A Pocket APRS Transmitter

Here's a great project for APRS. Its widespread use could save many lives

By Jim Hall, W4TVI, and Tony Barrett, N7MTZ

One day Tony, N7MTZ, walked into the shack and said "Wouldn't it be neat if we could build an inexpensive APRS transmitter that weighed only a few ounces, would operate off a 9 V battery for several days and had an integrated GPS interface? A transmitter like that would open APRS operation to a whole range of personal activities such as biking, hang gliding, backpacking, skiing or snowmobiling. It would also be a great asset for emergency or Search-and-Rescue situations.[1] Just put the transmitter and a GPS receiver on anything (person, vehicle, even a search dog) to automatically track it. (See Fig 1 and the sidebar, "An APRS "Killer App?") And it would be a natural for Near-Space ballooning.[2] The concept was so compelling that we immediately agreed we should attempt to build such a unit. The Pocket APRS Transmitter presented here is the result of our effort.

Discussions with other hams revealed that a Pocket APRS Transmitter is also good for those who can't justify the cost of a separate transceiver dedicated to APRS and those shy about interfacing an APRS encoder to their transceiver.

[1]Notes appear on page 11.

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Design Considerations

Transmitter design objectives:

- Output frequencies: 144.39 and 144.34 MHz (with crystal stability).
- An integrated APRS encoder for automatic position transmission.
- Low cost.
- Small size (fit in a standard mint tin with a 9-V battery).
- 200-250 mW output.
- Battery life: At least 4 days with a standard 9 volt alkaline battery.
- Simple to assemble, align and configure.
- Use modern, readily available parts.
- FM modulation: 5 kHz peak deviation with low distortion.
- Meet FCC spurious-emission requirements.

The RF output power requirement was a major question. The final output power goal was based on the need to minimize dc input power and the fact that most urban areas have a well-developed APRS repeater infrastructure. In such areas, APRS stations using handheld power levels have demonstrated good results. For emergency or other special situations out of repeater range, it is easy to configure a standard mobile APRS station to provide digi-peater capability.[1] For Near Space Ballooning, our local team has successfully used APRS transmitters with only a few hundred milliwatts of RF power to cover distances up to 200 miles on many of their flights.[2]

A second question was the architecture for the FM transmitter. We could have used a crystal oscillator followed by a phase modulator.[3] Experiments showed that the output frequency of a simple phase modulator would need to be multiplied by at least nine to achieve the required deviation with reasonably low distortion. This would mean using a 16 MHz crystal oscillator/phase modulator followed by at least two frequency-multiplier stages. Narrow-band filters would be required to reduce spurious frequencies to levels meeting FCC requirements. The required circuit complexity ruled out this approach for our application.

Another popular method uses a voltage controlled oscillator (VCO) operating directly at the desired output frequency, phase locked to a crystal oscillator.[3] Frequency modulation of the VCO is still possible at modulation frequencies greater than the feedback-loop bandwidth. RF filtering is simplified with this method, because RF is generated directly at the output frequency. This approach was selected for the Pocket APRS Transmitter.

Most modern electronic components and designs use surface-mount technology (SMT).[4] The small size of SMT components permits a more compact design, while improving electrical performance by reducing parasitic inductance and capacitance. SMT was a natural choice for this project, given our goal of a small pocket transmitter using modern, commercially available parts. We did, however, use through-hole parts where they were less expensive than SMT and readily available.

The TinyTrak3 (TT3) GPS position encoder (**www.byonics.com**) provides an off-the-shelf, single-chip interface between an external GPS receiver and the FM transmitter. Its power requirements are low and by using SMT parts, it was made to fit in less than half the board space of a standard through-hole TT3. This size reduction is accomplished even with a standard TT3 DIP packaged micro-controller. As a result, we were able to keep our TT3 circuit schematically identical to the standard through-hole TT3, use a genuine TT3 PIC, and support all TT3 features.

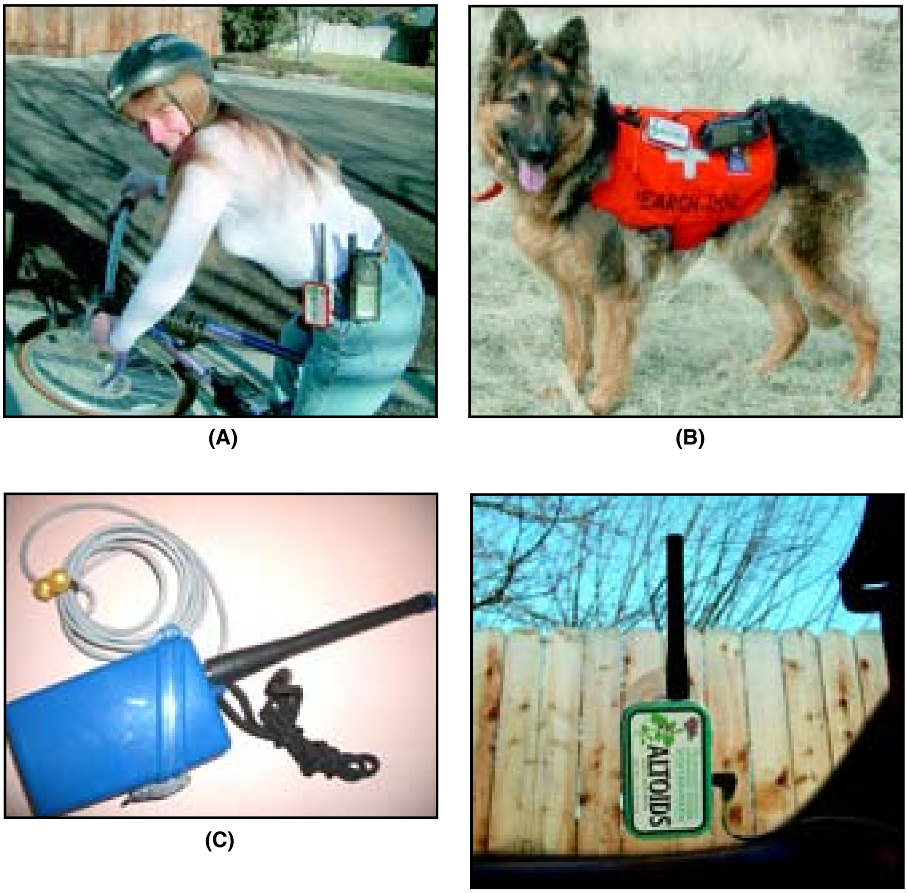
Fig 2C shows an internal view of the Pocket APRS Transmitter. The internal 9-V battery compartment is at the bottom of the photo. The TT3 is above that in the area dominated by its DIP micro-controller. The transmitter is at the top and occupies the area from the crystal to the BNC output connector.

