Software, Software, Everywhere!

Just A Small Matter Of Programming

Telonics began to use embedded-controller software (code for small microprocessors) nearly eight years ago, and I became personally involved as an outside contractor about six years ago.

In the beginning, the work load was very light — just an occasional small project. But within about three years, we all realized there was more work to be done than one individual could possibly handle on a part time basis. In retrospect (although it appears funny now), our biggest fear was that there wouldn't be enough programming to keep a software engineer busy. Nevertheless, since there were jobs on hand that couldn't be completed within the required customer schedules, we decided that I would have to start working on a full time basis.

During the first couple of weeks after coming on board, I did have a little spare time. But after those first few weeks, that status changed to being permanently swamped. In fact, there are now three full time device programmers on staff, supported by at least two part time contractors from the outside — and there are still more projects than we can handle in the time frame we would like!

So what is it that's changed over the past six years? There was a time when none of our products had microprocessors installed to control standard functions. Microprocessors were too large and required too high a voltage with too much current. Since our products needed to be extremely small and have a long operational life, standard integrated circuits were used to implement every needed logic function. Beacon transmitters were built with a couple of flip-flops and one-shots. Even our scanning receiver was built with simple counters, gates, flip-flops and simple memory chips.

We soon realized that to implement ARGOS PTT's for wildlife applications would require additional, and more complex control functions. Anytime there's a need for more control logic than can reasonably be built from simple logic circuits, the solution readily dictates the use of a small microprocessor. Fortunately, during that same time, a line of single chip microprocessors with low power and low voltage specifications became available. Our original designs were very successful and proved what wonderful things could be done with a microprocessor and a "little" software.

User requirements are frequently a step ahead of what can be accomplished with the technology of the day. As technology continues to evolve, we are able to marry the latest technological innovations to those user applications awaiting solutions. Hence, we are constantly producing new systems to meet more and more user needs. For example, we are currently shipping fourth and fifth generation satellite transmitters, each performing more sophisticated user-required functions than was previously possible. We have written dozens of different programs for each generation of transmitter and we continue to fine tune them to meet specific application requirements. And, by the way, many of these programs are not so "little" anymore.

As it turns out, satellite transmitters were just the tip of the iceberg. There are antenna rotator controllers, satellite uplink receivers, and many other products almost too numerous to recall. The vast majority of new products which we are currently designing contain one or more microprocessors. Our intelligent beacon transmitters will soon be controlled by microprocessors and there will be many different versions, each requiring specific software development for specific customer needs.

It is clear that the microprocessors which invaded your desktop several years ago have moved in to control everything from transmitting subsystems to the newest and most advanced receivers. We have made a very serious commitment to developing these sophisticated systems to meet a wide array of needs. Microprocessors will continue to play a big part in this. Which, of course, implies that the programming staff is going to be very busy for quite some time to come.

We all chuckle when we think that there was ever a concern about there being enough work to keep one programmer busy! Roger Degler

More On The TR-2 Receiver

Special Power Supply Options Are Available

Our standard TR-2 Receiver is supplied with a self-contained power pack. The pack can be recharged using an RP-2 wall current charger, a 12 VDC power source such as the RP-4, or the cigarette lighter of your automobile. In addition, special power supply options are available which many researchers have found useful.

The TR-2-A (External Power Modification) is a popular alternative. The Receiver is modified for use with any external 12-28 VDC negative ground power source, and a battery access cover is installed at the laboratory. When the external 12-28V source is removed, the unit runs on replaceable internal alkaline AA cells. The Receiver can also be used with an external power source when used as part of a data acquisition site. In this case, the "external power modification" automatically disconnects the internal alkaline batteries and allows the unit to operate for extended periods of time. The TR-2A also allows the user to plug into the electrical systems of most aircraft. However, it is important to note in this option that rechargeable (Nickel-Cadmium) batteries cannot be recharged while in the TR-2 since no charging circuit exists.

Another option available for the TR-2 is the RP-1-B "hatchback" battery pack. This modification allows the Receiver to be used with either conventional alkaline or Ni-Cad cells. Alkaline batteries are convenient in remote areas where an external power source is not readily available for recharging. However, since a standard 12 VDC charging circuit is in place to support the charging of Ni-Cad batteries, users must be careful not to accidentally recharge the alkaline cells.

