Unique Features of the TAPR TNC

by Lyle Johnson, WA7GXD
c/o Tucson Amateur Packet Radio Corp
P.O. Box 22888
Tucson AZ 85734

Background

The Tucson Amateur Packet Radio (TAPR) Terminal Node Controller (TNC) began as a local project done by a handful of Tucson-area Amateurs late in 1981. The project attracted enough attention to cause the formation of a formal club as well as an enlarged number of participants. As interest continued to grow, TAPR incorporated as a non-profit R&D group, and the TNC project changed from a local effort to include active participation in the design, implementation and testing phases with Amateurs from the West Coast to the Northeast.

The original Alpha-level TNC, of which only a dozen kits were distributed, led to the development of the current Beta-level TNC, now undergoing testing in dozens of sites, with site sizes ranging from three to over twenty stations. The total Beta distribution is approximately 175 preassembled TNCs.

While there have been, and continue to be, many other methods of getting involved with Packet activity, the TAPR TNC offers a number of unique features that are worth noting. It is the intent of the author that this paper accent those features, and it is the hope of TAPR that other exnerimenters may benefit from the experience and insight gained by the TAPR effort.

System Design

The TNC was designed as part of a system to allow an individual Amateur station to operate using the Packet mode with a minimum of integration problems. To this end, the required radio and terminal/computer interfaces are as general as possible. All I/O areas of the physical PC board surround a user wire-wrap area to allow for custom configuration. Further, the wire-wrap section has all significant power supply rails bordering one side.

Since it was designed as a system component, a radio-oriented MODEM (modulator-demodulator) is included on-board. To minimize the software design effort that might otherwise be required, an on-board microcomputer was designed to handle all aspects of lower-layered protocol implementation, with special emphasis in hardware to allow operation in an Amateur radio environment,.

In any microprocessor- based device, software is a very important consideration. Consistent with the TAPR philosophy of modular flexibility, considerable efforts were made in hardware design to accomodate the desires of the software groups. Parallel software efforts were made, with the Pascal-based implementation of the "standard" protocol adopted in Washington on October 10, 1982, being initially distributed with the Beta TNCs. A FORTH- based design, implementing a dynamic addressing level-two protocol, -is in process of being integrated on the TNC for the Beta testing phase.

Without proper documentation, most equipment is either rendered useless, or requires an inordinate amount of operator interaction to discover its "secrets." TAPR determined early on to provide as complete a manual set as was practical.

Finally, since it is generally conceded that Packet radio is in its infancy, the TNC design group made particular efforts to ensure flexibility as well as capacity for expansion.

MODEM Design

The MODEM incorporated in the TNC is designed for compatibility with the de facto standard Bell 203 tone pair, 1200 and 2200 Hz, using simple AFSK at a maximum data rate of 1200 baud.

The tone generator is straightforward, using the Exar 2206 FSK IC in a low-distortion, sine-wave configuration. The output is buffered by a simple +1 op- amp circuit, then ac- coupled to the radio interface connector. The output amplitude is user settable via a twenty- turn trimpot over a range from millivolts to volts.

During early experiments with the TNC, it was discovered that the WD 1933 HDLC controller did not allow direct control of the output state of its Tx Data pin when used in the NRZI mode. This complicated the issue of the US-required CW identification. In the end, use was made of the Exar 2206's analog multiplier input to allow for tone on-off keying of the CW ID. This input is buffered by a TTL inverter, allowing the tone state to be set under software control, independent of any other MODEM parameter.

The tone generator frequencies are easily changed via adjustment of individual twenty-turn trimpots. To facilitate such adjustment, the TYC hardware includes, and the present software supports, a frequency counter. This is a programmable 16-bit counter/timer used by the calibration routines as a period measurement timer. The software is designed such that the user may calibrate almost any frequency within the range of 10 Hz to over 230 kHz. The resolution is +/- 1.08 uSecs (one cycle of the system master clock of 921.6 kHz).

Although not strictly a MODEM function, control of the transmit control line is a necessary feature of the radio transmitter interface. To help prevent a "glitch" from allowing the TNC to lock up a radio frequency by continual assertion of the transmit control line, a monostable multivibrator, or "one-shot", is in series with the software- controlled transmit command line. A time constant of about 14-seconds allows a multiple- frame Packet transmission at the "normal" VHF packet rate of 1200 baud, along with a CWID of a typical Amateur call sign at 20 WPM. The particular circuit implemented utilizes a 555 timer IC in a non- retriggerable configuration. Non- retriggerable simply means that the 14- second timeout can't be held "on" by a continuous input -- the input must be removed before the 555 will accept another trigger. Thus, a Packet "channel" is protected from a runaway transmitter with minimal impact on system performance.