Operation

Fig 3 shows a block diagram of the Pocket APRS Transmitter. The TT3 receives position data from an external GPS receiver and produces an audio signal representing the GPS position report in one of several user-selectable APRS packet data formats. This audio signal is applied to the FM pre-emphasis circuit, which attenuates lower audio frequencies, spreading modulation energy more evenly across the audio band. The output of the pre-emphasis circuit modulates the frequency of the VCO.

The VCO is a transistor oscillator operating directly at 144 MHz. It drives a single-stage 144 MHz amplifier. The amplifier output passes through a low-pass filter that attenuates harmonics of the desired 144 MHz signal and then through a diplexer circuit and finally to the RF output connector.

A sample of the VCO output drives



(A) (B) (C) (D)

Fig 1—At A, Tony's wife, Delora, prepares to go mountain biking with the Pocket APRS Transmitter at her waist. B shows a search dog, Xena, with the first attempt to secure a Pocket APRS Transmitter to her vest. The horizontal antenna isn't ideal, but it works over a mile and isn't likely to get caught on anything. The authors are thinking about a tag a user could remove so the TinyTrak3 would send a different status message. This is a standard feature of the Tinyrak3 / Pocket APRS Transmitter requiring only an added switch. Serious field work calls for a rugged, weatherproof package. C shows a weatherproof plastic case available at many sporting-goods stores for about $7. It includes an O-ring seal and the lanyard shown. The FPS receiver connects to the two-conductor cable. D shows a pocket tracker stuck to the inside of a vehicle window with suction cups. It has ridden there for thousands of miles. A similar arrangement with a $^{5}/_{8}$ λ antenna routinely reaches a directly to a digipeater 45 air miles away.

a PLL IC.[5] Fig 4 shows the PLL IC in more detail. In the IC, programmable frequency divider N divides the 144 MHz VCO signal down to 5 kHz. This 5 kHz signal is applied to input A of the phase detector. An 8 MHz crystal reference oscillator drives programmable frequency divider R, which divides the 8 MHz signal down to 5 kHz. This 5 kHz signal is applied to input B of the phase detector. The phase-detector output consists of pulses that vary in width and sign (positive or negative going) depending on whether input A is leading or lagging input B.

The PLL IC frequency dividers are controlled by a serial data input signal generated by a second dedicated PIC microcontroller. Each time the transmitter is keyed by the TT3, this PIC generates a serial data stream, programming the N and R dividers as well as other PLL IC parameters. The R divider is set to divide by 1600 (8 MHz reference divided by 5 kHz). For an output frequency of 144.39 MHz (the most popular APRS 2 meter operating frequency), the N divider is set to divide by 28,878 (144.39 MHz divided by 5 kHz).

The output of the phase detector passes through a 120 Hz active low-pass filter. This filter attenuates the fundamental and harmonics of the phase detector output pulses and delivers a dc voltage proportional to the phase difference between the two 5-kHz phase-detector inputs. Since these 5 kHz signals are derived from the 144 MHz VCO and 8 MHz crystal reference oscillator, the active-filter dc output is also proportional to the phase difference between these two signals.

The dc output of the active filter drives voltage-variable capacitors (Varactor diodes[6]) that are part of the VCO frequency-determining circuit. Increasing the Varactor voltage increases the VCO frequency, while decreasing it decreases the VCO frequency.

When the VCO starts to drift upward in frequency, the phase of its output will start to lead that of the reference frequency by an increasing amount. The phase detector is programmed to decrease the VCO Varactor voltage, tuning the VCO back down to the desired frequency. Similarly, if the VCO starts to drift downward in frequency, the Varactor voltage increases, tuning the VCO back up to the desired frequency. In this way, the feedback loop formed by the VCO, PLL IC and active filter, locks the VCO into a fixed frequency

(A)

(B)

(C)

Fig 2—Views of the project. A is an outside view of the Pocket APRS Transmitter with antenna and GPS receiver. B shows a side view with the GPS port jack. C is an internal view of the Pocket APRS Transmitter.

An APRS "Killer App?"

Have you heard the term "Killer App"? It's an application that brings hitherto underused technology into common usage. For example, one could argue that Microsoft *Office* was a "killer app" for the *Windows* operating system.

Scene 1: APRS began when hams wanted to track the progress of the runner who makes the trek from Annapolis to West Point for the annual Army versus Navy football game. Since then, it has developed into a fascinating Amateur Radio activity used by hams to report their positions or those of their vehicles to other hams or Web sites. While this is fun, it is not a *compelling* use for the technology.

Scene 2: Some years ago, as I was driving to ARRL HQ for work, I heard a news story about a fire at a group home in Hartford, Connecticut. Medical attention was delayed for some of the injured because the Emergency Medical Technicians (EMTs) had trouble locating the patients at the site.

