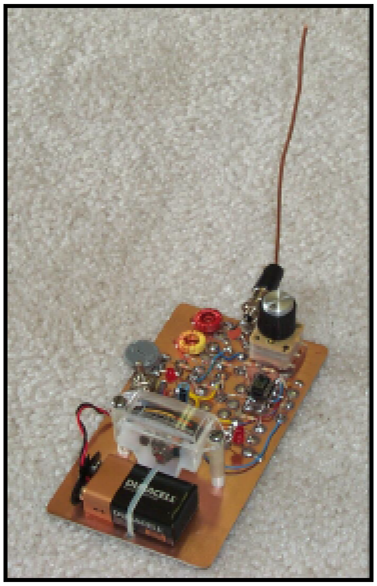
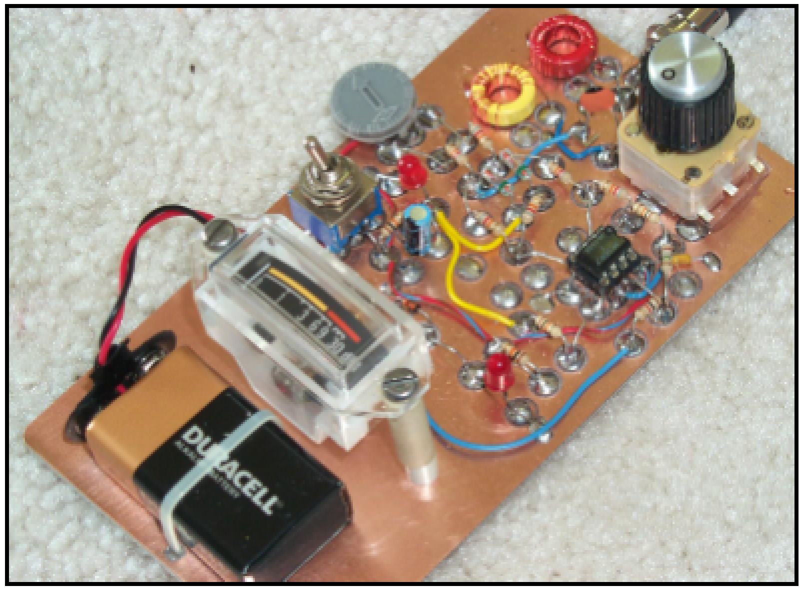
NJQRP *Sniffer*
A Tunable Multiband Field Strength Meter

Designed by Joe Everhart, N2CX n2cx@voicenet.com
Productized by George Heron, N2APB n2apb@amsat.org
Kitted by the New Jersey QRP Club at www.njqrp.org





INTRODUCTION

An RF field strength meter is one of the simpler – yet more valuable – pieces of test equipment a ham can have around the shack. By nature, our interest centers on the characteristics of the radio frequency energy we are pumping out of our antenna … how much, how efficient, its directivity and bandwidth. A properly used Field Strength Meter (FSM) can provide invaluable relative insight to each of these characteristics, and more.

The **NJQRP *Sniffer*** is a tuned-input, multiband-capable FSM for the HF amateur bands that is easily constructed using commonly available components. The NJQRP Club has provided this kit of parts and instructions to help guide you through *Manhattan-style* assembly of the Sniffer, and a theory of operation section that will help you understand the circuit fundamentals. We also describe common uses and operating techniques for this piece of test equipment. By assembling this simple kit you'll have an enjoyable homebrew experience using a popular construction technique and you'll end up with a very useful measurement device for years to come.

BACKGROUND

The Field Strength Meter (FSM) has long been a mainstay in the area of antenna measurement out in the field. An FSM is actually just a very sensitive RF voltmeter that measures the relative field strength of radiated signals. The device senses (or sniffs!) a portion of the RF spectrum by means of a short whip antenna and "detects" the signals by rectifying and filtering them to indicate as a DC voltage on a sensitive meter. A simple block diagram of this arrangement is shown below.

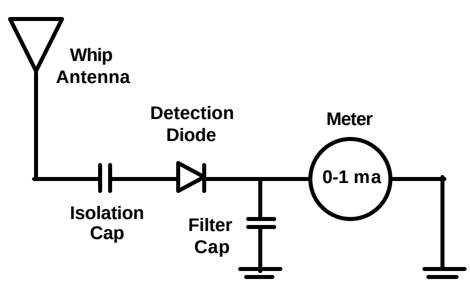


Figure 1: A Simple Field Strength Meter

There are no tuned circuits used in this simplest example and thus a very wide range of frequencies may be measured without any tuning requirements. A drawback, however, is that this approach has very low sensitivity – only strong signal register on the meter – and the selectivity is quite wide yielding an inability of the operator to distinguish which of many possible signals are being measured.

Several modifications can be easily made to this simple circuit to provide improved sensitivity and increased utility across the HF spectrum.

Selectivity may be dramatically improved by adding a tuned circuit on the input of the FSM, between the antenna and the isolation capacitor. If the FSM is to be used on a specific and unchanging frequency – for example, on your favorite operating frequency of 7.040 MHz – a fixed parallel-resonant tuned circuit consisting of an inductor and capacitor may be used to filter out all other signals, be they nearby ham signals, AM broadcast stations or other man-made interference. The positive effect of this modification can be quite dramatic and greatly improve the devices usefulness.

If a single band of frequencies if of interest – perhaps the entire 40-meter ham band, or even several adjacent ham bands – a tunable filter may be placed on the input of the FSM to yield similar improvements in operation. The only drawback is there now is a need to manually tune this added selectivity to the specific frequency of interest … but what ham among us has ever complained about having at least one knob on a project?! Seriously though, this simple manual control adds tremendous utility to the measurement device and it's worth its weight in gold.

The **sensitivity** of an FSM is the result of a combination of the frequencies being measured, length of the whip antenna, frequency response of the detection diode and basic sensitivity of the meter. In fact, the sensitivity is also (positively) affected by using the tuned circuit discussed above for the input. In this case the narrower received bandwidth ultimately allows only the desired frequencies to be detected and registered on the meter.

Another common sensitivity improvement one can do is to amplify the DC signal produced by the detector diode and filter capacitor. By boosting this voltage you will ultimately be able to register a smaller detected signal on the meter. By adjusting this amplification, or the length of the whip antenna, or even de-tuning the parallel resonant circuit on the input, you can in effect control the sensivity of the FSM to better read the relative RF field strengths of interest.

