An Enhanced Terminal Node Controller

by Lyle Johnson, WA7GXD
President
Tucson Amateur Packet Radio
PO Box 22888
Tucson AZ 85734

ABSTRACT

This paper describes changes made in the Terminal Node Controller (TNC) developed by Tucson Amateur Packet Radio (TAPR) as a result of extensive field evaluation during the TAPR Beta test.

BACKGROUND

Tucson Amateur Packet Radio is a non-profit Research and Development group with over 700 members worldwide. During 1981-1982, a complete, self-contained Terminal Node Controller was developed. During the period of January, 1983, through June, 1983, over 170 preassembled TNCs were placed in more than 19 sites worldwide for testing and evaluation.

The testing revealed many things beyond the evaluation of the TNC: primary among this list is the finding that non-technically oriented Amateurs were both interested in Packet radio as a mode and capable of placing a Packet station in operation.

Another important observation was that a volunteer group would quickly reach burnout if the participants were required to assemble and test each and every TNC prior to shipment. This observation, along with tightened FCC type classifications under Part 15 for manufactured equipment, led TAPR to the first major change in the Beta TNC for general distribution -- the new TNC would be in the form of a kit.

THE BETA TNC

TAPR's first generally distributed TNC design has become known as the Beta Board. This device was based on the 6809 microprocessor, included 6k-bytes of RAM, 24k-bytes of EPROM, 64 bytes of non-volatile memory (NOVRAM), a Western Digital HDLC controller, serial and parallel ports, an on-board 1200-baud radio modem with watchdog timer, built-in regulated AC power supply and a generous wire-wrap area for the experimenter.

Software was written in the PASCAL language for high-level functions, with low-level routines written in 6809 Assembler. The software design was accomplished by a team scattered between Tucson and the Los Angeles area, while the hardware design was effected in Tucson.

A comprehensive manual was written and distributed with the Beta Board; it contained nearly 200 pages of descriptions, operating procedures, interfacing data, protocol definitions and general Packet radio background information.

THE KIT TNC: DESIGN EVOLUTION

The response of the Amateur community to the Beta Board was overwhelmingly positive: nonetheless, there were some minor difficulties reported. In addition, TAPR wanted to increase the flexibility of the TNC to more easily accommodate the anticipated users of PACSAT, HF, METSCAT, OSCAR 10 and others. Finally, the unit had to be designed in such a way as to allow assembly and calibration by the less technically oriented members of the Amateur fraternity to help encourage the growth of the mode through on-the-air application.

A few users found the non-polarized connectors used on the Beta Boards to be a problem. Worse, the radio input/output (I/O) and power transformer disconnect used identical connectors. The solution to this problem meant a different form factor for the board: this provided the opportunity to include subtle changes to the TNC's hardware design since a completely new printed circuit (PC) board would have to be laid out.

Field feedback coupled with local experience on the part of the software design team led to suggestions for improved performance and an even more friendly user interface. Naturally, this meant an increase in the standard program code storage capacity (from 24k-bytes to 32k-bytes)!

The documentation would require a complete rewrite. The operating section would have to reflect new commands and capabilities. The circuit descriptions would have to be revised. And a detailed assembly manual would have to be written and field-tested.

The opportunities roughly defined, it was time to go to work! During the next few months of intensive effort, the design team kept true to the premise that

> "the sooner you get behind in a project, the more time you have to catch up!"

HARDWARE ENHANCEMENTS

The TAPR kit TNC offers 8k-bytes of RAM (up from 6k-bytes on the Beta Board) as standard. The Program storage has been increased from 24k-bytes to 32k-bytes. In addition, through the use of an 8k-byte single chip static RAM chip (TAPR was one of the very first US corporations to use this IC), an empty memory socket is provided with jumper options to allow the use of any JEDEC "bytewide" memory IC from 2k- through 32k-bytes in capacity. The memory decoding circuitry is pre-programmed to accommodate a 16k-byte part in this site. Thus, the TNC can utilize up to 56k-bytes of memory without any modification whatsoever!