Since battery leakage can damage the Receiver (or any other electronic device), both modifications allow for the removal of batteries when the Receiver is stored for extended periods of time.

All options available with the TR-2 can be supplied at the time of initial purchase, or the Receiver can be sent to our laboratory for modification at a later date. Susie Crow

Antennas, Collars And Sealants

Helpful Hints

Throughout the years, we have been asked many questions concerning our products and their deployment. Many of the answers have application in a number of telemetry studies. One reason for publishing this newsletter is to provide a way to answer questions for a lot of folks at one time.

Some of the questions include, "Can I use this RA-2A 150/152 Mhz center section with these 164 Mhz elements and still get good performance?" "Can I wrap my collar in foil tape so that I can see it easily?" "Can I use some of this caulking material that I bought at the hardware store to seal my transmitters and receiving antenna connectors?" The answers to these questions could be critical to the success of a program and are certainly worth careful consideration.

ANTENNAS: The antenna system is a critical component in the data link and it needs to be kept in good working order. Before we ship your antennas, each one is tuned and optimized for the frequency range of the particular study in question. Unfortunately, antennas ordered for different studies at different times, or by different agencies, can be confused "back at the office." The RA-2A antenna is particularly susceptible to "element inter-changing" because the elements are so easy to install and remove. Elements should only be interchanged among antennas of the same frequency range. In fact, you should only use elements which are the same length as the original ones. NOTE: Even within the same frequency bands, older center sections sometimes require elements of slightly different length than newer center sections because of differences in tuning.

If an antenna has the wrong elements, the performance is completely unpredictable. Both sensitivity and directionality can be affected. A great deal of time and effort is invested in a system before it is deployed. To pick a handful of elements from a bucket, without checking for proper frequency, can negate our combined efforts for success. Occasionally an element will be broken or lost while the antenna is being used. The safest approach is to order one or two spare elements with your antenna. When replacing damaged elements, verify if possible that the replacement is the same length as the original. Note that both front elements (left & right) are of identical lengths. The two back elements should also match, and they are always longer than front elements.

COLLARS: It is often desirable to mark collars to enhance visual sightings. This has been done with a variety of materials. Foil tape or reflective materials which contain metal flakes will detune the transmitting antenna. Various materials and methods have been developed which allow collars to be marked without affecting the antenna. They range from cellular non-metallic reflective materials to paint, or other products which are glued and/or sewn to the collar. In some cases, marker collars are made with simple color schemes. The code allows the animal to be identified as to a specific group or geographic area. Vinyl tape is sometimes used but since it's not very durable, it should only be used when it is necessary to mark the collars for a short time. In addition, the adhesive can stick to the animal's fur in extremely warm environments, or the tape may cut like a razor in extremely cold environments. Collar marking can be as elaborate or as simple as required, and the correct choice of techniques and materials can be critical. We are more than happy to work with you to achieve optimum performance from the entire system.

SEALANTS: Various sealants have been used throughout the history of radio telemetry to seal transmitter packages, antenna connections and other electronic gear with varying degrees of success. Many of the silicon sealants available at hardware stores contain acetic acid. You'll notice a definite "vinegar odor" when the container is opened and also during the curing process. While curing, the acid comes out of the silicone, mixes with moisture, and attacks any exposed copper, causing corrosion. In some cases, the copper can be completely "eaten away." With the advent of our fully hermetically sealed transmitters, the need for silicones was virtually eliminated. So component corrosion is no longer a problem. However, there are still times when the environment necessitates the use of silicones. For example, silicone is sometimes used to seal antenna connections when they must be exposed to salt air. If the application requires a sealant, there are silicones which do not contain acetic acid. As for the other silicones which do contain it, the bathtub is still the best place for their use! Gary Jones

Avian PTT'S
The Time Has Come

The ARGOS system was designed to provide data recovery and location information for oceanographic and meteorological studies. The original PTT's associated with these applications were large, and required sizable battery packs and controlled antenna structures. In 1980, we began an intensive effort to develop PTT's specifically designed for tracking wildlife. The incorporation of high energy density battery packs, very low current microprocessor-based controllers and sophisticated RF design with the capability of driving a completely uncontrolled antenna impedance were integral components of the development process.