As it turns out, the NJQRP Sniffer provides each of these types of selectivity and sensitivity improvements to provide an extremely usable and low-cost measurement unit. ***So let's now get into actually building the Sniffer!***

KIT CONTENTS

Carefully unpack the bags and ensure that all of the components are present, as listed in Figure 2. The NJQRP volunteer kitting team has taken every reasonable step to ensure that everything is included. In the event that something is missing, please see if you might have a replacement in your junk box to help you along most quickly, or contact Dave Porter AA3UR (aa3ur@njqrp-kits.net) to request some assistance.

QTY	Reference	Description
1	R1	Potentiometer, trimmer, 50K
8	R2, R3, R4, R5, R6, R7, R8, R9	Resistor, 100K, 1/4W
2	R12, R13	Resistor, 10K, 1/4W
1	R10	Resistor, 10M, 1/4W
1	R11	Resistor, 1K, 1/4W
3	D1, D2, D3	Diode, germanium, 1N34A
2	LED-1, LED-2	LED, T1
1	C1	Capacitor, dual 10-280pF, Polyvaricon
1	C2	Capacitor, 100pf, disc
1	C3	Capacitor, 0.1uF, disc
1	C4	Capacitor, 10uF, 16V, electrolytic
1	J1	Battery clip, 9V
1	J2	RCA phono jack
1	P1	PCA phono plug
1	L1	Inductor, 2.1uH, 23t on T50-6 toroid core (yellow)
1	L2	Inductor, 5.4UH, 34t on T50-2 toroid core (red)
1	Magnet Wire	46"
1	Whip	Copper wire, 12 ga., 6"
1	Socket	IC socket, 8-pin DIP, wire-wrap pins
1	U1	Integrated Circuit, LM358
1	M-1	Microammeter, 0-200ua
1	PCB board	PCB board, 2-sided, 3"x6"
1	pad strip	6" strip 3/16" wide 2-sided copper clad (for pads)
1	SW-1	Switch, slide, minature

Figure 2: Parts included in the Sniffer Kit

Note that you will need some other common materials to complete and/or customize your kit. The **parts not included** in the Sniffer Kit are … a 9V battery, tie-wrap, knob/shaft/screw for the Polvaricon tuning capacitor, small lengths of hookup wire, mounting hardware for the meter, rubber feet for the bottom of the unit and glue for the *Manhattan-style* pads. Again, improvise from the materials available in your junk box to make your kit a unique creation!

CONSTRUCTION

The Sniffer Kit is constructed using *Manhattan-style* construction techniques, which has become quite popular among homebrewers today. One basically assembles the components in an open, free-form arrangement on a blank piece of copper-clad pcb material. The leads of resistors, capacitors and even IC sockets are soldered to little pads that are glued to the surface of the board, thus providing interconnection points that are isolated from the ground plane of the baseboard. This style of circuit assembly lends itself well to an "open air" type of circuit with components that can be custom-arranged to fit specific enclosures and easily debugged or modified at a later time.

For the purposes of this Assembly Manual, we'll assume you have a basic understanding of the technique as we guide you through the steps necessary to build your Sniffer. Many articles have been published concerning Manhattan-style construction techniques – so if this is the first time you've tried using it, you might do some research in past issues of QRP Homebrewer, QRPp or QRP Quarterly magazines to learn more.

Preparing the Board – In order to end up with the most attractive looking Sniffer when complete, you should first thoroughly remove the oxidation from the 6" x 3" copper-clad material supplied in the kit for the base board. Many homebrewers use a Brillo pad or some non-abrasive cleaner for the top and bottom copper surfaces. I often just lightly rub the surfaces with steel wool. Next you should wash the board with soap and water to remove any grease and oils present from handling. This will leave a very clean surface that is ideal for gluing on the pads. Finally, a light coat of clear lacquer may optionally be sprayed on to keep the board from oxidizing and turning brown again. Don't spray it on too thickly, as the pads won't stick that well and it'll be harder to solder the ground connections to the baseboard.

Component Layout – Only a little forethought is required to determine the arrangement of components on your clean baseboard. Here is where your individuality can come in! We've provided a template in Figure 13 that is very close to the way I built the prototype units pictured in this manual, but you could of course use your own arrangement to better suit the enclosure you have planned for the Sniffer, the size of your project, or perhaps to accommodate alternate components that you may wish to use from your junk box. Just draw out the phy sical components on a piece of graph paper and then use that as a guide for mounting the pads.

Marking the Pad Locations – Carefully align your drawn layout diagram on top of the baseboard and hold it in place with tape or rubber cement. Using a sharp pen or the point of a hobby knife, place a small mark at the center of each pad on the drawing, pressing hard enough to mark through the paper and onto the baseboard. Don't use a center punch or otherwise dent the copper, as you want the baseboard surface as smooth as possible to best hold the pads when glued down. Remove the paper layout template and again mark each of the pad areas with a felt-tipped marker to better help you see each pad location. Be sure to also mark the locations for the screws/standoffs used to mount the meter, and those used to hold down the battery.

Drill Holes -- You'll need to drill holes at the locations marked to mount the mater and battery.

Mounting the Pads – You first need to create the pads by snipping off little pieces of the thin strip of copper-clad materil supplied in the kit. Using a pair of side cutters, snip off pieces of the strip that would yield small rectangles of board material about 3/16" x 5/16". These will become the pads you'll glue down at each of the marked locations on the baseboard. Place a small drop of Super Glue at each marked location, and use the tip of needle nose pliers to firmly press the pad on that drop of glue. Keep applying pressure to the top of the pad for about 30 seconds. Do this gluing operation for each of the other pad locations on the baseboard.

Note: Instead of gluing down pads, you could cut "isolated islands" into the base board by using the popular NJQRP Islander Pad Cutter, a diamond-tipped end mill that cuts a 5mm diameter circle into the copper-clad material. I used this technique in building the Sniffer pictured in this Manual and it worked out just great. After taping the layout to the board, I merely used a small drill press chucked up with my Pad Cutter to cut through the copper surface at each of the locations, thus creating an isolating "moat" around each pad of copper. (See Note 1 at the end of the manual for Islander ordering information.

Preparing the Toroids – It's a good idea to prepare the L1 and L2 inductors right up front and get these tedious toroid winding steps out of the way. It's really quite simple and most of you have likely done this many times before. **To create L1**, measure out about 20" of the magnet wire supplied in the kit and wind 23 turns through the **yellow T50-6 toroid core** as shown in Figure 2 below. Each time the wire passes through the center of the core counts as one turn. After placing 23 tightly-wound and equally-spaced turns around the core, snip off the end to leave about 1/2" leads sticking out. Scrape the enamel coating off the ends for about ¼" and tin these exposed leads with your soldering iron. Do the same preparation for **L2** by using the remaining length of magnet wire (about 26") and winding **34 turns on a red T50-2 toroid core**.