On the receive side, an Exar 2211 phase-locked loop (PLL) FSK demodulator is used. This circuit has a wide dynamic range input circuit (3 mV to 3-volts), and features both data and "carrier detect" outputs. (Note that the carrier referred to is the audio subcarrier, not the rf carrier.)

The circuit parameters have been optimized for operation at a data rate of 1200-baud, utilizing simple FSK with tones of 1200 Hz and 2200 Hz. After initial design, extensive testing was conducted and the circuit values "tweaked" for best operation. A few problems cropped up that may be of interest to others experimenting with similar MODEM designs.

The XR2211 chip is very sensitive to amplitude differences of the two input frquencies greater than about 3 db. At 6 db, the PLL will take so long to lock as to render the channel inoperative at the desired baud rate. Specifically, TAPR found that a typical 2-meter FM transceiver would not operate reliably above about 450 baud with the XR2211 used in an uncompensated circuit, while 1200 baud was easily realized in a compensated one. Various means of compensation were tried, and the best appeared to be an active filter. A CMOS switched capacitor filter was implemented, with a DIP header carrying the resistor network needed to configure the filter for a particular radio. The DIP header allows easy reconfiguration. This design is presented in detail in another paper in these proceedings.

In addition, a means of operator feedback for receiver audio level setting was deemed desireable, to prevent overloading of the filter while maintaining sufficient audio to prevent serious degradation of the s/n ratio. This was implemented with a simple back- to- back LED pair between the audio input buffer (a -10 amplifier) and the filter input network. Initial results from the field indicate this method to be both easy to use and effective.

Microcomputer

The TNC uses a 6809- based controller for logic implementation. This is believed to be the first, Amateur radio application of the 6809 apart from individual efforts. The architecture of this microprocessor (uP) lends itself readily to high level, block-structured programming environments, and the first cut of TNC software is in fact written in Pascal.

The memory subsystem of the TNC utilizes a six- site bank of 2% pin sockets configured in the JEDEC "two line control" bytewide standard. This means that RAM, ROM, EPROM and/or EEPROY may occupy any socket. In addition, the memory may occupy any integral multiple of 2k- bytes capacity. To allow for future memory devices of greater density than used in the current TNC configuration, the memory map was carefully planned and executed in a bipolar Shottky PROY decoder.

The initial TNC consists of 6k- bytes of RAM contiguous from address 0, 4k-bytes of I/O space starting from address 2000H, and 24k- bytes of EPROM contiguous from address 0A000H through 0FFFFH. 2k-byte RAMs are used, along with 8k- byte EPROMs. 8k- byte RAMs can easily be accomodated, and 16k- byte and larger EPROMs can be used with a simple one- pin jumper (the socket wiring is presently compatible with 2764 and smaller EPROMs -- the one- pin change will make them compatible with 2764 and larger EPROMs). One Beta tester is building a piggyback adapter to utilize all 64k- bytes of address space.

Another unique aspect of memory design is the incorporation of the Xicor NOVRAM. This is a 256-bit device that can be accessed as a normal RAM (access time 300 nSec) as well as a 5- volt only EEPROM. This allows the user to store such parameters as station call sign, serial port parameters, HDLC **port** parameters, etc., and have the information retained after power is removed. However, the **user** can also change these parameters interactively. This provides a significant degree of freedom for the operator / experimenter, and is believed to be a first in Amateur radio.

Software Considerations

The Beta TNC is designed to support a variety of protocols by virtue of its large address space and third- generation UP. The initial Beta release software, discussed in much greater detail elsewhere in these proceed ings, was designed to be compatible with the existing "Vancouver" protocol as **well** as implementing the lower layers of the AMRAD sponsored "AX. 25" protocol adopted by the major US Packet groups in Washington, DC, on October 10, 1982.

The software package produced not only supports these modes, but it also supports operation of the TNC as a digipeater under either of the two protocols as well as a beacon (under either protocol). The TNC can in fact be used as all three of the above devices simultaneously, the only limit being that all functions must be under either one **or** the other of the two supported protocols, but not both.

Further, the software package supports certain powerful trace and debugging modes, which have proven to be of extreme value during system troubleshooting.

Other Features

The TNC design provides for software configuration of nearly every parameter associated with the I/O ports. **For** the serial (RS-232) channel, these parameters include baud **rate,** number of stop bits, **parity** options and data word length. **For** the HDLC port, the baud **rate is** under software control-, using a 16-bit programmable timer. This allows using nonstandard data **rates,** such as the 400 baud being considered for experiments on the upcoming Phase 3B AMICON channel.

The parallel I/O port, to be supported in an upcoming revision to the Beta test software, is a full handshaking **parallel** interface, with **separate** S-bit channels for input and output . Further- , an EPROM programming adapter is being readied to allow users to bootstrap themselves along in software development and **distribution**.

Documentation

The TNC Beta document is a very comprehensive manual, both of the TAPR TNC in particular and Packet radio operation in general.