Most of the early wildlife work involving PTT's was conducted on large mammals. Although mammals undertake migrations, they are often relatively short when compared to the migrations of some birds. For this reason, it became important to consider the development of an avian PTT.

We knew initially that the weight of the PTT would limit the design to larger bird species. As the size and weight of the power sources could be reduced, the total unit size and weight could be reduced accordingly to accommodate smaller species. A primary concern in development was that the electronics and power supply, packaging, and antenna system be interfaced with the bird in a way which would minimize the impact of the equipment. The entire process of instrumenting animals, and the effect of that instrumentation on animals, has come under more critical review in recent years. The impact of telemetry on behavior, physiology, energy expenditures, and reproductive capabilities are all considerations in assessing the performance of a PTT. In the past, it was often thought that weight was the principal factor determining the degree of impact on the bird. It has become clear over the past twenty-five years that many additional and sometimes subtle factors are also involved.

In telemetry studies, the first parameter required by scientists is often location. Once that is achieved, other parameters become important. There-fore, in our development, we have maintained a fully microprocessor-controlled PTT which allows flexibility in duty cycling and data collection without compromising size or weight.

Under current software regimes, duty cycling makes it possible to program the PTT to transmit during those intervals of the day when satellite passes are of the highest frequency. Addtitionally, duty cycling allows the PTT to be turned "on" or "off" during periods when data collection or location are not important. For example, some birds have a relatively brief migratory period. Collecting vast amounts of information when they reach the terminus of the migratory route may not be essential. However, an intense data collection and location regime during the period of migration is desirable. Appropriate duty cycles can be programmed into the PTT prior to deployment, resulting in a period of maximum data collection and a period of relative quiescence. This conserves the power supply by restricting transmissions to periods of time when they provide the most useful information.

Both our first and second generation avian PTT designs monitor package temperature, and provide long term and short term activity counters. The short term activity counter provides information on activity levels monitored over the course of a one-minute time frame. The long term activity counter data, which is acquired over a 24-hour period, can serve as a mortality indicator. Alternative data collection formats can be established and incorporated into the data stream. Any limitation is quite often a function of the sensors involved in collecting physiological or environmental parameters, and simply the imagination of the biologist designing the experiment.

The first generation avian PTT was 6.35 x 2.54 x 10.16 cm and weighed 175g. PTT's were deployed on a captive eagle in conjunction with the Wildlife Wildland Institute, and on a giant Canadian goose in conjunction with Southern Illinois University. A third unit went through extensive testing with the USFWS, although it was not deployed on an animal.

These first generation PTT's for birds were all solar powered, and utilized a rechargeable Ni-Cad battery as an intermediary charge storage device. They had a solar array composed of 4 x 8 cells, thus providing a total of 32 cells in series. When arrays are composed of series-connected cells, they do have a major drawback. If any single cell fails, or is totally blocked from sunlight, the entire array's net output can plummet to virtually zero. As with all solar cell arrays, the amount of current available for recharging the Ni-Cad cells was directly proportional to the intensity of solar radiation and the orientation of the solar panels relative to the incident solar radiation. The performance of the electronics was good; however, the Ni-Cads were simply unable to provide the required pulse current of 350 milliamperes for long periods of time.

A second generation PTT has been under test since Summer 1988. The package measures 4.7 x 2.54 x 11.76 cm, and utilizes 30 solar cells. The new, narrower packaging was better adapted to being positioned as a backpack between the wings of the bird, and lessened the chances of impeding wing movement during flight. Additionally, the power level was reduced from 0.50 watts to 0.25 watts to minimize the impact on the power supply. The weight of the PTT (including packaging, electronics, battery and antenna) was also reduced to less than 140 g, excluding the harness.

A primary lithium battery configuration of the avian PTT has also been designed which weighs 140g. With its specialized pressure resistant housing, this design has been utilized successfully in Antarctica by Lloyd Davis in locating feeding penquins.