Nonvolatile RAM (NOVRAM) has been increased from 32 bytes to two "banks" of 64 bytes each. This non-battery backed memory technology allows the TNC to store callsign, terminal parameters, radio link data and similar information indefinitely without requiring the operator to manually enter them each time the unit is powered up, or forcing the operator to utilize very conservative default values for the link that are not optimum for his particular local area network.

To simplify interfacing the serial I/O port to ((three-wire" RS-232 devices, default pullup resistors have been included to eliminate the need for jumpers, yet provide hardware handshaking for those attached devices that can support CTS/RTS and DTR/DSR protocol. As with the Beta Board, true RS-232-C levels are implemented on the serial port, although the TNC can communicate with devices that utilize TTL output levels.

The power supply circuitry utilizes 3 amp diodes in the 5-volt supply and the electrolytic filter capacitors are much further from the heatsink to slow the drying of the electrolyte that normally occurs with time. The negative voltage regulators are more heavily bypassed to suppress any tendency towards oscillation. Finally, a separate 5-volt regulator and ground return path is provided to the on-board modem for more complete noise rejection. The 5-volt regulator IC and heatsink are wired in such a way as to allow easy relocation off-board in the event a cabinet is used while allowing on-board operation if the TNC is not enclosed. A Molex connector is provided for the power transformer disconnect: a redesigned power transformer is included with multiple line voltage taps for best efficiency.

The clock oscillator frequency has been doubled and a jumper provided to allow operation of the digital circuitry at a faster rate in the event high-speed packet operation (greater than about **9600** bauds) becomes commonplace.

Link status is output on the parallel port in the default condition: this allows easier interfacing to "host" computers that may have one or more slave TNCs attached for bulletin board and other services.

A standard DB-25S connector is provided on the TNC for the serial portandthe TNC is configured as "Data Communications Equipment'" (DCE) -- it appears as a standard modem to an attached terminal or computer.

A DB-25P connector is used to interface to the parallel port, while a DE-% connector is included to attach a radio to the TNC. The pinout of the DE-9 is such that, if ribbon cable is used and attached to all nine pins (as would occur if an insulation displacement connector were used), alternate leads will be grounded for good signal separation and shieldinq.

The TNC was designed with a cabinet -in mind. In addition to the heatsink considerations mentioned above, there is a complete "front panel" disconnect on the unit. A 16-pin IC socket located immediately behind the front panel of the cabinet repeats all on-board LED functions as wel l as all DIPswitch connections. The LEDs have their own current limiting resistors.

LED monitored functions have been increased from those on the Beta Board. In addition to received audio input level monitoring and transmitted data, there are monitors for data carrier detect (very useful for HF and OSCAR operation), CWID, PTT, HDLC RESET and SPARE (user configurable). The switch functions have been increased and include ROM/NOVRAM default parameters, NOVRAM BANK SELECT (for multiple operator or multiple function stations), NOVRAM DISCONNECT (for rebooting with "non-permanent" parameters) and, of course, RESET.

The area that received the greatest attention in the hardware rework effort was the modem. This is perhaps the most critical part of the entire TNC hardware.

With flexibility and performance as the bywords, the modem design -was picked apart by several people and extensively tested. The results of these investigations were consolidated and incorporated in the new TNC design.

Careful rework of the power supply and power distribution on the hoard resulted in a reduced noise floor for the modem. Increased physical separation of the modulator and demodulator reduced crosstalk tendencies. Post filtering of the MF-10 switched capacitor filter by an op-amp removed high frequency switching transients from the input to the XR2211 PLL demodulator. The demodulator can be completely reconfigured (for 300 baud HF work, for example) by swapping a 16-pin

DIP header plugged into a standard IC socket. This encourages experimentation with other shifts and data rates for optimizing communications over a given path.

As with the Beta Board, the MF-10 filter is defined via a plug-in DIP header containing only resistors. Similarly, the XR2206 phase-coherent FSK modulator is configured via a 14-pin DIP plug-in header.