I had a vision. If we had small, inexpensive APRS transmitters, they could be distributed to police and fire departments. Then, police or firefighters could place them with injured persons. EMTs with cell-phones and notebook computers could read the positions from APRS Web sites and use GPS location to navigate within a few feet of those needing medical attention.

Scene 3: Jim Hall, W7TVI, and Tony Barrett, W7MTZ, develop the Pocket APRS Transmitter for search and rescue work in the Pacific Northwest. Mass production of the pocket transmitter could make it inexpensive enough for the vision to become reality.—*Bob Schetgen, KU7G, QEX Managing Editor* relationship with the crystal controlled reference oscillator.

Design

The schematic for the Pocket APRS Transmitter is shown in Fig 5. The VCO consists of Q4 and its associated circuitry. The common-collector configuration in conjunction with base-to-emitter capacitor C27 produces a negative resistance looking into the base of Q4. The series-tuned circuit at the base of Q4 determines the oscillation frequency. This tuned circuit consists of the capacitance formed by C26 in parallel with the series combination of C25 and the two Varactor diodes (D9) plus inductor L3. A quite linear frequency versus diode voltage characteristic is obtained by using hyperabrupt Varactor diodes (capacitance nearly proportional to the square of the applied voltage) for D9. RF choke L1 provides a dc path for bias to D9, but it isolates D9 from the active filter and pre-emphasis network at RF frequencies. L2 completes the dc path for the upper diode in D9.

The nominal operating frequency of the VCO is adjusted using slug-tuned coil L3, with +2.5 V applied to D9. The sensitivity of the Varactor circuit is such that the VCO frequency varies by about 450 kHz for a 1 V change in the voltage applied to D9. It was a conscious decision to set the VCO frequency sensitivity so. The transmitter circuits operate from a 5-V supply, which limits the D9 drive-voltage range. It's from about +0.5 V to +4.5 V. This voltage range must tune the VCO frequency far enough to compensate for frequency variations caused by temperature, vibration, antenna SWR and voltage. On the other hand, the frequency sensitivity should not be too great, as that can introduce undesired FM noise. 450 kHz per volt was chosen as a good compromise.

The VCO output is taken from the emitter of Q4. C28 was chosen to optimize power transfer from Q4 to the 50 Ω (nominal) input impedance of the following circuitry. RF choke L6 isolates the RF output from R27. The RF power output of the VCO is around +14 dBm into 50 Ω.

The VCO RF output is coupled via a resistive divider (R29 and R30) to the input of a common-emitter RF amplifier Q5, which operates as Class C. Inductive emitter degeneration (L10) helps stabilize operation against changes in drive power and output loading. The input impedance of Q5 is a series R C circuit. L7 tunes out the capacitive component, yielding a resistive input impedance. R30 also provides the dc path to ground for Q5 base current.

The collector of Q5 is isolated from the power supply at RF by the parallel-resonant circuit L9/C30. The combination of L8 and R31 provide a resistive collector termination at frequencies between 3 and 50 MHz, eliminating a tendency of Q5 to oscillate at those frequencies.

The RF output of Q5 passes through a standard five-section, 0.25 dB-ripple Chebychev low-pass filter that ensures all harmonics are at least 45 dB below the 144 MHz fundamental. The first inductor in the filter (L11) was modified slightly (65 nH, not the theoretical 73 nH) to provide a collector load of about 40 Ω, maximizing RF power output. The output of the low-pass filter connects to a simple diplexer[3] circuit (L13, R32, C35) that resistively terminates the low-pass filter at frequencies below 50 MHz. This further reduces any tendency of Q5 to oscillate at low frequencies. The 144 MHz output signal passes through the diplexer to the BNC output connector with minimal loss. The RF output power delivered to a 50 Ω load is typically around 200 mW.

A sample of the VCO output is taken via R28, supplying the N divider input for the PLL IC (U4 pin 4). An 8-MHz crystal (×1), connected between U4 pins 1 and 2, determines the PLL reference frequency. The crystal we used is specified to oscillate in parallel resonance at 8.0 MHz with a 20 pF load. The actual oscillation frequency was measured to be about 1.1 kHz high. This is largely because the actual crystal load capacity obtained with the series combination of C9 and C10 in parallel with the input capacity of U4 is only about 15.7 pF. It is impossible to increase the crystal loading to 20 pF without exceeding the maximum value (30 pF) allowed by the PLL data sheet for C9 and C10. Programming U4 with a slightly lower N

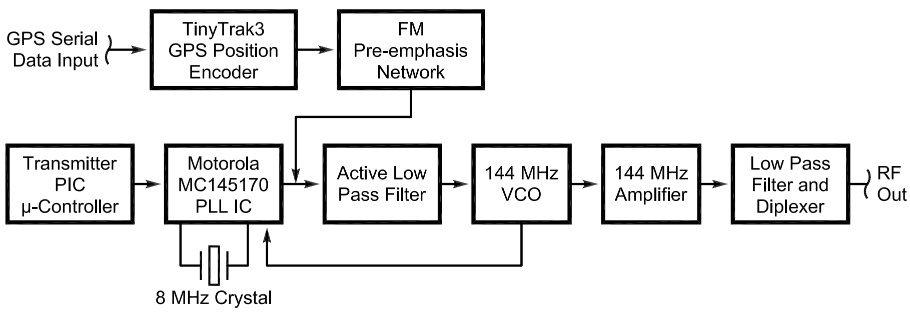


Fig 3—Pocket APRS Transmitter simplified block diagram.

