just high enough to get a change of agc voltage at TP4. At 10μV, you should notice some degree of change in agc voltage.

Also, check the 10.240 MHz oscillator with a scope or by listening with an hf receiver or service monitor.

A signal generator on the channel frequency can be injected at various points in the front end. If the mixer is more sensitive than the RF amplifier, the RF stage is suspect. Check the dc voltages looking for a damaged fet, which can occur due to transients or reverse polarity on the dc power line. Also, it is possible to have the input gate (gate 1) of the RF amplifier fet damaged by high static charges or high levels of RF on the antenna line, with no apparent change in dc voltages, since the input gate is normally at dc ground.

Synthesizer Circuits.

Following is a checklist of things to look for if the synthesizer is suspected of not performing properly.

a. Check the output frequency of the vco buffer with a frequency counter. It should be 10.695 MHz above the channel frequency.

b. Check tuning voltage at TP1. It should be about +4Vdc. Actual range over which the unit will operate is about +1Vdc to just under +8Vdc. However, for optimum results, the vco should be tuned to allow operation at about +4Vdc center voltage.

c. Check the operating voltage and bias on the vco and buffer.

d. Check the 10.240 MHz oscillator at pin 1 of the synthesizer ic (actually best to check at lead of R3; avoid trying to probe surface mount ic leads which are close together). A scope should show strong signal (several volts p-p) at 10.240 MHz.

e. Check the oscillator at pin 1 of microcontroller ic U1 with a scope. There should be a strong ac signal (several volts p-p) at the oscillator frequency.

f. The data, clock, and /enable lines between the microcontroller and synthesizer ic's should show very brief and very fast activity, sending data to the synthesizer ic shortly after the power is first applied or a dip switch setting is changed. Because this happens very fast, it can be difficult to see on a scope. Use 100μSec/div, 5Vdc/div, and NORMAL trigger.

g. Check the microcontroller to see that its /reset line is held low momentarily when the power is first applied. C1 works in conjunction with an internal resistor and diode in the ic to make C1 charge relatively slowly when the power is applied. It should take about a second to charge up.

h. Check the switch settings to be sure you have the correct frequency information going to the microcontroller. Check each of the output lines of the switch to verify that the voltage actually is present.

i. If you have a scope or spectrum analyzer, you can check the output pin of the divide by 64 prescaler at pin 13 of U2. There should be a strong signal (several volts p-p) at about 2 MHz. If this signal is absent, there may not be sufficient level of sample signal from the buffer at U2 pin 11. *Be careful not to short adjacent pins of the ic.*

Microphonics, Hum, and Noise.

The vco and loop filter are very sensitive to hum and noise pickup from magnetic and electrical sources. Some designs use a shielded compartment for vco's. We assume the whole board will be installed in a shielded enclosure; so we elected to keep the size small by not using a separate shield on the vco. However, this means that you must use care to keep wiring away from the vco circuit at the right side of the board. Having the board in a metal enclosure will shield these sensitive circuits from florescent lights and other strong sources of noise.

Because the frequency of a synthesizer basically results from a free running L-C oscillator, the tank circuit, especially L1, is very sensitive to microphonics from mechanical noise coupled to the coil. You should minimize any sources of vibration which might be coupled to the receiver, such as motors. In addition, it helps greatly to prevent the molded coil from vibrating with respect to the shield can. Both the coil and can are soldered to the board at the bottom, but the top of the coil can move relative to the can and therefore cause slight changes in inductance which show up as frequency modulation. Securing the top of the plastic coil form to the shield can with some type of cement or nail polish greatly reduces the microphonic effects. This practice is recommended in any installation where vibration is a problem, and the factory normally cements this coil for that reason.

Excessive noise on the dc power supply which operates the receiver can cause noise to modulate the synthesizer output. Various regulators and filters in the receiver are designed to minimize sensitivity to wiring noise. However, in extreme cases, such as in mobile installations with alternator whine, you may need to add extra filtering in the power line to prevent the noise from reaching the receiver.

