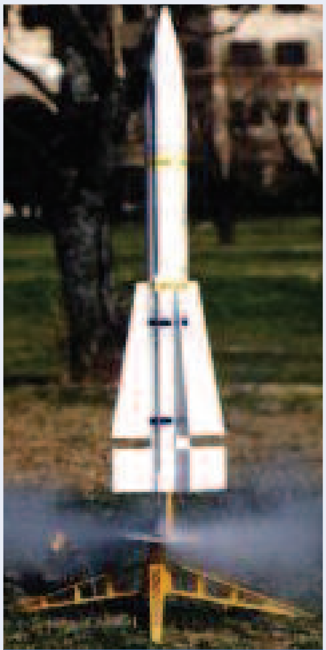


www.ninfinger.org/rockets

Radio Locator Beacon for Flying Objects

By Dan Gravatt

This project came about when I started launching model rockets high enough that I couldn't track them visually. I have lost some small rockets over the years and not been too upset, but I like to hang onto the larger ones I've designed myself. When you can't find the 'chute in the sky, or it drifts away behind some trees, you need a non-visual tracking method like the radio beacon presented here (**Figure 1**).

The locator beacon weighs about an ounce with its 12-volt A23 alkaline battery, and could be made lighter with the use of surface-mount parts. It's also simple and inexpensive, so you can afford to build another one if necessary.

Oscillator Design

This is actually only the second RF oscillator I've tried to build that really worked well. It is based on designs available on the web, including a wireless microphone project by Harry Lythall SM0VPO. In the schematic in **Figure 2**, the RF oscillator is based on transistor Q1. As the frequency of an oscillator goes up, the tolerances for stray capacitance goes down, so circuit layout becomes more critical. I strongly recommend you build this project dead-bug style on a copper-clad board as I did, even at the prototype stage. Pre-etched perfboards, stripline boards, and especially solderless breadboards will have too much stray capacitance for the oscillator to work reliably. RF oscillators of this type (Colpitts) need a very stable power supply voltage to maintain a stable frequency. Although this circuit only draws about 15 milliamps, it's a big load for an A23 battery. As the voltage drops, the transmit frequency will too. Linear voltage regulator U1 and bypass capacitor C1 provide a stable

Figure 2: Schematic for the radio locator beacon.

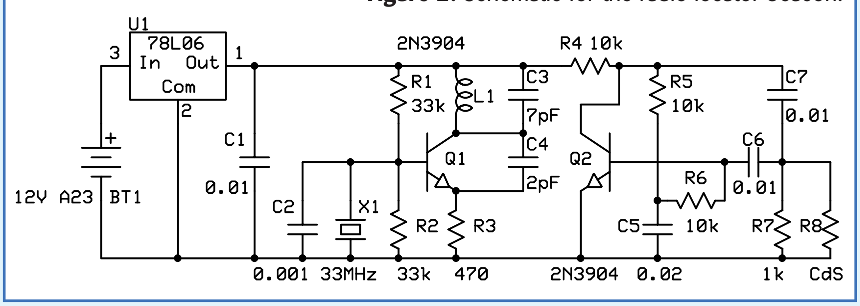
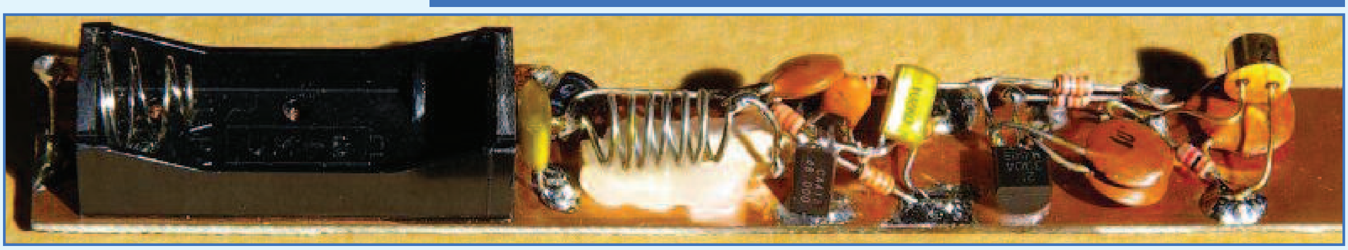


Figure 1: Radio locator beacon, ready to go. Note how the N-cell battery holder was trimmed to fit inside the rocket's body tube. Optional crystal X1 is the small, dark rectangle.