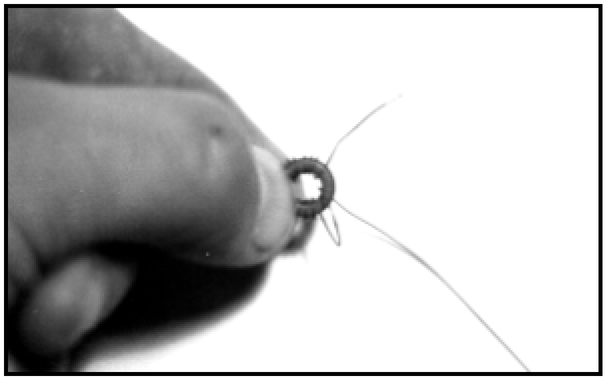


Figure 3: Winding toroids for L1 and L2

Attaching the Components – This is the fun part! Assuming that you gave each component enough room when laying out the pad locations, it should be a piece of cake to solder the parts to their respective nodes. One of the nice features of Manhattan-style assembly is that the physical circuit topology (i.e., the arrangement of components on the board) can often closely resemble the schematic diagram. This makes assembly and interconnection a simple matter of just following the schematic.

I'll provide a number of suggestions and hints for putting components onto the Sniffer baseboard. These are the steps and the order followed in constructing my units, but you could assembly yours in any manner whatsoever – which is yet another beauty of *Manhattan-style* construction!

Starting at the left-hand side of the schematic, which corresponds to the top of my board (as shown in the photos), I attached the whip **antenna jack J1** to the board by tightly screwing on the nut to hold the ground lug, bending the ground lug at a 90-degree angle and then soldering the lug to the edge of the base board.

Note: When ***soldering wires and component leads to the baseboard****, it's necessary to hold your soldering iron against the baseboard for a tad longer than usual in order to "burn through" the light coating of clear lacquer that was suggested earlier. The same is true for soldering each of the island pads, if you used the Pad Cutter to create the pads. Pre-tinning all these pads before any component assembly can be done quickly and it helps in later when attaching each component lead.*

In order to mechanically strengthen the connection of J1, I soldered a piece of stiff wire from **J1 center conductor lug** down to the pad beneath that lug. This provided a two-point mechanical connection of the RCA phono jack, which proved to give it greater strength needed for the plugging and unplugging of the whip antenna plug P1.

I next attached the **Polyvaricon tuning capacitor C1** by gluing it to the baseboard as shown in Figure 4. I actually used a small plastic "spacer" to electrically isolate it from the ground plane just in case the little trimmer screws on the bottom were to touch the copper baseboard. The ½"-square plastic was cut from an old CD jewel case and glued on the bottom to the base board, and then C1 was glued to it. When soldering to the lugs of the capacitor, be sure to make a good solder joint. Tarnish or oxidation may be present on the lugs, which is a common occurrence on older parts from some manufacturers.

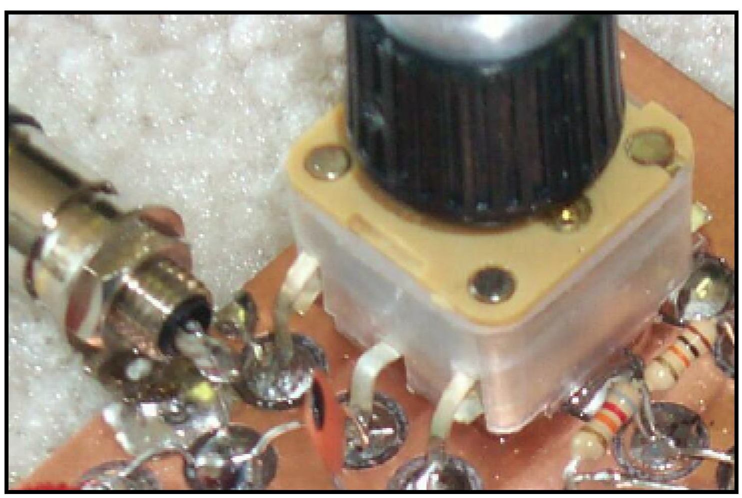


Figure 4: Close-up view of mounting C1 and J1

I next mounted the **L1 and L2 toroids** by gluing them to the base board as shown in the Layout and photo below. I actually used fast-curing epoxy to hold them in place against the base, although you could use many other forms of adhesive (e.g., RTV or silicon calking material). Once the glue was cured and holding the toroids well in place, I just soldered the ends of the inductors over to the adjacent pads.

Figure 5: Mounting the L1 and L2 toroids

I then proceeded to **solder in many of the resistors, capacitors and interconnecting wires** in the center of the baseboard. There's nothing really tricky about attaching these components except that more evenly-spaced and orthogonal component orientations tend to make the board look like a work of art when complete. (For outstanding examples of such craftsmanship, see Jim Kortge's K8IQY project pages on the Internet at www.qsl.net/k8iqy). I'm normally in a hurry to get my projects completed and don't take too much time to make things pretty, as you'll note in the photos … but it doesn't look too bad either! You can achieve a polished look by just bending the component leads in a uniform way, placing them at right angles to the pads, and routing your interconnecting wires at right angles along the baseboard.

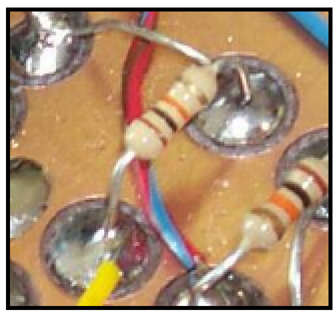


Figure 6: Mounting components

Mounting the IC socket might seem like a daunting task, but not really! If you were careful in placing the small pads as indicated in the Parts Layout diagram, all you then need to do is slightly bend the socket leads outward at an angle and cut them off evenly before soldering to the pads.

Figure 7: Mounting the IC socket

Trim pot R1 has three pins coming out the bottom of its case. Carefully bend those leads outward to line up with the three pads in your Parts Layout diagram. Just solder them to the pads and you'll have a relatively solid mounting for this component. There's not too much of a need to adjust this potentiometer once set, so it won't be undergoing undue amounts of mechanical stress.