In comparing the solar panel configuration to the primary lithium battery configuration, two important facts become evident. While the solar power configuration offers the potential for achieving a much longer operational life, it is also more subject to varying environmental conditions. Performance can be limited by the Ni-Cad battery under high pulse currents, and by temperatures lower than 0˚C. In addition, if portions of the solar array become occluded, the transmitter will cease to function after the Ni-Cad battery has been discharged. Function will not resume until such time as the solar panels are capable of recharging the Ni-Cad battery.

Primary battery power supplies suitable for use with avian PTT's also have limitations. Lithium powered systems have been used extensively and have been extremely reliable in powering VHF telemetry systems.

Much is known about the various lithium battery technologies and their performance characteristics under pulsatile current regimes. However, there are size restrictions associated with an avian package. Only the smaller cells can be utilized and they provide less current. Thus, the primary lithium cells utilized in avian applications are on the edge of their current capability, and their total capacity is limited as well.

Three solar powered second generation PTT's are currently under test. The U.S. Fish and Wildlife Service in Anchorage has been testing a PTT under varying conditions since September 1988. The unit has consistently operated with a high degree of reliability. In addition, the U.S. Fish and Wildlife Service has several "mock-up" PTT's. They are currently being tested on eagles in captivity to examine the suitablility of the package. A second functional PTT has been undergoing extensive tests at the University of Tennessee's Space Institute since October 1988. They expect to deploy the PTT sometime this summer. A third PTT has undergone an extensive testing regime by Minnie Nagendran at North Dakota State University. On two separate occasions, the unit has been deployed on two different Sandhill Cranes. During the most recent deployment, the crane's migration between Florida and Michigan was monitored during late March and early April.

Our current plans involve moving out of the experimental testing phase and into an operational program in Fall 1989. Stan Tomkiewicz

Satellite PTT'S They Do More Than Just "Beep"

ARGOS PTT's (Platform Terminal Transmitters) differ from "conventional" VHF transmitters in many ways. The transmission of a VHF unit is a simple pulse which is typically 12-25 milliseconds in duration, and which is repeated about once per second. (Both the pulse duration and repetition rate vary depending on specific requirements, but these values approximate those used in many studies.) In contrast, PTT's have a very complex transmission which lasts 360 to 920 milliseconds and is repeated once every 40 to 240 seconds. PTT's also consume and radiate much higher power, and the frequency stability and message structure require more complex circuitry. This article focuses on the composition of the PTT transmission and on its software control.

A PTT's transmission can be divided into two major parts: the unmodulated carrier and the phase-modulated segment containing a binary-encoded data stream. The transmission starts with 160 milliseconds of unmodulated carrier followed by 48 bits (120 milliseconds), which includes a preamble, format synchronization, initialization, specification of amount of sensor data to follow, and an ID number. The ID number identifies a specific PTT, which is critical because all PTT's operate on exactly the same frequency. The final 32-256 bits (80-640 milliseconds) of the transmission consist of encoded information provided by various sensors associated with the PTT. ARGOS operational rules require a minimum of 32 bits of sensor information. Therefore, either data is transmitted or the 32 bits must be otherwise filled

(e.g. with zeros). The type of sensors used and the data transmitted can be defined by the researcher. Thus, a great deal of information in addition to location can be obtained via the PTT. In fact, for some applications data transmission is the primary, or only, objective. It should be noted that a "location" is not transmitted by the PTT. Locations are mathematically calculated by ARGOS or an Earth Station (such as Telonics THRPT-1) based on at least two transmissions as received by the satellite during an overpass.

Sensor monitoring and format of transmitted data is controlled by software which has been developed in response to individual researcher's particular requirements. Specific applica-tions software can be programmed into any of our appropriately configured PTT's. Because of the diversity of software available, no attempt is made in this writing to specify all the software currently available in our library. We are happy to work with you to review existing hardware and software options, and to modify or develop applications software to meet your particular needs. Even with existing applications software, certain parameters must be specified by the user with each order.