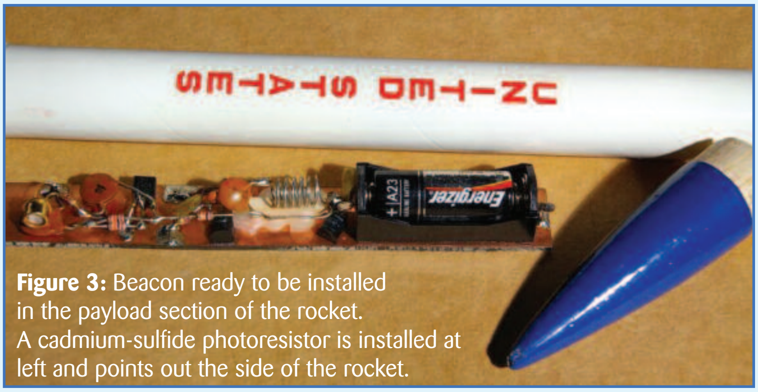


Figure 3: Beacon ready to be installed in the payload section of the rocket. A cadmium-sulfide photoresistor is installed at left and points out the side of the rocket.

the "up" end when you load the beacon into your rocket. If the spring-loaded terminal of the battery holder is "down," when the rocket launches the acceleration will cause the battery to compress that spring, turning off the transmitter.

Once the epoxy cures, solder a wire from the negative battery terminal to the exposed 1/8" bit of the circuit board, and install U1 and C1 at the positive end of the battery holder. Fabricate L1 according to the instructions in the **Parts List**, with axial leads of 1/8"- 1/4" on each end. This will be installed between the output terminal of U1 and the collector of Q1, so use it to eyeball where Q1 needs to be located on the board. Next, build the RF oscillator, starting with Q1, R1, R2, R3, and C2. It's helpful to install one or more parts which connect at one end to the groundplane first, then use these to hold the transistor in place. Install the remaining parts in the RF oscillator, except the optional crystal X1. Make sure L1 is suspended about 1/8" to 1/4" above the circuit board and that it is at least 1/8" from other nearby components. Keep the construction neat and compact with leads as short as practical.

Install the battery, turn on a nearby FM radio, and sweep the tuning of the radio across the entire FM broadcast until you hear the transmitter's signal, which will sound like a "dead spot" or lack of static on the radio. If you don't hear it at first, tweak L1 a little bit at a time by compressing or stretching the turns, and sweep the radio tuning again. Once you find the signal, touching the inductor should stop the oscillation and bring back the static.

If you can't find it after several rounds of tweaking and sweeping, check your construction again thoroughly and make sure the output voltage of U1 is six volts. If no errors are found, try swapping different parts for C3 and C4, and/or rebuilding L1 — the oscillator's performance

six volts to the oscillator even as the battery voltage drops.

The other half of this beacon — the twin-T audio frequency oscillator based on transistor Q2 — is extremely stable and easy to build with any construction method you would care to use. You can prototype this oscillator on a breadboard if you would like to fine-tune the frequency of the audio tone before building the flight-ready beacon. Note that in the schematic there is no connection between the base of Q2 and the junction of R5 and C5.

Build It!

The first consideration for construction would be the dimensions of the circuit board. It's easiest to make the board as wide as the inside of the rocket's body tube, for example, and mine is 9/16" inches wide to fit inside an Estes BT-20 tube with the battery holder installed. Whatever you plan to use the beacon in — an airplane, balloon, or UFO — size the board accordingly. Start by epoxying the N-cell battery holder to one end of the copper side of the board, about 1/8" from the end, with the spring-loaded battery terminal (negative) closest to that 1/8" exposed bit of circuit board. This end will be

DEAD BUG STYLE

The "dead-bug style" is a method for prototyping high-speed circuits that helps to eliminate capacitive coupling. The method gets its name from the idea that upside down ICs look like dead bugs with their legs sticking up in the air.

When prototyping high speed circuits — generally in the RF range (>1-2 MHz) — capacitive coupling between traces can lead to signal degradation. The dead-bug style helps to eliminate this by building the traces in the air to maximize the distance and minimize the parallel runs that various leads travel with one another. The dead-bug style also has the advantage of having a monolithic ground plane which helps to minimize circuit noise.

The generic dead-bug style begins with a single-sided copper-clad PCB. The ICs are glued upside-down to the surface of the copper cladding. The circuit is wired up in the air above the ICs with ground connections bent over and tacked down to the ground plane. Care must be taken with ICs that are in conductive packages (metal cans); the metal portion is meant to be at ground potential. Otherwise, it must be isolated from the ground plane when gluing down.