Over 140 pages in length, it includes chapters on setting up, operation and calibration, as well. as in- depth discussions of the hardware, protocol and system design. It sets a standard seldom seen in manuals accompanying very expensive Amateur equipment, and far exceeds what many have come to deplore as "manuals" for the more common Amateur radio devices,

The Beta Test manual is currently in a state of rapid expansion as reports come in from Beta Test sites. The eventual manual will include expanded appendices with detailed information on interconnection with a plethora of commonly used &meter FM radios, as well as hardware and software installation data for many personal computers and terminals. The intent is to provide sufficient detail to allow a non-technical Amateur to successfully bring up a Packet radio stat ion wi 'thou t other assistance.

Beta Test

Perhaps the most unique feature of the TAPR TNC is the manner in which it is being tested. Many innovative Amateur devices have been built as a result of a club project, involving perhaps 20 or 30 units. Commercial interests often build prototype units and allow selected customers to test them, who then offer feedback for the final production release of the product in question.

When TAPR decided to go ahead with the TNC design and implement it, the mailbox was full of requests from Amateurs desiring to be included in the initial distribution. Realizing the tremendous resource represented by these eager **participants**, and recognizing that the 'local Tucson "c0re" **would** be hard-- pressed to fully shakedown, test and debug the TNC in a reasonable time frame, the decision was taken to allow a fairly large number of TAPR members the opportunity to contribute to the TNC design effort by providing a test bed.

The participants were informed that this was to be a test in 'both word and deed, and **that all** Beta testers **were expected** to file formal **reports via** Beta Test Coordinators to be located in each area. Further , to make the test sites as autonomous a s possible, each local site was to determine its own coordinator. 4 network was established that now spans the USA. and reaches, via AMSAT- **sponsored** participants, to Asia, Africa, Europe and Oceania.

Beta sites were to include both technical and non-technical Amateurs, and were to be self-suffcient as to support, modification, **repair** and updating of the TNCs within the site. It was felt that this would both **relieve** the pressures on the Tucson group and provide a reasonable cross-section of Amateurs with regard to technical expertise, climatic variation, rfi and frequency congestion (jammers and the like).

Further, by using this method, it was believed that a maximum number of Amateurs in varied locations would be exposed to the raucaus noises generated by the packet frames, and inquiries would lead to further interest in the mode. A local group could then "spread the packet gospel" and help ensure the further growth of the mode, even while it undergoes changes associated with its infancy.

Finally, many people who contacted us, and continue to contact us, indicated that there seemed to be no cohesive force amongst packeteers, nor central clearing point for information. TAPR has therefore attempted to fill this void, and the results to date have been most gratifying. By making Beta Test a national endeavor, participants are able to become involved in a broad- based, grassroots packet effort. By providing support for the TNC, people are reassured that, in the event they face real problems, there is a source for technical assistance, both in hardware and software.

The Beta Testing of the TAPR TYC is still in its initial phase, that of distribution. As of this writing, over 110 of the scheduled 170 TNCs have been shipped to a number of sites scattered across America. Yost sites have had little trouble getting the TNCs on-the- air. Many radios, terminals and personal computers have been successfully interfaced.

Already, defect reports are coming in. A few significant hardware bugs have been noted, and work has commenced on solving the problems. Software- related problems have been reported, and the second release of Beta software will be appearing around the time of this conference.

It is believed by the author that this level of testing and cooperation has not been seen in Amateur radio before. The Beta Test participants have been very enthusiastic, as well as patient and supportive of the entire effort.

Conclusion

The TAPR TNC includes a variety of unique and innovative circuits, concepts and ideas. It is designed for both the technically inclined experimenter , for whom it offers a host of features accenting flexibility and expandability, as well as for the less- technically inclined operator, for whom it offers ease of operation.

The documentation of the TNC is at a level uncommon in Amateur radio, with a depth and breadth seldom seen outside of professional circles.

The initial software release incorporates many advanced features to allow the experimenter great latitude in optimizing system parameters, as well as flexibility in his particular system configuration. Compatibility with both the "Vancouver" and the "AX.25" protocols is provided.

The method of Beta Test is unique within Amateur radio endeavors, and is designed both the enhance the TNCs suitability for Packet radio use as well as increase the exposure of the general Amateur community to the strengths and benefits of this mode.

Acknowledgments

The author wishes to express his gratitude and thanks to the more than 250 members of TAPR, without whose support this project would never have gotten off the ground; to AMRAD and the ARRL for the opportunity to present this paper; to the Los Angeles and St. Louis contingents of TAPR for help in the areas of software, board layout and transformer procurement; and a special thanks from TAPR to Modular Mining Systems of Tucson for the extended use of their lab and other facilities, without which the TNC might never have been initially designed, nor built for so low a cost.