One of the (apparently) least understood causes of problems with Packet signals is due to overdrive of the microphone amplifier circuitry in the associated radio. The Beta Board used the output of the '2206 modem (buffered by an op-amp with unity gain) to feed the radio directly. This resulted in a rather critical setting of the audio output adjustment trimmer near the low end of its rotation. The new TNC includes a 30:1 attenuator to provide a greater usable adjustment range and minimize the possibility of overdrive to the attached radio.

The radio PTT circuitry is now based on a power FET. Unlike the Darlington transistor keying circuit used in the Beta Board, with its 0.6 volt minimum level when "on," the new TNC has an effective "on" resistance in the keying circuit of about 4 ohms. The "off" voltage can be nearly 36 volts as well. TAPR has not received a report to date of anyone having trouble keying any common radio with this new circuit: several late model radios would not tolerate the standard Beta circuit.

The watchdog timer can be reconfigured via the modulator header. This allows easier interfacing with HF and other radios that typically use lower data rates on the air. The default timeout was increased from about 15 seconds to about 1 minute for similar reasons.

The calibration circuitry for the modem was revised. The XR2211 has an unusual waveform that many commercial frequency counters won't accept: the Beta Board waveshaping circuit only worked for about 60% of the TNCs. The kit TNC includes a Schmitt trigger in the wave shaping circuit that drives the on-board counter: this has proven effective in every case that the author is aware of.

The CWID is now done via FSK rather than tone on-off keying. This prevents a listening TNC from mistaking the pause between letters in a call sign for a free channel and "colliding" with the remainder of the CWID. Further, the TNC suppresses the audio output from the '2206 modulator when it is not attempting to key the transmitter: this allows the user to use voice override without disconnecting the TNC from the radio.

Of course, no matter how good the modem is, others will want to try their own designs. This being a goal of TAPR's, a complete modem disconnect is provided on the kit TNC. Utilizing a standard IDC 20-pin polarized connector, it is a simple matter to reconfigure the TNC to use an external modem. This is desirable when experimenting with radio link data rates in excess of 1200 baud, or when using a scheme other than (A)FSK for modulation.

SOFTWARE ENHANCEMENTS

The added memory space for program storage allowed the already friendly user-interface to become friendlier.

Several commands now have more flexible arguments: for example, the DISPLAY command, which used to dump all user-alterable parameters, now may optionally show only those parameters that relate to a specific use, such as terminal characteristics.

TAPR took the liberty to allow multiple digipeaters to be specified in AX.25 mode. The Beta software allowed up to three "hops" while the new kit software allows up to eight! While digipeaters are a bit of a kludge to a "pure" level two, they have proven invaluable during this early phase in the development of packet radio and the multiple hop concept has been invaluable in many areas that otherwise would be cut off from "local" activity.

Link status is now output on the parallel port. This was provided in response to numerous requests from users who wanted to interface bulletin boards and other "host" computer applications.

Baud rates for both the terminal and radio ports are now specified by the data rate (e.g, 1200) rather than by a table lookup value (e.g., 8). Similar human factors improvements have been made in specifying many other parameters.

The suppressable CWID may now include text instead of simply the station call sign.

Beacon text and non-connected-mode packet transmissions may now specify up to eight digipeaters in their output routing.

To provide greater compatibility with users of the VADCG board, special options were included to allow the sending of CR and LF characters as well the methods of receiving them.

In addition to the standard RTTY-like CONVERSE mode, a full "transparent" mode of operation, proven on the Beta Boards, is retained for such tasks as computer-to-computer file transfers.

A special full-duplex mode (the TNC always operates in a full-duplex mode on both the radio and serial I/O ports) has been included for use on OSCAR 10 and other very noisy environments.

Support for the TAPR EPROM programming adapter is included in the software. This allows duplicating the TNC software for field updates and the like. Using the INTEL "intelligent" programming algorithm, 2764s are typically programmed in 1-1/2 minutes and 27128s in under 3 minutes.

The above serve as examples of the extensive software effort associated with the release of the new TNC kit -- there are many more changes, some very subtle, which contribute to the ease of use and general acceptance of the device.