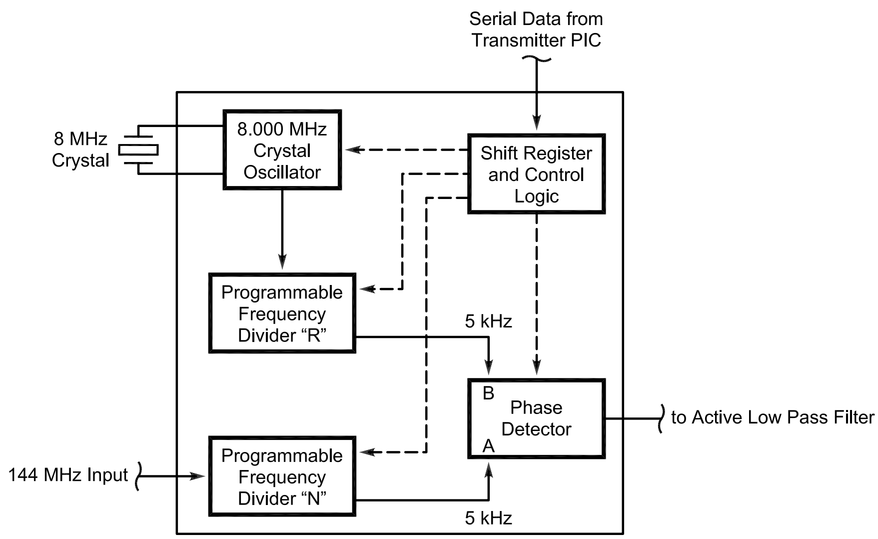


Fig 4—A simplified block diagram of the Motorola MC145170 PLL IC.

division ratio compensates for this and other frequency inaccuracies caused by the crystal. Although this means the phase-detector input isn't at exactly 5 kHz, this is of no practical consequence.

The PLL IC memory is volatile and must be reprogrammed each time the TT3 applies power to the transmitter. This is accomplished with an inexpensive PIC micro-controller (U6). The PIC is programmed for the transmitter to operate on either of two popular APRS frequencies. With no connection to U6 pin 7, the internal U6 pull-up resistor holds pin 7 high, and the transmitter operates on 144.390 MHz. 144.340 MHz operation is selected by grounding this pin. Different frequencies can be selected by modifying the PIC firmware.[7] The only constraint is that the two frequencies selected should be within about 150 kHz of each other to ensure enough tuning range remains to compensate for environmental changes in VCO frequency.

Theoretically, the TT3 chip could perform the functions of U6 in addition to its normal GPS position-encoding duties. However, this would require a non-standard TT3 chip and could easily add more incremental cost than the cost of U6.

The phase-detector output (U4 pin 13) drives active low-pass filter U5a. This filter is a 2 pole, multiple feedback (MFB), Butterworth design with a 3 dB bandwidth of 120 Hz and a dc gain of 5.3. This filter was designed using *FilterPro*, (available for free download at **www.ti.com**). The non-inverting input to U5a is biased with a fixed +2.5 V from voltage divider R18, R19. When the VCO is tuned to the programmed operating frequency with L3: the phase detector output is +2.5 V, the active filter output (U5a pin 1) is +2.5 V and the voltage applied to VCO Varactor (D9) is +2.5 V. When the VCO starts to drift off frequency, the varactor bias is changed up or down to maintain the correct frequency as determined by dividers N and R.

Actual operation of the PLL is a bit more complex than the simple description given above. In control system terminology, the feedback loop used in this transmitter is a Type 1 system (one loop integration). This type of feedback system forces the two frequencies at the input of the phase detector to be exactly equal. However, a static phase difference is allowed between the two phase-detector input

Table 1
Parts List

C15—470 nF ±2% metalized polypropylene [BC2083-ND].
C16—22 nF ±2% metalized polypropylene [BC2144-ND].
C22—1 nF ±2% metalized polypropylene [BC2177-ND].
C23—100 nF ±2% metalized polypropylene [BC2054-ND].
C32, C34—30 pF mica ±5% [338-1056-ND].
C33—47 pF mica ±5% [338-1053-ND].
D8—Diode, silicon, 1A, 200V [1N4003MSCT-ND].
J4, J9, J11—Jumper shunts with handles [A26242-ND].
J8—3-Conductor stereo 3/32" subminiature phone jack RadioShack 274-245.
J10—9-V battery clip (123-5006).
J12—BNC connector, female Allied Electronics 713-9085.
L1, L2, L4, L5, L6, L8—3.3 µH ±10%, axial molded unshielded choke [DN2532-ND].
L3—6.5 turn, unshielded variable inductor (434-1012-6.5C).
L7—0.12 µH ±10%, axial molded unshielded choke [DN2596-ND].
L9—0.1 µH ±10%, axial molded unshielded choke [DN2594-ND].
L10—5 nH, 26 AWG wire, see instructions at **www.byonics.com/pockettracker**. Form using #26 AWG wire listed below.
L11—65 nH, #20 AWG magnet wire, 3 inches, 3 turns on 3/16" drill. Wind using #20 AWG wire below.
L12—73 nH, #20 magnet wire, 3", 3 turns on 13/64" drill. Wind using #20 AWG wire below.
L13—0.22 µH ±10%, axial molded unshielded choke [M9R22-ND].
U1—PIC 16F628-20/p programmed with TinyTrak3 firmware version 1.1 Available at **www.byonics.com**.
UX1—18-pin DIP socket (571-3902615).
X1—8.000-MHz crystal, 20 pF, HC-49/UA [X021-ND].
Y1—10-MHz ceramic resonator [X906-ND].