Note: Many times a component has one of its leads "going to ground", meaning that the lead must be soldered to the common ground plane in the project: the copper plane of the baseboard. The trim pot is such an example, whereby one end of the fixed resistor gets grounded. In these cases, a separate pad is not necessary and you can just solder the lead to the baseboard. Sometimes, however, a pad may be useful to use even for this ground connection because of the physical limitations or orientation of the component lead. Again using this trim pot as an example, it's useful to employ a third pad for the grounded end of the pot because the leads are all at the same level. In this case, just put an extra wire (like a scrap lead nipped off from a resistor) from that third pad to the ground plane

Figure 8: Mounting the trim pot

Power switch S1 is the next big component I mounted to the baseboard. Several different styles of switches are supplied in the Sniffer kits, so yours may be different than the one shown in these photos. Regardless of style, the main idea is to solder the two "hot" switch lugs directly to pads, and the unused "cold" switch lugs directly to the baseboard. It's a good idea to solder the lugs in a manner that gives solid mechanical support since you'll often be switching the unit on and off. Be creative and mount your switch in a convenient location and orientation!

The **meter** is mounted to my baseboard using two thin 1.5" machine screws through some standoffs grabbed from the junk box. Homebrew standoffs could be fabricated from the tube of a plastic BIC pen. Just cut off equal lengths of the pen's tube and you'll be all set. (Remember to remove the inner ink tube or you'll have a real mess on your hands!) When wiring to the meter terminals on the bottom, be sure to observe the polarity as indicted in the plastic by the lugs.

Figure 9: Mounting the meter on standoffs

The last major item to be mounted on the baseboard was the **9V battery**. I secured it with a tie-wrap around the battery and through the holes in the baseboard on either side of the battery. Instead of using a tie-wrap to hold down the battery, you could just use a piece of stiff wire.

While still in the construction mood, I made up my simple **whip antenna** by taking the short length of #12 copper wire and soldering it to the center conductor of plug P1. I slid the wire into the rear of the tube of the RCA phono plug and soldered it in place. I then slid the plastic shell over the wire and screwed it onto the threads of P1. Lastly, I bent the wire upward at a 90-degree angle as shown in the photos, which also tended lock the plastic shell on the threads of P1.

Some **rubber feet** were scrounged from my junk box and attached to the bottom of the baseboard to finish off the mechanical assembly of the Sniffer. This provided a convenient, non-skid base when the unit sits on the table.

TEST

Chances are your newly-assembled Sniffer won't work when you first apply power – at least that's been my own experience with projects! But don't worry, we'll outline some easy steps that you can follow to resolve possible problems just by using a VOM (volt-ohmmeter).

1) Check your voltages – Make sure you have around 8.5-to-9 volts coming from the battery, as measured on the Inward" side of the power switch when in the ON position. Then check to see that you have the same voltage on U1 pin 8, at the wiper of the trip pot R1, and at the LED resistors R12 and R13. These LEDs should be faintly illuminated -- turn your room lights off to ensure the LEDs are indeed dimly glowing. The LEDs should each have about 1.2V across them. If any of these conditions are not as indicated, you've got a basic problem in your DC power or distribution wiring and you'll need to resolve this before trying anything else.

2) Check diode polarity – Measure the voltage at the D1-R2 junction, and the D2-R4 junction. Each one should be about 2.4 volts or so – if not, the diodes are likely in backwards. This is an important checkpoint because if the diodes are connected backwards, the main function of the Sniffer (i.e., RF detection) will not work.

3) Adjusting the Sniffer – Disconnect the whip antenna and ensure that you are not in any direct RF fields. Monitor the output of the first amplifier at U1 pin 1 while turning the trim pot across its range. You should see a minimum voltage dip around the midpoint of rotation, probably in the millivolt range, indicating that the detector bridge is presenting the proper voltages to the op amp. You can monitor the output of the second amplifier on U1 pin 7 and see a similar dip occur, but at a higher voltage. And finally, you should see the meter indicate a minimum reading (very close to zero, or no movement) when the trim pot is at the "dip" position. If any of these conditions are not as described, you have a wiring problem that will need to be resolved for the Sniffer to work properly.

4) Check out the Sniffer with known frequency sources – Connect the whip antenna, turn the power ON and turn on a transmitter at a known frequency, say 7.040, while using a dummy load. You can try using the rig in your shack, or perhaps any of the QRP kits you've built up over the years – FB40, Snap, Tuna Tin II, etc. Any of these rigs should produce enough RF for your Sniffer to detect and give a meter indication. (Some dummy loads are pretty well shielded and you might need to hang a clip lead from the Sniffer's whip over by the dummy load on your rig if you're having trouble getting a reading.) While keying the transmitter, rotate the Polyvaricon capacitor C1 until you see a reading on the meter. If the meter immediately pins to the right, try reducing the power of your transmitter, move farther away from the rig, or turn C1 a bit off resonance. This should allow you see relative changes in the RF field when other conditions are changed, like moving to a different location or angle of the whip antenna. Switch the transmitter to other bands and notice that the meter peaks at different settings of the tuning cap. The Sniffer is able to detect RF fields across all the ham bands from 80m through 10m. If operation is not as described, you likely have a problem in your "front end" wiring around the variable capacitor and toroid inductors. Check that wiring, the number of turns on the L1/L2 toroid cores, and proper connection of terminal lugs of C1.

USAGE

As hopefully you've found in the previous checkout section, it's not really complicated at all to operate a field strength meter. The basic principle is to read the relative strength of an RF field in order to determine field patterns emanating from antennas, look for stray RF fields in unexpected places, or determine optimum settings of transmitters by reading relative changes in the resultant RF field. Once you get the hang of adjusting the Sniffer's sensitivity and selectivity so as to isolate the desired signal from background interference, you'll find the device a pleasure to use. Sometimes increasing the length of the whip antenna helps in increasing its sensitivity, and other times shortening the antenna helps to reduce its sensitivity when used in higher power RF fields. In this regard, a telescoping antenna would be a very useful improvement over the fixed-length whip.

To make the Sniffer more rugged and less prone to stray signals or body interference, it would be good to enclose the device in a metal enclosure. This would protect the circuit components from mechanical stresses and enable you to toss the unit into a backpack or tool chest when measuring out in the backyard or while on Field Day. The creativity that hams demonstrate in packaging their projects is a great source of amazement to me – how will you bundle up <u>your</u> Sniffer?!

SNIFFER THEORY OF OPERATION

The Sniffer design is based on the simple FSM described at the start of this manual, but N2CX added a variable tuned circuit on the input to provide continuously variable center frequency for the selectivity throughout select HF ham bands. His design also provides an enhanced detector scheme for added sensitivity, and a two-stage buffer-amplifier to boost the very low detected signals to give the Sniffer great sensitivity. Refer to the Sniffer schematic (Figure 12) as we go through the nitty-gritty circuit description in this section.

Okay, let's start at the very beginning – which is indeed a very good place to start! (With apologies to Julie Andrews and the Von Trapp family.) Pretend you're a 7.040 MHz QRP-level RF signal having been just launched from that nifty new antenna in your back yard. The short 4"-6" whip antenna of the FSM *sniffs* the nearby RF fields emanating from the antenna and you (the signal) slide down the whip and into the **L1-C1 parallel tuned circuit**.