For more details, check out **www.opencircuits.com/Dead_bug_style**.

and stability is dependent on fairly accurate values for these parts.

Next, build the twin-T audio oscillator based on Q2. Layout and construction of this oscillator is not nearly as critical as for the RF oscillator, but remember that if you want the beacon to survive a rocket launch and landing, all components need to be installed securely. The audio oscillator should be built fairly close to the RF oscillator, but not touching it. Depending on how you have laid out your board, R4 will probably end up being parallel to L1, so make sure they are 1/8" or more apart. Power up the beacon again and you should hear an audio tone on the FM radio where you heard the dead spot previously. You're in business!

Observant readers may have noted by this time that there is no direct path for the audio oscillator to modulate the RF oscillator. So, how is the audio tone making it to your radio? Modulation is accomplished by coupling through the common power supply, as well as parasitic or stray capacitance between the adjacent components of the two oscillators. Simple, but effective.

Modify It!

At this point, if you like you can tweak L1 to achieve a transmit frequency of about 99 MHz and then install X1, a third-overtone 33 MHz crystal. This will provide further stability to the transmit frequency over a wide range of temperatures and mechanical shocks encountered during a rocket's flight. Depending on the crystal you use, you may need to reduce the value of C2 slightly to compensate for the capacitance of the crystal itself. If you have a Technician class (or higher) amateur radio license, you can make this beacon transmit in the two-meter band at about 144.100 MHz by replacing X1 with a 48 MHz crystal, using a 4.7 pF capacitor for C3, and compressing L1 a bit. Make sure to follow FCC rules for amateur radio use, including station identification.

I have added optional resistor R8 to the twin-T audio oscillator schematic to represent a resistive sensor measuring light, humidity, temperature, or some other condition of the rocket in flight. Changes in the resistance of this sensor will change the audio tone and provide data on what's happening on-board. For example, a cadmium-sulfide photoresistor pointing out the side of the rocket will give alternating high and low tones as the rocket spins during flight, providing an indication of its roll rate.

Once you have the entire beacon working the way you like, drip some candle wax onto the circuit in several places to hold everything securely in place. You may want to place a thin wooden spacer between L1 and the circuit board prior to applying the wax. Don't use too much — a very thin layer is adequate. I have found that for transmit distances of several hundred feet in free space, it is not necessary to add a wire antenna to the beacon. In fact, doing so may add stray capacitance that destabilizes the RF oscillator or changes its frequency. However, if you would like to add one, solder it to L1 about one or two turns away from the end connected to the output of U1. Don't allow the antenna connection to bridge between adjacent turns of L1.

Experiment with different receiving antenna configurations for your FM radio that allow you to determine the direction of the beacon. Beam-type antennas will offer the best directional performance, but you can also get some directional indication with wire loops or by changing the angle of the rod-type antenna used on most portable FM radios. Sometimes placing yourself between the beacon and the receiving antenna helps. Search for "foxhunting antennas" on the web for more ideas.

Parts List

U1	78L06 linear voltage regulator TO-92 package
Q1, Q2	2N3904 NPN transistors, TO-92 package
R1, R2	33K ohm resistors, 1/8 watt
R3	470 ohm resistor, 1/8 watt
R4, R5, R6	10K ohm resistors, 1/8 watt
R7	1K ohm resistor, 1/8 watt
R8	Cadmium-sulfide photoresistor or other resistive sensor (optional)
C1, C6, C7	0.01 µF capacitor
C2	0.001 µF capacitor
C3	7 pF capacitor, NP0 ceramic, silver-mica or other high stability type
C4	2 pF capacitor, NP0 ceramic, silver-mica or other high stability type
C5	0.02 µF capacitor
L1	Air-core inductor, six turns 22 gauge solid wire, 1/4" diameter, 1/2" long
X1	33 MHz third-overtone quartz crystal (optional)
BT1	12 volt A23 alkaline battery
Misc	N-cell battery holder, solid copper-clad PCB

Launch It!

On launch day, install the battery and tape it into place, then install the transmitter into the rocket with the battery holder's spring terminal towards the top (**Figure 3**). Check that the signal is being received clearly on your radio, then launch! You may hear distorted sounds from the beacon during launch in addition to the audio tone. This is caused by vibrations in L1 which provide additional frequency modulation, turning it into a crude microphone. If you installed a sensor, listen for any changes in the audio tone during flight and use a tape recorder to save this data for later use. Then, go find your rocket by following the beacon's signal! **NV**