The kinds of data which can be transmitted via PTT's are diverse. For terrestrial animals, the most commonly used software includes temperature, a 60-second activity count, and a long term activity count. Other software includes six, 4-hour activity counters. For marine animals, commonly transmitted data includes temperature, dive counts over various time periods, length of last dive, and average dive length. Other software includes scaling of depth of dive, activity information similar to that used for terrestrial animals, or information regarding the amount of time spent out of water for species which commonly come ashore. PTT's deployed on buoys for oceanographic research can transmit data including temperature and pressure at the surface and at various depths. Information regarding the amount of time a sensor on the buoy has been submerged, and the bouy's motion or orientation is also available. PTT's are also used to transmit between 32 and 256 bits of user-specified data by utilizing an asynchronous interface between the PTT and a host computer or remote sensors.

It should be realized that there are limitations associated with data collection and transmission. Users should consider that transmission of data streams longer than the 32 bit ARGOS minimum increases current drain on the battery supply. In addition, data must often be accumulated and then math-ematically reduced such that it can be transmitted within the available data stream. This typically requires transmission of averages or categorized data rather than individual samples. Data must also be collected without damaging the mechanical integrity of the PTT package. For example, external probes or leads are generally inappropriate for deployment on wildlife. Easily damaged sensors are also unsuitable, and all applications require adequate protection from moisture, shock, and other abuse.

...And all you wanted was a location, right?
Bill Burger

Collar A Snake

All You Have To Do Is Ask

In the Spring 1989 newsletter, Boyd Hansen discussed the fact that hybrid circuit technology has allowed for a reduction in the size of transmitter electronics. Utilizing hybrid technology, we currently produce compensated transmitting subsystems weighing as little as 4 grams, including power supply, packaging, and antenna.

In fact, the electronics portion of the transmitting subsystem can be made even smaller by using simple circuits made of discrete components. The smallest transmitters available are possible because the printed circuit board has been eliminated, and the number of componets comprising the circuit has been limited. Such simple "one-stage" and "two-stage" circuits were some of the first circuits utilized for wildlife telemetry, and they are still used for some applications where very small size (i.e. less than 4 grams) is essential. While the small number of components (typically 10 or fewer in one-stage transmitters and 12 in two-stage transmitters) allow production of a pulse, they provide very little control of the transmission characteristics of that pulse.

To improve transmitter performance and dependability, additional components and circuitry must be utilized. At Telonics, we have designed our transmitters to maximize performance. Miniaturization is achieved by utilizing smaller components and hybridization rather than by elimination of components. The result is a transmitter which has greater stability in the critical parameters involving timing, such as pulse width and pulse period, and improved frequency stability in both the short term (during a pulse) and long term (days, weeks, and longer). NOTE: In simpler circuits, these parameters often drift appreciably with changes in power supply voltage, temperature, and even component aging.

Of course, a transmitter isn't of much value in a snake (or anywhere else) unless it's connected to a power supply. For the vast majority of wildlife telemetry applications involving larger transmitting subsystems, the power supply of choice has become lithium electrochemical systems. With very small subsystems, other battery systems are often preferable because of considerations which include packaging, pulse current capabilities, and teminal cell voltage. While a full discussion of battery technologies is beyond the scope of this article, it should be noted that small cells tend to operate over a much more limited temperature range than large cells, and they often limit the pulse current which can be drawn by the transmitter. Our smallest transmitters, the CHP series, have been designed to provide consistent performance over the operable temperature range defined by the batteries (approximately 4-21˚C), and to optimize performance when utilizing such small power supplies.

So what about the snake collar? Well, actually, no one has ever asked us for one. Transmitters are usually implanted in (or ingested by) snakes, and we're beginning to work with an increasing number of people in this field. However, I recently spoke to a researcher who said that while he had received numerous recommendations on our receiving equipment, he had not heard much about our snake transmitters. That's because we've worked with a relatively small number of "snake people," and we are admittedly little known in this field. While we have provided transmitter configurations for large snakes since the early 1980's, we were not developing transmitters for many of the smaller species until several years ago. Of course, things are changing and at the time of this writing, we have CHP transmitters in production for Black Snakes, Garter Snakes, Cat-Eye Snakes, Coachwhips, and Sidewinders.