Other usual practices for mobile installations are recommended, such as connecting the + power and ground return lines directly to the battery instead of using cigarette lighter sockets or dash board wiring.

To varying degrees, whine from the 5kHz reference frequency may be heard on the signal under various circumstances. If the tuning voltage required to tune the vco on frequency is very high or low, near one extreme, the whine may be heard. This can also happen even when the tuning voltage is properly near the 4Vdc center if there is dc loading on the loop filter. Any current loading, no matter how small, on the loop filter causes the charge pump in the phase detector to pump harder to maintain the tuning voltage. The result is whine on the signal. Such loading can be caused by connecting a voltmeter to TP1 for testing, and it can also be caused by moisture on the loop filter components.

Phase noise is a type of white noise which phase locked loop synthesizers produce. Many efforts are made during the design of the equipment to reduce it as much as possible. The phase noise in this unit should be almost as good as a crystal oscillator radio. If you notice excessive white noise even though the signal is strong, it may be caused by a noisy vco transistor, Q1. Try swapping with the buffer transistor, Q2, which is the same type and see if that helps. When using a replacement transistor for repairs, be sure to use one of good quality.

If you suspect noise is being introduced in the synthesizer, as opposed to the signal path from the antenna to the detector, you can listen to the injection signal at 10.695 MHz above the channel frequency on a receiver or service monitor and hear what just the injection signal sounds like. Put a pickup lead on top of the receiver board so you have a strong sample to hear so you are sure the noise is not due to weak signal pickup at the test receiver.

Typical Dc Voltages.

Tables 4-6 give dc levels measured with a sensitive dc voltmeter on a sample unit with 13.6 Vdc B+ applied. All voltages may vary considerably without necessarily indicating trouble. The charts should be used with a logical troubleshooting plan. All voltages are positive with respect to ground except as indicated.

Use caution when measuring voltages on the surface mount ic. The pins are close together, and it is easy to short pins together and damage the ic. We recommend trying to connect meter to a nearby component connected to the pin under question. Also, some pins are not used in this design, and you can generally not be concerned with making measurements on them.

Note: On the schematic diagram, these symbols indicate logic levels:

‾|_|‾ indicates active lo (0V in stated condition)

_|‾|_ indicates active hi (5V in stated condition)

Typical Audio Levels.

Table 7 gives rough measurements of audio levels. Measurements were taken using an oscilloscope, with no input signal, just white noise (squelch open) so conditions can be reproduced easily.

REPAIRS.

If you need to unsolder and replace any components, be careful not to damage the plated through holes on the pc board. Do not drill out any holes. If you need to remove solder, use a solder sucker or solder wick. A toothpick or dental probe can be used with care to open up a hole.

If you need to replace surface mount ic U2, first be very sure it is damaged. Then, carefully cut each lead off the case with fine nose cutters. Once the case is removed, individual leads can be unsoldered and the board can be cleaned up. Carefully position the new ic, and tack solder the two opposite corner leads before any other leads are soldered. This allows you to melt the solder and reposition the ic if necessary. Once you are sure, the remaining leads can be soldered. If you get a solder short between leads, use a solder sucker or solder wick to remove the excess solder.

Table 4. Typical Test Point Voltages

TP1		Tuning V. Normally set at 4V
TP2	Buffer	approx. 0.8V
TP3	Test Input	(No reading)
TP4	AGC	Varies from about 4.5V with no signal to 0.2V with strong signal (~3000µV)