Of course, with the exception of the EPROM programmer support, a set of EPROMs that incorporate the full "Version 3" software enhancements is available for use on unmodified Beta Boards -- modified Beta Boards can use kit software.

DOCUMENTATION

The TNC manual was extensively revised to include full operating details for the new software. A tutorial-like "front-end" was added to the operations section for the first-time user who is not in an area where there is other local Packet activity*

The largest single "new" effort in the manual, however, was in writing the assembly instructions. The instructions had to be sufficiently detailed to allow a relatively inexperienced constructor to assemble, calibrate and verify the operation of the TNC.

While not often considered as documentation, the PC board had to be silk screened in a non-ambiguous manner and keyed to the manual in such a way as to reinforce the accuracy of assembly and, hopefully, assist in locating assembly errors and later troubleshooting during the useful life of the TNC.

The manual organization was carefully considered and a looseleaf notebook format with tabbed index dividers was developed. The result is an easy-to-use reference for Packet station operation along with a clean appearance.

KIT TEST

In the late summer of 1983, the kit TNC was ready to be tested. Two "Rev 1" TNCs were built and evaluated. After numerous delays (if anything can go wrong, it will), twenty "Rev 2" test kits were sent to carefully selected participants in early October. The testers were asked to build the kits, evaluate the instructions (the manual was very preliminary, as was the software) and give a detailed report on the overall "kit-ability" of the unit.

The response was gratifying. Every kit worked! Valuable insight was gained into the assembly process, the directions were revised and the graphics taken to a commercial firm for finalization.

PRELIMINARY FIELD RESULTS

Over the period from November, 1983 through early March, 1984, TAPR shipped over 500 kits. None have been returned for repair, although several dedicated packeteers in a few locations have assisted other locals in getting some kits up and running.

Special MF-10 filter resistor packs have been developed and used successfully for routine HF and OSCAR-10 communications.

Packet QSOs with TNCs of other manufacture have been made regularly, the only difficulties being in the non-uniform implementation of the "Poll/Final" bit of the AX.25 protocol specification.

Various bulletin board systems have been successfully interfaced to the TNC. Radios of many types and computers/terminals of various manufacture have been connected with minimal difficulty.

Experiments with the on-board modem have resulted in solid copy over marginal paths at 1200 baud; 1800 baud operation has been regularly achieved over very good paths.

CONCLUSIONS

The development of the TAPR TNC kit was a very challenging experience to those involved. The TNC itself has been widely accepted in the Amateur community; the fact that it is a complex piece of equipment offered only in kit form has not seemed to restrict that acceptance.

An extensive refinement of the Beta Board tested during 1983, the TNC represents the unselfish efforts of hundreds of Amateurs worldwide to help usher in an era of error-free digital communications for the Amateur community at large.

REFERENCES

[1] Henderson, David L., KD4NL, "Design Decisons for the TAPR TNC Link Level," Proceedings of the Second ARRL Amateur Radio Computer Networking Conference, 1983.

[2] Johnson, Lyle V., WA7GXD, "Unique Features of the TAPR TNC," Proceedings Of the Second ARRL Amateur Radio Conputer Networking Conference, 1983.

[3] Morrison, Margaret, KV7D, "Real-Time Low-Level Software on the TAPR TNC," Proceedings of the Second .ARRL Amateur Radio Computer Networking Conference, 1983.

[4] Morrison, Margaret, KV7D, and Morrison, Dan, KV7B, "Designing the TAPR TNC

Audio Input Filter," Proceedings of the Second ARRL Amateur Radio Computer Networking Conference, 1983.

[5] Price, Harold E., NK6K, "Multi-Use Design Considerations for the TAPR TNC," Proceedings of the Second ARRL Amateur Radio Computer Networking Conference, 1983.

[6] Tucson Amateur Packet Radio, Packet Radio System Beta Test, February, 1983.

[7] Tucson Amateur Packet Radio, Packet Radio Terminal Node Controller System Manual, First Edition, November, 1983.