Miscellaneous parts included in the kit:
12-pin strip of breakaway header posts, square 25 mil (517-2312-6111TG).
#20 AWG polyurethane coated magnet wire, 6.0 inches long, Allied Electronics 293-0316.
#26 AWG black wire, 4 inches long [K386-ND].
#26 AWG red wire, 4 inches long [K387-ND].
#26 AWG yellow wire, 6 inches long [K388-ND].
#26 AWG blue wire, 4 inches long [K327-ND].
#26 AWG white wire, 4 inches long [K389-ND].
RF shield plate, 10-mil-thick tin plated copper, 0.941×0.560 inches, chemically milled. Custom fabricated, contact N7MTZ*.
Battery pad (top), 1/8" thick gray foam, 0.8"×1.5", adhesive backed custom fabricated, contact N7MTZ*.
Battery pad (side), 1/8" thick gray foam, 0.75" × 2.8", adhesive backed custom fabricated, contact N7MTZ*.
Lid label, printed, laminated, adhesive backed custom fabricated, contact N7MTZ*.
Insulating liner material, 3.8"×2.5" white polycarbonate, 5 mils thick, printed and punched custom fabricated, contact N7MTZ*.
#4-40 ×3/8" long flathead screws (3), nuts (6), lockwashers (3) from The Nutty Company, PO Box 473, 135 Main St (Rte 34), Derby, CT 06418; Toll Free 800-4-NUTTY, 1 (800-468-8891), (203) 734-1604, fax (203) 735-1097; **www.nuttycompany.com**; e-mail **sales@nuttycom.**

Notes
Part numbers in (parenthesis) are for Mouser. Part numbers in [brackets] are for Digi-Key.
A complete set of parts, including U1, is available as a kit from **www.byonics.com**. The kit does not include: battery, tin, antenna, GPS receiver, PC / GPS cable(s) and connectors. Check the Web site for availability.
*A PC Board is available with all surface-mount parts soldered in place, including a programmed U6. Contact N7MTZ via e-mail at: **tonybarrett@sunvalley.net**.

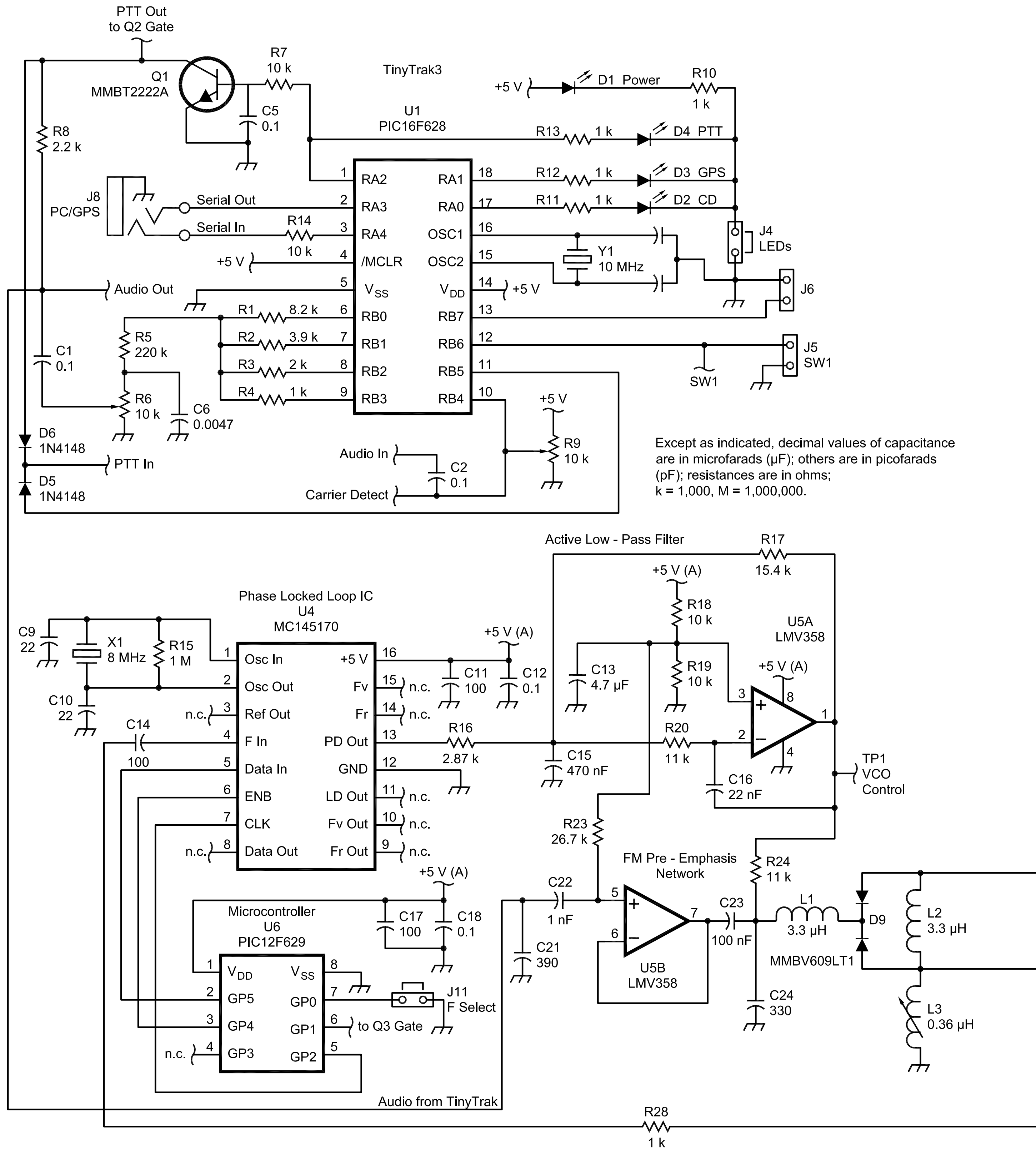
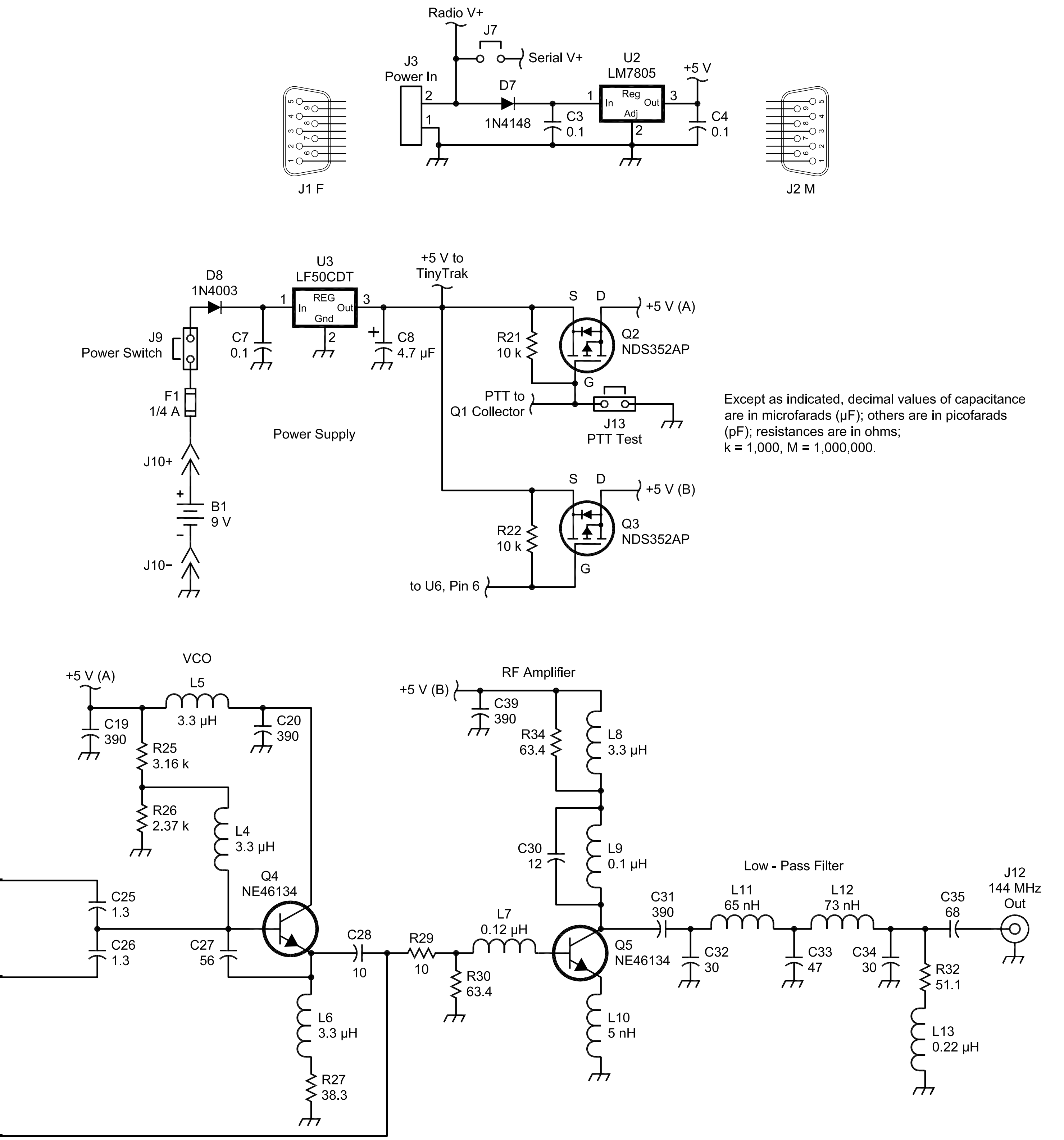