Table 5. Typical Xstr DC Voltages

Xstr	Stage	E(S)	B(G1)	C(D)	G2
Q1	vco	1.5	2.0	7.0	-
Q2	buffer	0	0.75	4.5	-
Q3	dc filter	6.8	7.4	7.6	-
Q4	RF ampl	0	0	8	3.5
Q5	Mixer	0	0	8	0
Q6	5V regul.	5	5.6	8	-
Q7	sq open	0	0.67	0.15	-
	sq closed	0	0.03	5	-
Q8	sq open	0	0.14	0	-
	sq closed	0	0.66	0.01	-
Q9	Buffer	0	0.7	3.3	-
Q10-Q12	on	0	0.7	*	-
	off	0	0	*	-

* depends on circuit being switched

Table 6. Typical IC DC Voltages

U1-1	2.3	U1-20	5
U1-2	2.3		
U2-1	2.2	U2-10	2.6
U2-2	5V locked,	U2-11	2.6
	2.5V unlocked	U2-12	5
U2-3	8 *	U2-13	3 .2*
U2-4	8 *	U2-14	5
U2-5	8	U2-15	*
U2-6	0-8 (4V tuned)	U2-16	*
U2-7	0	U2-17	5
U2-8	4.5	U2-18	0
U2-9	5 *	U2-19	5
* = pin not used		U2-20	2
U4-1:	0.86	U4-11:	0.64
U4-2:	1.4	U4-12:	0.2 (no meter connected)
U4-3:	5.4		
U4-4:	0.68	U4-13:	4.5
U4-5:	0	U4-14:	
U4-6:	5.5	sq open	0.72
U4-7:	1.4	sq closed	0.85
U4-8:	1.4	U4-15:	
U4-9:	0.77	fully open	3.2
U4-10:	5.6	fully closed	0
U5-1	2.3	U5-20	5
U5-2	2.3		
U6-1:	0	U6-5:	0
U6-2:	0	U6-6:	6
U6-3:	0	U6-7:	13.6
U6-4:	0	U6-8:	6.8

Table 7. Typical Audio Voltages

Audio Test Point	Normal Level
U4-9 Detector	100mV p-p
Top of Volume Control R31	75mV p-p
Speaker Out E2 with volume up full	up to 4V p-p

PARTS LIST.

Following are notes specific to certain parts.

❶ Microcontrollers must be factory programmed for each application, and they are not interchangeable.

❷ Resistors used as test point or external connection point. These must be installed on the board oriented properly and with the top loop an extra 1/6” high to allow for connections to the loop later. (See detail in component location diagram.)

❸ This part is surface mounted on rear of board.

💣 Caution: Ic’s and fet's are static sensitive. Use appropriate handling precautions to avoid damage.