By the way, if you use a **whip antenna** longer than 6", you may damage the meter because too many of your buddies (other signals) would be gathered by the antenna and will all be detected, amplified and registered on the meter, thus over-driving the sensitive meter coil. Indeed by using a longer whip, the Sniffer will respond better to far-off RF source – but those nearer/stronger ones will really pin the meter. A helpful improvement in constructing the Sniffer would be to use a telescoping whip antenna (like one from Radio Shack, used for walkie-talkies) to give an added control of sensitivity.

Okay, back to the **tuned input circuit**. You (the 40-meter signal being measured) have just slid into a rather unusual variable tuned circuit consisting of L1 and C1. The actual circuit components are a dual-section Polyvaricon tuning capacitor (like the kind used to tune FM radios and the EMTECH ZM-2 antenna tuners) and two toroidal inductors. The tuned circuit is resonant at two frequencies simultaneously, eliminating the need for a band switching mechanism while tuning from 80 through 10 meters. It may also be intentionally off-tuned to reduce sensitivity. The frequency plots and the table of resonant frequencies show the frequency ranges achievable with this tuned input circuit. In a way of speaking, this tuned input circuit was made <u>just for you</u> (the 7.040 MHz signal) when the variable capacitor is adjusted to be resonant in the 40m band. When this is the case, it rejects all other signals and lets you pass on through to the next stage. This characteristic is called *selectivity* because only certain signals, those at the circuit resonance are allowed to pass. In this way, other interfering signals would be rejected and would not have the ability to get further into the FSM to affect its measurements. Only the signals of interest get through. This should make you feel pretty important!

A **100 pf capacitor, C2**, couples the RF signals into the diode detector while blocking DC. This component keeps DC current from coming down the R1-R3 path and getting into the tuned circuit, thus unbalancing the diode detectors (described next). So in essence, you (the RF signal) are able to slide on through the DC blocking capacitor as if it were not there and you then head on into the detector.

"Detection", the heart of all field strength meters, can be defined as the translation or demodulation of radio frequency energy to its original form. In the case of antenna field measurement with an FSM, the transmitted signal often is a continuous wave (CW) RF signal and the detection process in the FSM rectifies the RF sinusoidal waveform in a diode junction. A capacitor then smoothes out this half-wave signal to produce a DC voltage which is proportional to the strength (amplitude) of the original RF signal. This is the basic operation shown in the simple FSM diagram shown in Figure 1.

However in the actual Sniffer circuit, N2CX wanted to provide a more sensitive detection scheme, so he utilized <u>two</u> diodes and arranged them in a bridge-like configuration. These diode detectors, **D1 and D2,** form a balanced network in conjunction with bias resistors **R2 and R4** to provide equal voltages at the anode mid-points of the bridge. **Trim pot R1** gives the operator a means to fine tune the current flowing through each leg of the bridge, thus getting the anode of each diode to be precisely the same voltage. *Now here's the key point* – when the sinusoidal RF signal is presented to one of the diodes in the bridge, the rectified voltage produces an imbalance in the bridge that is able to be sensed, amplified and registered on a meter later downstream. Further helping the cause for sensitivity, N2CX employed germanium diodes which have lower forward-conduction voltages of 0.3V (as compared to silicon diodes). Thus the DC biasing provided in the bridge sets the diodes to a condition that yields very sensitive RF detection whenever RF signals are presented to one of the diodes.

So this detection process actually turns *you* from a radio frequency sinusoidal waveform into a half-wave signal. But I bet you still feel the same, albeit perhaps just half the person you were at the antenna, right? Well, to quote George W. Bush: "Things are going to change from this point forward!"

The DC voltage imbalance in the detector bridge is very small – often less than 1 millivolt – when *you* (the QRP RF signals) are presented to one side of the bridge. In the simple FSM circuit of Figure 1, this would be far too small to effectively register on a meter … *you'd* have a real hard time pushing that little needle up to a proper reading! N2CX realized this and came to your rescue by providing several stages of amplification to give *you* additional strength to do the job.

The key to amplifying that small microvolt signal lies in extracting it from that sensitive detector bridge without affecting its operation. This is accomplished by employing **low-power op amp U1** which has a very high impedance input impedance. U1a is configured as a *differential amplifier*, meaning that its two input voltages are compared and just the <u>difference</u> between them. In this way, the amplifier is able to internally calculate the instantaneous difference between the steady reference DC bias voltage on the anode of diode D1 (which is presented to the inverting input on U1 pin 2) and the detected RF signal riding on top of that same reference DC bias voltage present on the anode of D2 and presented to the non-inverting input on U1 pin 3. That's a complicated sentence, but suffice it to say that the reference diode voltage is subtracted from the diode voltage on which *you* (the signal) are riding, and the result coming from the output of the op amp is precisely you, that microvolt-level detected RF signal.

There is no amplification of the detected signal in this first stage, since U1a is configured with R4-thru-R7 having the same values. This effectively programs the op amp to have *unity gain*. So this first half of U1 serves a critical role in the process by determining the imbalance in the bridge when a signal is present, and because of its high input impedance it extracts that difference without affecting the bridge's operation.

We should mention here mention here that **a reference level of 1.5V is generated by LED-2** in order to properly bias U1 and eliminate the need for a dual-voltage power supply. This is accomplished with the circuit components **R13, LED-2 and C4**. The constant current flowing through the resistor and LED (approximately 780 ua) forward biases the diode junction in the LED to create a 1.5V voltage drop. The 10 uF electrolytic capacitor gives this bias source a low AC impedance for noise elimination and stability. That constant voltage is applied to the non-inverting inputs of both U1a and U1b, and to the diode detectors to eliminate the need for a dual-voltage power supply.

It's important to note here, as mentioned above, that the output of U1a presents the *difference* of the reference diode voltage and the signal diode voltage, which results in the microvolt-level detected signal being output on U1a pin 1 … as measured against <u>the reference voltage</u> coming from LED-2. If one were to measure the U1a output pin referenced instead to ground, that 1.5V reference voltage would be seen carrying the microvolt signal.

By the way, you might wonder where the capacitor is in the Sniffer circuits, as compared to the simple detector of Figure 1. After all, you need that cap to filter the half-wave rectified signal in order to create a DC level, right? Yes indeed Scarlet, you are right, but the stray capacitances in the circuit and inherent response times of the op amp actually provide that capacitance, and the outputs of the op amps are indeed filtered DC levels for all intents and purposes.