We have been producing CHP transmitters for several years now and the diversity of uses continues to expand. For example, the transmitters have been used in snakes with three different power supplies and package sizes. Many of the transmitters have also utilized a temperature sensing option. In various configurations and utilizing various power supplies, the CHP's have also been used on lizards, turtles, tortoises, ground squirrels, tree squirrels, chinchillas, domestic cows (yes, it's true, and size was a limiting factor), owls, pheasants, falcons, and various other species. The units have been deployed as implants, backpacks, legmounts, and on collars — but not yet as collars on snakes! Bill Burger

The Editor's Desk

Some Addtional Notes
And An Invitation

It doesn't seem possible, but the Telonics Quarterly is concluding its first year of publication with this summer issue. We'd like to take this opportunity to thank all of you who have expressed your enjoyment of the newsletter. Quite honestly, we didn't know what we were getting into, and we wish all of you could sit in on one of our "story" conferences! Since our industry is as diverse as it is dynamic, we sometimes have a hard time deciding what to cover in each issue. We encourage you to write or call us at (602) 892-4444 with any specific questions you would like answered, or with suggestions on topics and issues you would like addressed.

For those of you who need more complete technical information on a particular subject, please don't hesitate to call or write. A number of technical papers are available and the subjects range from "Antennas and Antenna Theory" to "Avian Telemetry" and "Implant Technology." Just let us know what you are working on and we'll be happy to send you whatever we have available.

We would also like to announce that beginning in Fall 1989, we hope to include one guest article per issue. While the Telonics Quarterly is a small publication, it's distributed to a wide audience and can serve as a practical forum for the sharing of information. We encourage anyone who is interested to submit an article on field techniques, methods and experiences. In general, our articles are either one, two or three columns, and there are approximately 350 words per column. Please don't hesitate to call if you would like more information. We look forward to hearing from you.

VHF Transmitters

So How Long Is This Thing
Going To Run

Most VHF transmitters used for wildlife tracking purposes are operated in the pulse mode to conserve battery power. The pulse width, or pulse duration, is simply the time between the start and end of the transmission. During this "on time," a VHF transmitter sends an RF signal, and consumes significant power from the battery. To keep the power consumption down, the pulse duration is kept to a minimum and 15-25 milliseconds [ms] is typical for many applications. Pulse period is the time from the start of one pulse to the start of the next.

While the operating life of the transmitter's battery and pulse period are directly proportional, operating life and pulse width are inversely proportional. When you know the pulse width (PW) and pulse period (PP), a duty cycle (DC) can be calculated. This is the amount of time a transmitter is "on" versus the pulse period. We calculate duty cycle in order to determine how long a transmitter will operate with a given battery. When the pulse width (PW) = 15 ms and pulse period (PP) = 1000 ms, we can calculate the following duty cycle:

$$DC = \frac{PW}{PP} = \frac{15 \text{ ms}}{1000 \text{ ms}} = 0.015 \text{ or } 1.5\%$$

The current drawn by the transmitter as it pulses is called "peak current" (Ip) and it accounts for the majority of current drawn from the battery supply. The higher the transmitted power, the higher the peak current. Quiescent current is negligible as compared to the average current, and may be disregarded for practical purposes.

When you know the duty cycle and peak current of a transmitter, the average current (Iavg) can be determined. For example, when peak current (Ip) = 17 milliamperes (mA) and duty cycle (DC) = 0.015, we can calculate the following average current:

$$Iavg = (DC)(Ip) = (0.015)(17\text{mA}) = 0.255 \text{ mA}$$

If the battery capacity (BC) is known to be 500 milliampere hour (mAh), the operational life can be estimated by dividing battery capacity by average current (Iavg) = 0.255 mA. This calculation provides the number of transmission hours, or operational life (OL) of the transmitter, with a given battery.

$$OL = \frac{BC}{Iavg} = \frac{500 \text{ mAh}}{0.255 \text{ mAh}} = 1961 \text{ hrs.} = 81 \text{ days}$$

24 hrs.

It is important to note that the calculations are only as accurate as the stability of the transmitter's power consumption, pulse width and pulse period. The actual battery capacity varies dependent on current drain and operating temperature. Joe Lessard