Ref Desig	Description (marking)
C1-C2 ❸	0.1µf
C3	n/a
C4	1pf
C5 ❸	27pf
C6 ❸	11pf var cap (blue)
C7 ❸	27pf
C8 ❸	.001µf
C9 ❸	0.1µf
C10	0.15µf mylar (red)
C11	.01µf
C12 ❸	.001µf
C13 ❸	0.1µf
C14	10µf electrolytic
C15 ❸	0.1µf
C16 ❸	10pf
C17-C18❸	.001µf
C19	10µf electrolytic
C20 ❸	15pf
C21 ❸	68pf (1206 size)
C22 ❸	4pf
C23 ❸	.001µf
C24 ❸	30pf
C25	82pf
C26 ❸	2pf
C27 ❸	.001µf
C28 ❸	33pf
C29	82pf
C30 ❸	220pf
C31 ❸	27pf
C32	0.5pf
C33 ❸	27 pf
C34 ❸	0.5pf
C35 ❸	22pf
C36	4pf
C37 ❸	27pf
C38	82pf
C39 ❸	4pf
C40	.01µf
C41 ❸	.001µf
C42	.01µf
C43	1µf electrolytic
C44	100µf electrolytic
C45	not used
C46	220µf electrolytic
C47-C49❸	0.1µf
C50	10µf electrolytic
C51	100µf electrolytic
C52	10µf electrolytic
C53	100µf electrolytic
C54	10µf electrolytic
C55	.01µf
C56	0.15µf mylar (red)
C57	1µf electrolytic
C58 ❸	47pf
C59	.01µf
C60-C61	1µf electrolytic
D1	BB809 varactor diode
D2	1N4148 switching diode
D3	mini red LED
FL1-FL2	455kHz ceramic filter, type "E"
J1	RCA jack
L1	2½ turn slug-tuned coil (red)
L2	0.33µH RF choke (red-sil-orn-orn)
L3-L8	2½ turn slug-tuned coil (red)
L9	0.33µH RF choke (red-sil-orn-orn)
Q1-Q2	2N5770
Q3	2N3904
Q4-Q5 💣	3SK122 MOS FET
Q6	2N3904
Q7-Q9	2N5770
Q10-Q12	2N3904
R1	100Ω
R2 ❸	2.2K
R3	10meg
R4 ❸	47K
R5 ❸	15K
R6 ❷	100K
R7 ❸	510K
R8 ❸	2.2K
R9 ❸	10K
R10 ❸	6.8K
R11 ❸	3.9K
R12 ❸	180Ω
R13	47Ω
R14 ❸	47K
R15 ❸	470Ω
R16 ❷	3.9meg
R17 ❸	100K
R18	27K
R19 ❷	47K
R20 ❸	2.2K
R21 ❸	270Ω
R22 ❸	2.2K
R23 ❸	4.7K
R24 ❸	2meg
R25	100Ω
R26 ❸	27Ω
R27	100Ω
R28 ❸	n/a
R29	270Ω
R30 ❷	15K
R31	100K VOLUME
R32-R33	47K
R34	100K SQUELCH
R35 ❸	27K
R36	15K
R37 ❸	6.8K
R38	8.2K
R39 ❸	100K
R40 ❸	100Ω
R41 ❸	470Ω
R42-R44❸	4.7K
R45 ❸	470Ω
S1	10 pos. dip switch
S2	7 pos. dip switch
T1	10.7MHz IF xfmr (7A-691F)
T2-T3	455kHz IF xfmr (T1003 or RLC-352)
U1 💣❶	MC68HC705J1A µP
U2 💣	MC145190F synthesizer
U3	78L08 regulator
U4 💣	CA3088 i-f ampl detector
U5 💣❶	MC68HC705J1A µP
U6	LM380N-8 af output
Y1	10.240 MHz crystal
Z1-Z3	Ferrite bead, prestrung

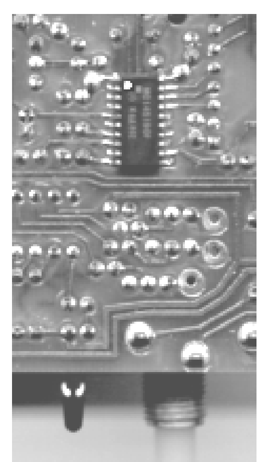
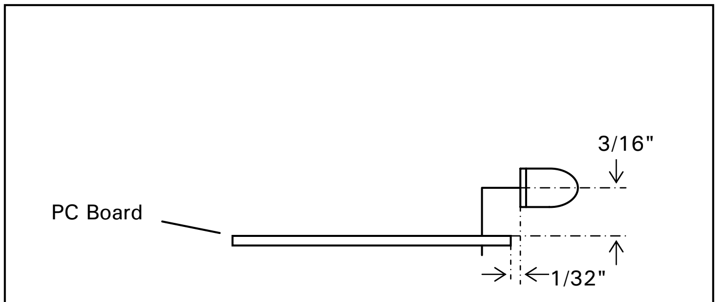


Figure 4. Placement of U2 Under PC Board.
Note that dot on ic goes toward rear of the board.