Okay, back to our story of *you* … you are the little detected RF signal is coming out of the first stage of buffering and now is at the output of U1, looking like a 500uV signal sitting on a constant 1.5V level. N2CX next worked some magic to amplify you 100-fold by squirting you into yet another amplifier – **the second half of the low-power op amp U1**. This amplifier has a 100 K-ohm input resistor **R8** and a 10 megohm feedback resistor **R10** which programs the U1b to multiply the input signal by 100. The equation to determine the output of this kind of amplifier is:

Vout = Vin x Rf / Ri,

where Rf is the feedback resistor R10 and Ri is the input resistor R8. But you recall that the microvolt detected signal is riding atop a 1.5V DC voltage coming out of the first amplifier, right? We don't want to amplify this DC voltage, but only the small detected signal.

N2CX configured **U1b as a differential amplifier** as well and applied that 1.5V reference bias voltage coming from LED-2 to the non-inverting input U1 pin 5. The net effect of this configuration is that the constant DC level on which the microvolt detected signal is riding is the only signal to get amplified by 100. Thus, the effective input voltage "Vin" to U1b noted in the equation above is actually:

Vin(b) = (Vout(a) – 1.5) x Rf/Ri

where, Vout(a) is the microvolt signal being measured riding atop the 1.5V constant level, and Vin(b) is the combined effective input voltage to U1b. Thus you can see that it is again the *difference* that gets amplified by U1b, just like the operation of the U1a stage before it.

So at this point, *you* (the detected signal) have been amplified by 100 and now have been strengthened enough to drive the meter. Feel pretty powerful? You should! Once a microvolt signal riding along on a DC bias, you are now a beefy volt-level signal all by yourself. You are next sent through a **current limiting resistor R11**, through the **meter M1**, and finally down to ground potential through **LED-1**. We'll next describe how these components interact.

Recall that the meter reads full scale when the current going through it is 200 uA. We want to be sure that we don't burn out the meter by pumping any more current than that amount, so we use a current limiting resistor of 1 K-ohm to do the job. This value was selected by considering the basic V=IR relationship and knowing that *you* (the signal) have now grown up to be about 7 volts at most (for example) coming out of U1b, and that LED-1 has a forward voltage drop of about 1.5V. The maximum current able to be supplied through the meter then would be:

Imax = (7-1.5) / 1000 = 5500 uA

which would clearly smoke the meter in a heartbeat. (How about that for *you* being a powerful signal!) But we'll keep the maximum current at this level in order to ensure that we achieve good sensitivity down in the lower range of interest for the detected signals, and in order to ensure that we keep LED-1 turned on enough to keep LED-1 turned on. N2CX used an LED in this circuit to provide the 1.5V offset voltage needed to allow the meter to read zero with no RF signal applied at the input of the Sniffer. Without the LED, the small, constant DC voltages coming through U1b due to slight differences in the reference voltage off LED-2 and the DC level coming from U1a would prevent the meter from being able to be adjusted down to zero with no signal present. (Recall all the "about 1.5V" terminologies in the preceding discussions!)

The 10 K-ohm **resistor R12** coming right off the battery also supplies some current to LED-1 to help establish this level, but the signal being measured really supplies the bulk of the current that provides its forward voltage. In fact, you can even see the LED's intensity brighten with a strong signal is being measured!

As further insurance that we don't burn out the meter, **diode D3** is connected across the meter terminals. When the measured voltage (*you*) exceeds the diode's forward voltage point, and it turns on to shunt current away from the meter. Thus if the operator inadvertently misadjusts the detector bias trimmer, or attempts to measure a whopping big signal, the meter will likely peg over to its maximum extreme but it won't be destroyed.

So that's the Story of *You* – how *you* initially get caught by the whip antenna, slide down and through the tuned input filter, get detected, amplified and turned into a DC voltage in order to push a little needle of a meter to indicate how relatively strong *You* are!

CREDITS

This kit was made possible by the dedicated work and contributions of several very special people.

Scott Gregson, KC7MAS, the owner and operator of **EMTECH**, was very helpful to the NJQRP Club and its annual Atlanticon QRP Forum extravaganza by graciously providing the Polyvaricon tuning capacitors at a more-than-reasonable price. Without his help, this project would not have been able to come to fruition as the "Atlanticon Kit" this year.

Doug Hendricks, KI6DS, co-founder of the NorCal QRP Club and *teacher-extraordinaire*, was also instrumental in making this Sniffer FSM Kit happen. Doug provided the NJQRP with the beautiful meters used in the design, at a next-to-nothing price. Once again, thank you Doug!

John Cawthorne, KE3S, a very active member of the NJQRP Club and veteran of multiple kitting efforts, came through again for the club by spearheading the kitting and shipping activities for the Sniffer. With the able assistance of kitting captain and chief club honcho **Dave Porter, AA3UR,** John was able to get the Sniffer kitted and out to everyone in a timely and quality fashion.

Joe Everhart, N2CX, co-leader of the NJQRP Club and my best buddy, once again demonstrated his technical prowess and mastery of analog and RF circuitry by designing such a useful project for the NJQRP. Many hams are going to be happily Sniffing for years to come. Joe also provided a good deal of the technical descriptions that I (N2APB) was able to put together in a usable manner for this manual.

NOTES

1. The Islander Pad cutter is available for purchase from the NJQRP for $9. Shipping is free to US and Canadian locations.

NEED HELP?

If you have any problems or questions, please visit the online web pages for the Sniffer at www.njqrp.org/sniffer . We've posted all the latest project information, tips & techniques for construction and usage, modifications for expanded or alternate use of the device, and the inevitable corrections to the circuit, components and manual. We'll share the findings and experiences of those who provide feedback in hopes of having all others benefit.

If, after checking the online Sniffer web pages, you find that you still have a question or problem, please feel free to send us an email describing your dilemma. Tell us as much as possible about the problem and we'll do our best to provide some guidance.

We hope you enjoy building and using the ***Sniffer*** field strength meter! Please let us know how it works out for you.