Fig 5—The Pocket APRS Transmitter schematic. Table 1 is a parts list. Traces and pads are on the PCB for C2, C3, C6, D1, D2, D5, D6, D7, J1, J2, J3, J5, J6, R8, R9, R10, R11and U2 but these parts are not included with the Byonics PCB. If loaded, J1 and J2 can be wired as the user desires.


Radio V+
J7
Serial V+
J3
Power In
D7
1N4148
C3
0.1
U2
LM7805
Reg
In
Out
Adj
+5 V
C4
0.1
J1 F
J2 M
D8
1N4003
U3
LF50CDT
REG
In
Out
Gnd
+5 V to
TinyTrak
C7
0.1
C8
4.7 µF
J9
Power Switch
F1
1/4 A
J10+
B1
9 V
J10−
Power Supply
S
D
G
+5 V (A)
R21
10 k
Q2
NDS352AP
PTT to
Q1 Collector
J13
PTT Test
+5 V (B)
R22
10 k
Q3
NDS352AP
to U6, Pin 6
Except as indicated, decimal values of capacitance are in microfarads (µF); others are in picofarads (pF); resistances are in ohms;
k = 1,000, M = 1,000,000.
VCO
+5 V (A)
L5
3.3 µH
C19
390
C20
390
R25
3.16 k
R26
2.37 k
L4
3.3 µH
Q4
NE46134
C25
1.3
C26
1.3
C27
56
C28
10
L6
3.3 µH
R27
38.3
RF Amplifier
+5 V (B)
C39
390
R34
63.4
L8
3.3 µH
C30
12
L9
0.1 µH
R29
10
R30
63.4
L7
0.12 µH
Q5
NE46134
L10
5 nH
C31
390
Low - Pass Filter
L11
65 nH
L12
73 nH
C32
30
C33
47
C34
30
C35
68
J12
144 MHz
Out
R32
51.1
L13
0.22 µH

signals. In this design, the phase difference increases to about 54° when the VCO frequency is corrected by 900 kHz. A Type 2 loop, more typically used for PLL applications, has two loop integrations and holds the phase of the signals at the two phase detector inputs exactly equal. We used a Type 1 feedback loop because it is simpler, easier to design and provides more than adequate performance for this application.