Detail of LED Installation

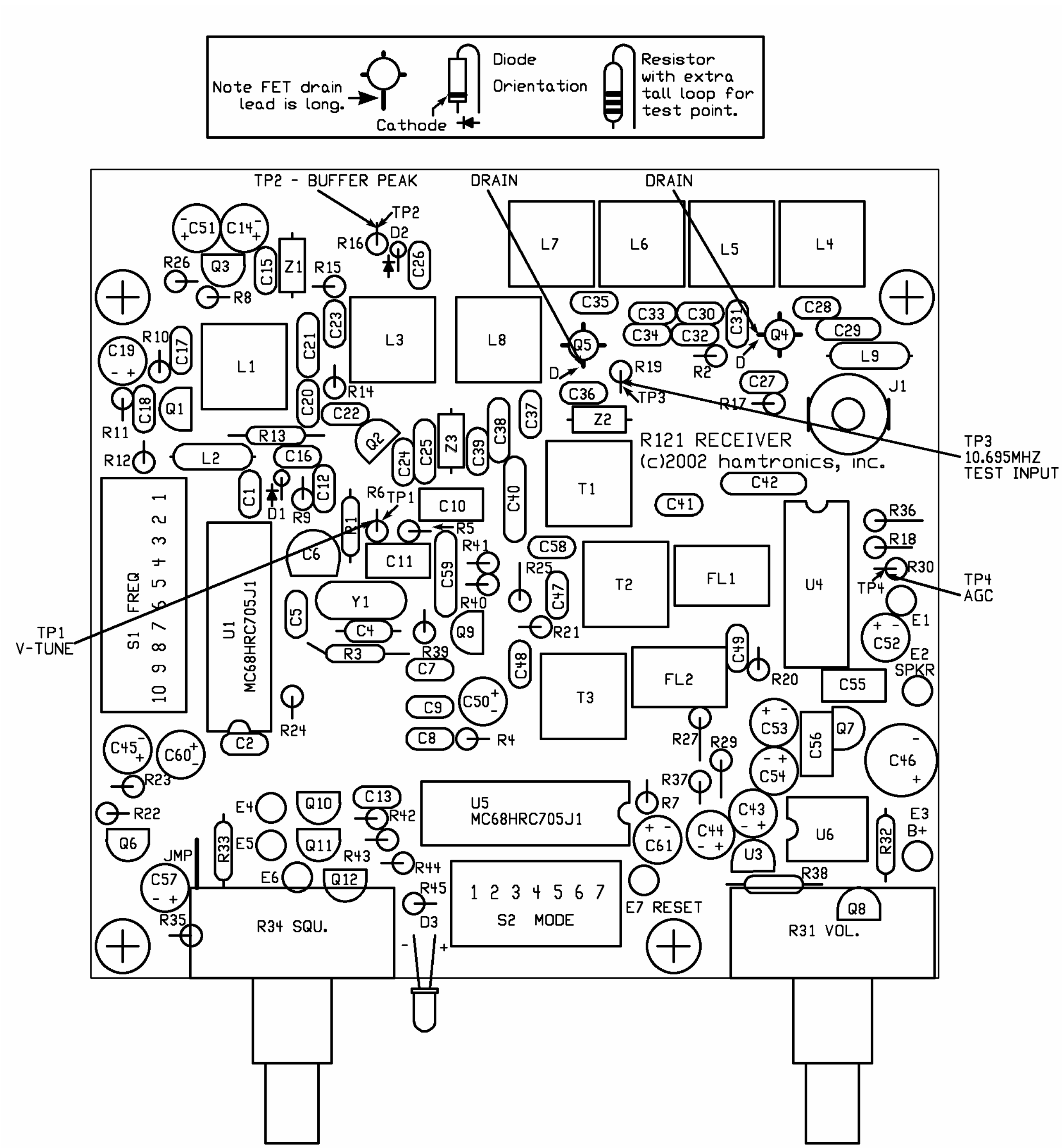


Figure 2. R121 VHF Aircraft Receiver, Component Locations