73,

George Heron, N2APB n2apb@amsat.org
2419 Feather Mae Ct., Forest Hill, MD 21050

Joe Everhart, N2CX n2cx@voicenet.com
214 New Jersey Rd., Brooklawn, NJ 08030

Dave Porter, AA3UR njqrp-kits@comcast.net
647 Middle Holland Rd., Holland, PA 18966

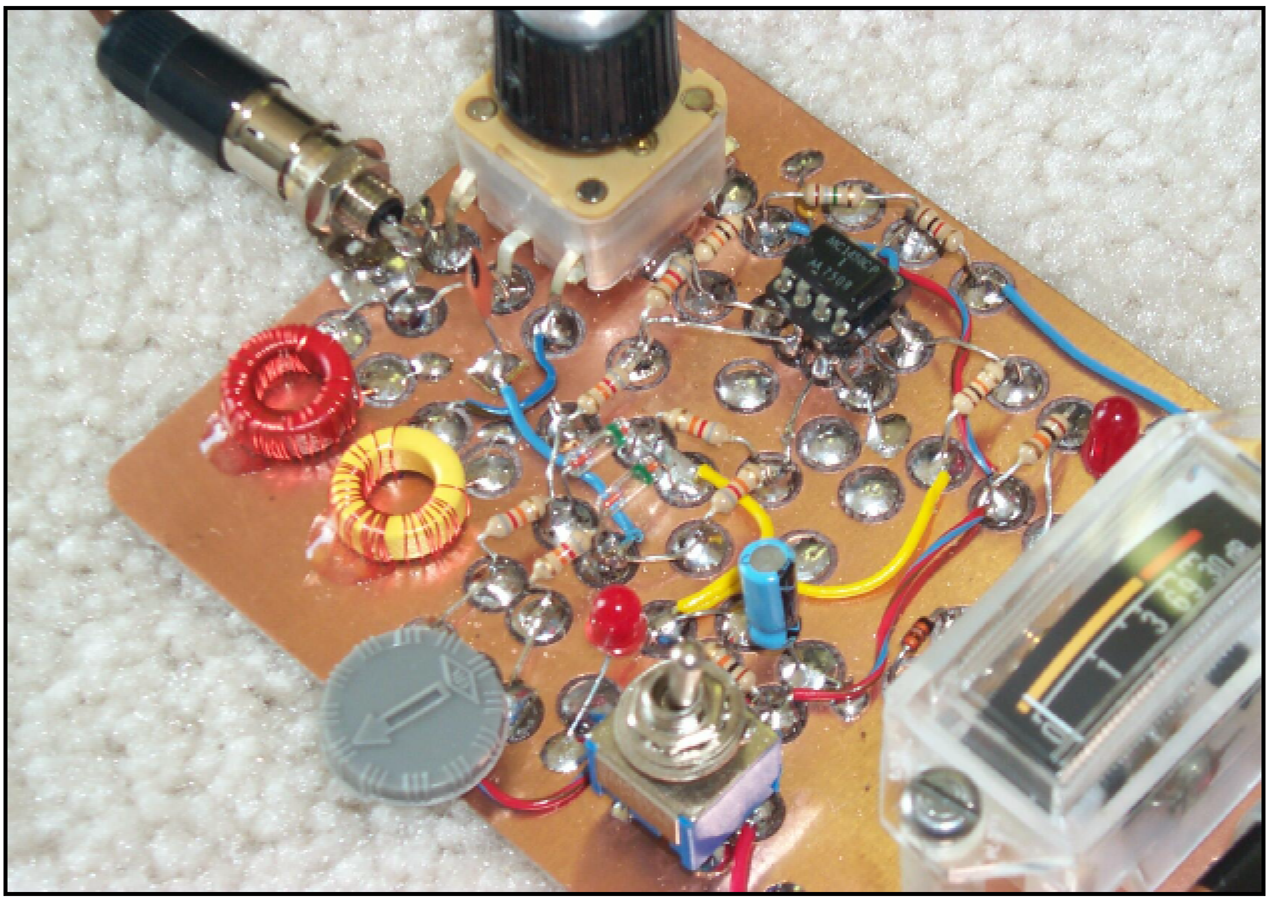
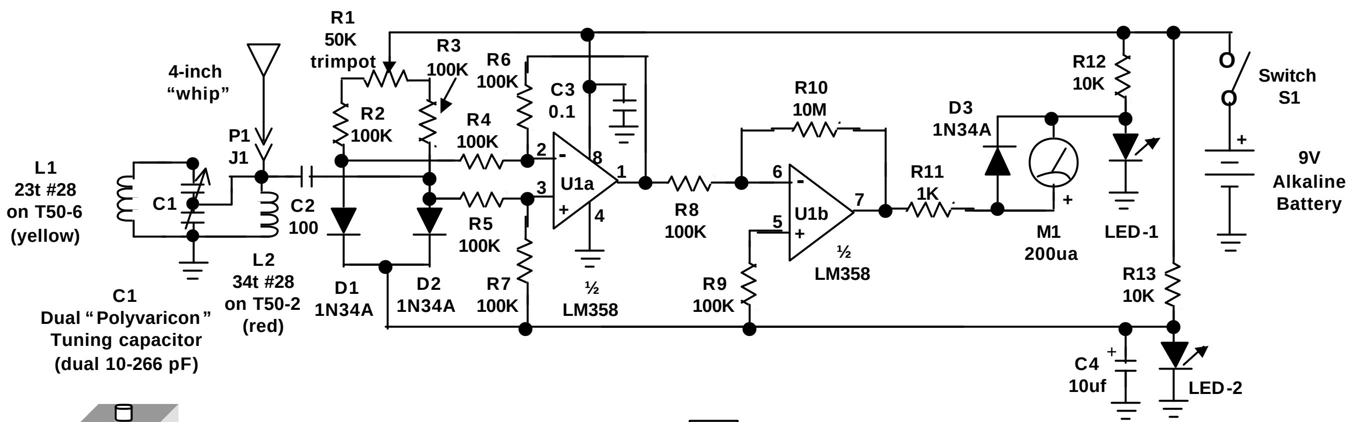


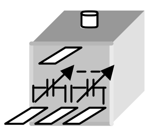
Figure 10: Closeup of the Sniffer's *Manhattan-style* construction