The FM sensitivity of the VCO is constant as modulation frequency changes. Therefore the *phase* deviation sensitivity of the VCO (and PLL loop gain) decreases at 6 dB/octive with increasing modulation frequency (remember, phase deviation = frequency deviation divided by modulation frequency), equivalent to a single loop integration. For the chosen dc gain, the loop gain crosses through unity (0 dB) at 33 Hz.

The phase-detector output contains a strong 5-kHz component that must be removed to prevent it from modulating the VCO and generating spurious sidebands at multiples of 5 kHz. The 120 Hz Active LP Filter attenuates this 5 kHz component by about 64 dB. The R-C filter formed by R24 and C23 in parallel with C24 (for signals originating in the active filter, the end of C23 attached to U5b pin 7 is effectively grounded) attenuates the 5-kHz component by another 30 dB. The total attenuation of 94 dB reduces all spurious 5-kHz sidebands to a level that is too low to measure.

Another major consideration in designing the PLL feedback system is phase margin. At the system unity-gain frequency of 33 Hz, the excess phase shift through the active filter is 23°. The R24, C23, C24 circuit adds 13° of phase shift at 33 Hz. The 6dB/octive rolloff in VCO phase deviation sensitivity adds 90° of phase shift. Therefore, the total loop phase shift at 33 Hz is 126°, resulting in good phase margin for the feedback loop.

The final consideration in the feedback system is the method for coupling APRS audio to the VCO. Audio from the TT3 first passes through the high-pass circuit formed by C22, R23 and voltage follower U5b. This circuit boosts the amplitude of the 2200 Hz APRS tone by a factor of 1.6 compared to the 1200 Hz tone, in compliance with FM pre-emphasis standards. C21 bypasses the input of U5b at RF but has negligible effect at AF. C23 couples the voltage follower audio output to Varactor diode pair D9. The PLL feedback system does not affect VCO modulation of the APRS audio tones because its 33 Hz bandwidth is much less than the lowest tone frequency of 1200 Hz.

The power-supply regulator circuit consists of reverse voltage protection diode D8 and voltage regulator U3. U3 is a low drop-out voltage regulator. It has a maximum drop-out voltage of 0.35 V. This, plus the maximum drop of 0.8 V across diode D8, means the regulator will still provide well regulated 5 V for supply voltages as low as 6.2 V. Supply voltages as high as 16 V can be used while maintaining the regulator junction temperature well below its maximum rating. No external heatsink is required, even for ambient temperatures as high as 150°F.

Power Sequencing

Proper design of the power sequencing circuit was critical for long battery life. When power is applied to the Pocket APRS Transmitter, U3 supplies regulated +5 V at about 4 mA to the TT3 circuitry. This assumes the TT3 LEDs are off. Since each LED consumes about 3 mA, they have a significant impact on power drain and battery life. Therefore, for maximum battery life, install LED jumper J4 only when checking TT3 status, then remove it during normal operation.

At user-defined intervals, the TT3 keys the transmitter to send APRS data. To do this, the TT3 turns on Q1, grounding the gate of Q2, which then supplies +5 V at a total current of about 36 mA to the PIC (U6), PLL IC (U4), active filter/pre-emphasis circuits (U5) and the VCO. After U6 goes through its power-on sequence, which takes about 72 ms, it programs the PLL IC to the correct frequency, taking an additional 20 ms. After another delay of about 40 ms to insure that the VCO frequency has stabilized, pin 6 of U6 goes low, turning on Q3 and supplying +5 V to the RF amplifier. After turning on Q3, U6 goes into sleep mode, drawing only a few microamperes. At this time, APRS data is transmitted, and the total dc supply current increases to about 110 mA. About 440 ms later (typical, assuming that the default TT3 Auto transmit Delay is set), the TT3 turns Q1 off, removing power from everything except the regulator and the TT3.

In summary, here's a power-supply current profile:

When APRS data is not being transmitted = 4 mA (TT3 plus U3 regulator, LED jumper J4 open)

Each time APRS data is transmitted:

Total supply current = 40 mA for 132 ms

Total supply current = 110 mA for 440 ms (typical)

The default TT3 configuration transmits position data once every two minutes, resulting in an average power-supply current of 4.4 mA. With this average current, the Pocket APRS Transmitter can operate from a standard 9 V alkaline battery for about 120 hours . In fact, even if position data is transmitted once per minute, the demonstrated battery life is over 100 hours.

Construction, Packaging and Options

There are several options for constructing the Pocket APRS Transmitter. A complete set of parts including the PC board with all surface-mount parts soldered in place is available at **www.byonics.com/pockettracker**. The bare PC board or the PC assembly with all surface-mount components soldered in place is available by contacting N7MTZ via the link at **www.byonics.com/pockettracker**. (Scroll to the bottom of the Web page.) Complete, step-by-step instructions for constructing the transmitter can be downloaded from **www.byonics.com/pockettracker**.

For our "pocket tracking" application, small size was important, leading us to package the PC board and battery in a 2.4×3.4×0.8-inch breath-mint can. You can use any enclosure or power source suitable for your application. The power source should be between +16 and 6.2 V and capable of supplying at least 120 mA. Make sure your enclosure contains a shielded compartment for the PC board to minimize VCO detuning by changes in the environment.

The set of parts available at **www.byonics.com/pockettracker** supports the basic APRS functions of automatic position transmission and "Smart Beaching". If the additional parts noted on the schematic (Fig 5) are loaded, the TT3 is completely equivalent to a normal Byonics TT3, giving additional functionality. A parts list, parts kit and loading instructions for adding these optional components is available on request by contacting N7MTZ via the link given at **www.byonics.com/pockettracker**.