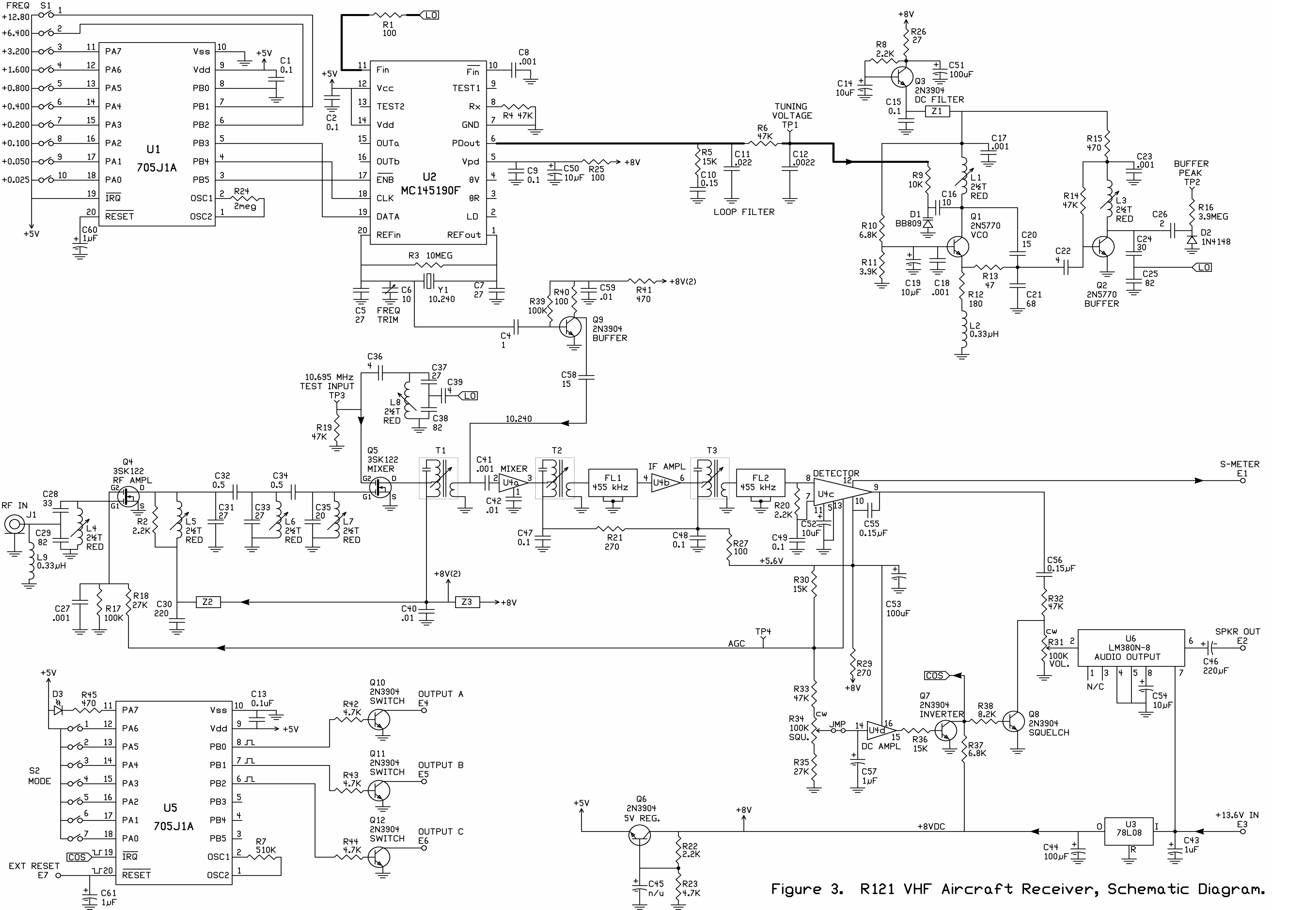


Figure 3. R121 VHF Aircraft Receiver, Schematic Diagram.