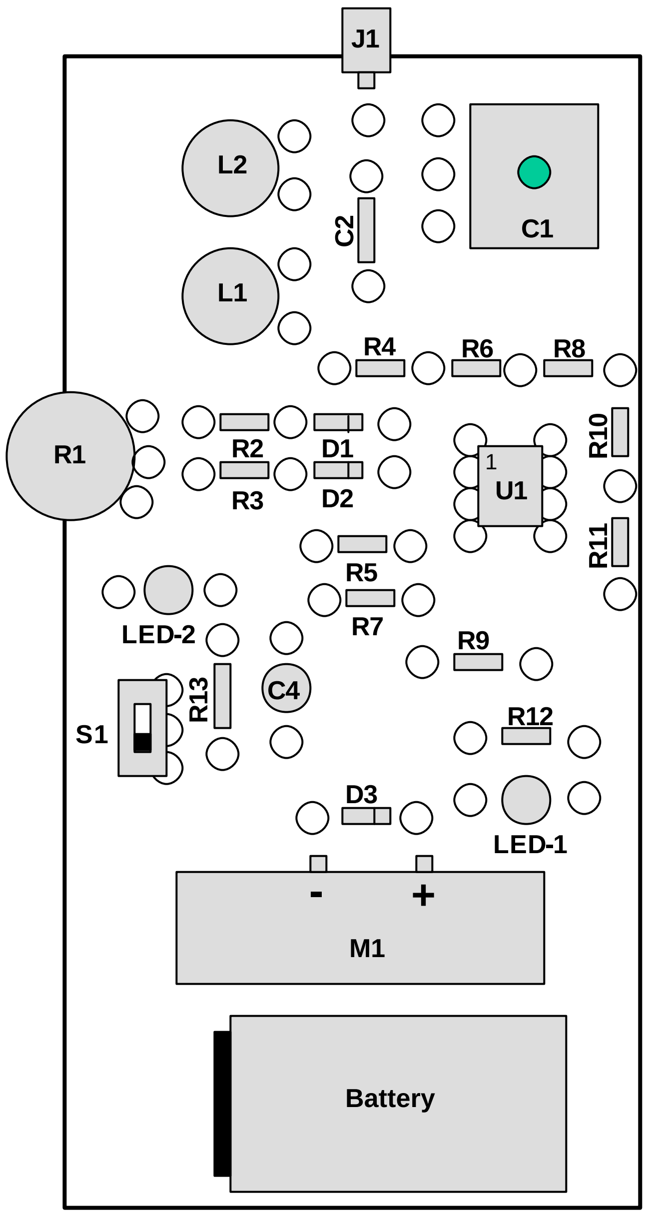
NJQRP *Sniffer*

A Tunable Multiband Field Strength Meter

designed by Joe Everhart, N2CX   January 2003







Here's one idea of a layout for the board.

The white circles represent pads.

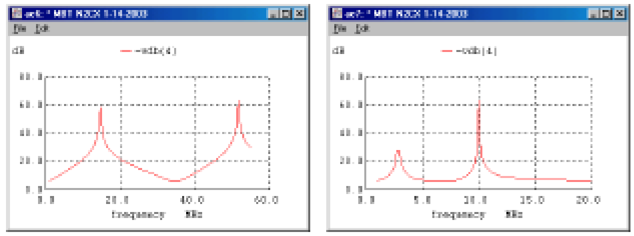
As indicated in the text, this just happens to be MY layout … yours could be entirely different, more ergonomic, and better performing for you.

Be ingenious and come up with your own version!

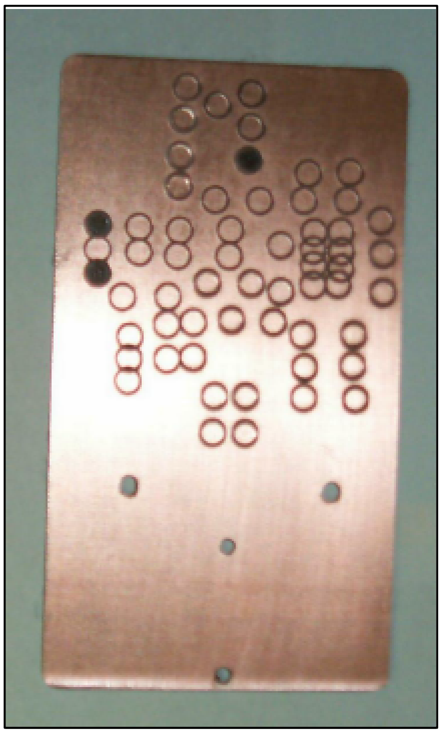
And how about an enclosure?!

Revised: 2/10/2003 N2APB

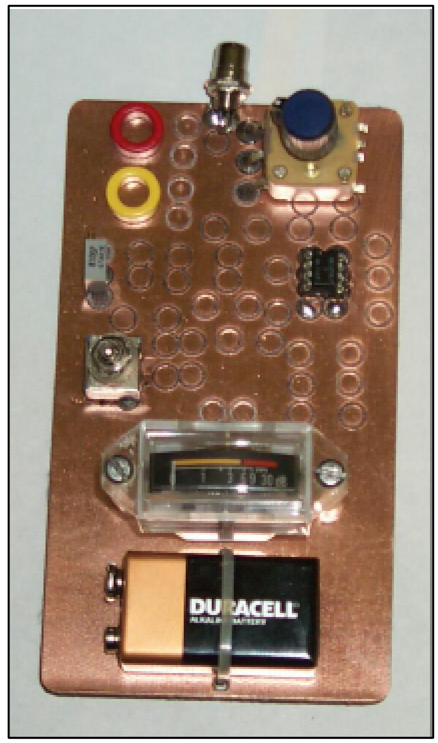
L1 2.1 uH (23t T50-6), L2 5.4 uH (34t T50-2)			
Shaft Rot	C1	Flo	Fhi
%	*pf*	*MHz*	*MHz*
0	10	14.6	51.5
10	35.6	7.7	27.4
20	61.2	5.8	20.9
30	86.8	4.9	17.5
40	112.4	4.3	15.4
50	138	3.9	13.8
60	163.6	3.5	12.75
70	189.2	3.4	11.8
80	214.8	3.2	11
90	240.4	3	10.5
100	266	2.8	10



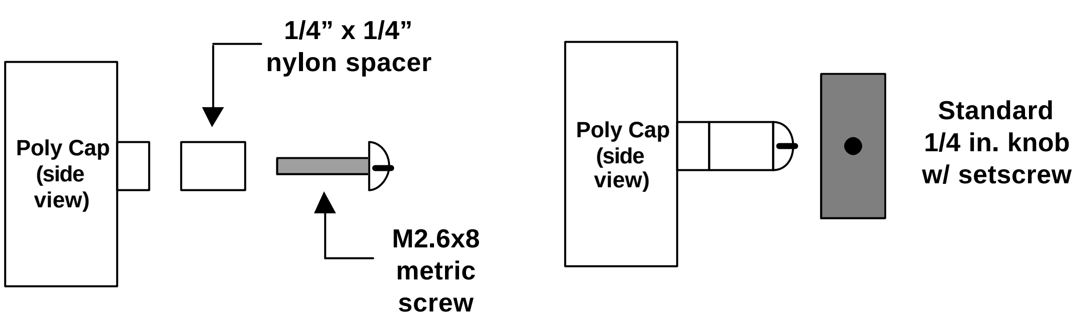
Left: Table of frequencies covered in tuning range.
Above: Simulation plots showing selectivity of front end



Manhattan-style base board, 3" x 6" with "island pads" cut with NJQRP Islander Pad Cutter. (Standard "PC dots" could also be glued on for pads.)



Partially assembled Sniffer.



Adapting poly trimmer to accept common round knob