The Pocket APRS Transmitter can send weather-station data via the APRS weather protocol[8] if you substitute the Byonics WXTrak chip for the TT3 GPS position-encoder chip.

Alignment and Testing

1. Connect the transmitter RF output to a 50 Ω dummy load.

2. Set the transmitter deviation to

≈4 kHz by adjusting R6 for a resistance of 2.8 kΩ as measured from its wiper (test pad marked D at the edge of the board near U1 pin 9) to ground.

3. Connect a 9 V battery to the battery clip. Make sure that jumper J9 is in the "on" position.

4. Configure the TT3 to transmit your callsign each time data is transmitted. To enter your callsign or to modify any of the other TT3 default settings, use the *TinyTrak3Config.exe* program. To get this program, download TINYTRAK3.zip from **www.byonics.com/tinytrak**. Extract all the files from the zip file. One of the extracted files will be the *TinyTrak3 Owner's Manual*. The document contains detailed configuration, adjustment and troubleshooting information. One of the other extracted files will be the *TinyTrak3Config.exe* program. Launch this program and follow the instructions in the *TinyTrak3 Owner's Manual* to configure your call sign or other settings.

5. Make the following adjustments with jumper J13 (at the point marked T on the PC board) in place. This ties the collector of Q1 to ground, thereby applying +5 V continuously to all of the transmitter circuits. Note that the TT3 will periodically transmit APRS data during the following adjustments. In addition, the enclosure lid should be closed for the following adjustments, since it affects VCO tuning.

Put the Frequency Select jumper (J11) on the pair of pins near the number 9 at the 3-pin connector marked FS. This selects 144.39 MHz operation.

Tune a 2-meter receiver to 144.39 MHz. With the lid closed, the tuning slug for L3 can be reached through an access hole in the back of the transmitter. Slowly tune L3 until you can hear a signal in the receiver.

Wait until you hear an unmodu-lated carrier in the 2-meter receiver, then measure the voltage at the VCO Control Test Point, which can be reached from the back of the transmitter through the other access hole described in the assembly instructions. Carefully adjust L3 for a reading of +2.5 ±0.2 V.

6. Move the Frequency Select Jumper (J11) to the pair of pins near the number 4 at the three-pin connector marked FS to select 144.34 MHz operation.

Important: Remove, then reinstall power jumper J9 to reprogram the PLL IC to 144.34 MHz. Remember that the PLL chip is only reprogrammed when the power is cycled.

7. Tune the 2 meter receiver to 144.34 MHz and confirm that the transmitter is now operating on that frequency.

8. If necessary, change the Frequency Select Jumper (J11) to select the desired operating frequency.

9. Remove jumper J13, allowing the TT3 to control the transmitter.

The RF amplifier isolates the VCO from the antenna, minimizing any detuning from changes in antenna impedance. However, if you expect the transmitter to experience extreme changes in temperature (for example, when "Near Space Balloon Tracking"), it may be prudent to maximize the PLL locking range. You can do this by adjusting VCO L3, as described in "Alignment and Testing", with the RF output BNC connected to the same antenna you will use when operating the transmitter.

Summary

Developing the Pocket APRS Transmitter was a fun project. It makes APRS tracking practical for many exciting applications where conventional approaches don't work well because of size, weight, cost or battery constraints. It was not designed to address every APRS application, however.

If the Pocket APRS Transmitter fits your requirements, try it. It can be a refreshing experience, especially if you package it in a breath mint can.

Jim Hall, W4TVI, grew up in Halifax, Virginia, earning his Novice license in 1951 at age 14. He upgraded to General the next year and later to Extra.

Jim received a BSEE from North Carolina State and an MS in physics from Lynchburg College. After college, he spent 13 years designing communications systems for General Electric. In 1972, he joined Hewlett Packard and designed communications and microwave test equipment. In 1976, Jim became R&D manager for HP's first laser printer. When he retired in 2000, he was responsible for all HP LaserJet printer R&D. Jim now enjoys electronics design, his grandchildren and travel You can contact him at **w4tvi@arrl.net**.

Tony, N7MTZ has been a ham for 15 years and his main interest for the last few years has been APRS. Before the APRS bug bit, he enjoyed building and operating ATV transmitters. Two years ago, one of his winter projects was to build a digipeater that was installed on a nearby mountain top when the snow cleared the following summer. He's an active local ham club member and a long-time supporter of ARES and RACES. He helps out with numerous public-service events, and for the past year he's concentrated on bringing the most valuable technology to Search And Rescue teams. The Pocket APRS Transmitter was conceived during a five-day search for some lost snowmobilers in March of 2003. He likes to participate in "Near Space" balloon missions (Pocket Trackers were developed with this application in mind) and he is very interested in the design, test, and operation of autonomous Unmanned Aerial Vehicles.

Notes

[1] J. Lehman, KD6DHB, "APRS and Search and Rescue," *QST*, Sep 2003, pp 75-77.

[2] L. Verhage, KD4STH, "Ham Radio Ballooning to Near Space," *QST*, Jan 1999, pp 28-32.

[3] 2004 *ARRL Handbook* (Newington, Connecticut: ARRL, 2003), Chapter 15 "Mixers, Modulators and Demodulators."

[4] 2004 *ARRL Handbook,* Chapter 25 "Circuit Construction."

[5] 2004 *ARRL Handbook*, Chapter 14 "AC/RF Sources."

[6] 2004 *ARRL Handbook*, Chapter 8 "Analog Signal Theory and Components."

[7] Firmware listing for the PIC (U6) is available at **www.byonics.com/pockettracker**.

[8] R. Parry, W9IF, "Amateur Radio, Paragliding and an APRS Weather Station," *QST*, Aug 2003, pp 28-33.