LA-9166-PR
Progress Report

UC-37
Issued: July 1982

# Electronic Identification

## October 1, 1979—September 30, 1980

C. T. Araki*
J. A. Landt
D. M. Holm
W. M. Sanders
D. M. Anderson**
G. L. Seawright
R. R. Brown
H. B. Puckett†
P. Salazar
R. J. Payne

*Department of Animal Science, University of Hawaii, Honolulu, HI 96822.

**US Department of Agriculture, Agriculture Research Service, P. O. Box 698, Las Cruces, NM 88001.

†US Department of Agriculture, Agriculture Research Service, 226 Agricultural Engineering Building, University of Illinois, Urbana, IL 61801.

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

ELECTRONIC IDENTIFICATION
October 1, 1979 - September 30, 1980

by

C. T. Araki, J. A. Landt, D. M. Holm, W. M. Sanders, D. M. Anderson,
G. L. Seawright, R. R. Brown, H. B. Puckett, P. Salazar, and R. J. Payne

## ABSTRACT

The progress of an electronic identification system developed for livestock applications is reported. This work was begun in 1973 and is now being field tested. Field tests are underway at the Jornada Experimental Range, Las Cruces, New Mexico, and at the University of Illinois, Urbana, Illinois. These tests have proven the viability of the concept of electronic identification. Preliminary results are very encouraging, but indicate that subdermal temperature measurement is markedly affected by environmental conditions.

## I. INTRODUCTION

Since 1973, Los Alamos National Laboratory has been funded by the US Department of Agriculture (USDA), Animal Plant Health Inspection Service (APHIS) to develop a means for electronically identifying livestock. The intent was to allow the rapid identification of animals and aid USDA disease control efforts in livestock, particularly cattle.

The electronic identification (ID) system was developed by Los Alamos to serve the interests of commercial livestock producers as well as USDA interests. For this reason, Los Alamos has directed much of its effort toward the development and testing of a system with broad-based commercial appeal. In our previous annual report[1] we described the start of a field test of the ID/temperature monitoring system in cattle grazing the Jornada Experimental Range, located northeast of Las Cruces, New Mexico. Temperature monitoring aspects of the identification system, along with transponder reliability, have been studied and a telemetry system was developed to assess and enhance the temperature monitoring capability of the ID system. Within the past year, Los Alamos has demonstrated a fully functional system in Las Cruces, New Mexico. Work continues in assessing the usefulness of subdermal temperature (which the ID system transponder monitors) and in the development of new electronic schemes that could be included in future developments of the ID system. The University of Illinois, one of the field test sites for electronic identification, has also made progress in applying electronic identification and computer technology to problems in dairy herd management.

An effort was begun in 1978 to procure commercial equipment for a large-scale field test. These negotiations broke down early in February 1980. As a result, the resources reserved for procurement of a complete commercial system were redirected to support the fabrication and assembly of equipment at Los Alamos. Support of the demonstration unit at Las Cruces intensified, and the Jornada Range became a fully operational field test site in August 1980. Support of the field test at the University of Illinois also increased with delivery of commercial equipment.

## II. ELECTRONICS

Progress in evaluating the electronic identification system consisted of two major efforts. The first was to upgrade the system installed at the Jornada test site for long-term uninterrupted operation. The second was to test alternative coding schemes for increasing the number of ID digits and simplifying the coding process (see Appendix).

On January 17, 1980, a demonstration of the electronic identification system was conducted on the Jornada Experimental Range for a USDA/Los Alamos program review. Following the demonstration, a test of the long-term reliability of the system was begun. The Jornada site was chosen because of harsh conditions associated with the site (for example, temperature extremes, dust, and lack of direct AC power). Because direct AC power was not available, equipment operated from a 12-V DC power supply. Batteries were recharged with a portable generator at the experimental site or at the Jornada Ranch headquarters, about 24 km away. Power consumption was 24 watts with 4 to 5 days between recharges. Because of limited power and the environmental conditions at the site, operational capabilities of the system were restricted to simple control functions and data collection. Data were analyzed off site, either manually or after the data were transferred to a large computer.

The ID system operated in conjunction with a single animal electronic scale (Weigh-Right Inc.).[2] The microprocessor supplied with the weigh scale was used as the main controller for both the scale and the ID system. Several problems were encountered in interfacing the two electronic units into a single working system. The major problems were (1) the failure of commercial equipment to perform in accordance with manufacturer's specifications, (2) environmental effects on the electronics, especially extremes in temperatures and dust, (3) timing problems between the Los Alamos equipment and the electronic scale, which required several interface components, and (4) erroneous weights that resulted from more than one animal entering the scale at the same time. Ambient temperatures above 37°C are very difficult to control because of power restrictions and still pose a problem to the electronics. However, equipment malfunctions caused by low winter temperatures have been adequately corrected with a thermostatically operated propane space heater. Sealing the doors and windows in the equipment trailer with weather stripping and caulking has substantially reduced dust accumulation.

To complete the automatic unattended livestock weighing procedure, an animal spacer is being constructed to ensure that only one animal enters the scale at a time. Currently, weather conditions are monitored on a separate mechanical strip chart recorder. Greater accuracy and significant time savings could be realized in the evaluation of the data if these data could be recorded along with other data on cassette tape. However, to include this would require significant modification to the instrumentation and power source.

As of August 1980, the ID and weight interrogation electronics have operated reliably, unattended. Some problems are still evident in maintaining transponder longevity. A total of 42 transponders were surgically implanted between June 29, 1979 and September 30, 1980. Of the original transponders implanted, four were surgically removed during 1979, two because animals were culled from the herd for management reasons and two because the transponders ceased to function. Of the 38 remaining transponders, 13 could not be interrogated on a consistent basis. Of the 25 transponders still working (as of November 1980), 1 has been in place for 389 days. The actual cause of transponder failure has not yet been determined. However, moisture leakage into the package is suspected because problems were encountered in adapting a metal case to house the electronics. Cases presently used are custom made for the transponder electronics and should give significantly better transponder reliability.

### A. Jornada Experimental Range Results

One of the main objectives of field testing the identification system was to determine its commercial usefulness. Money and labor constraints of commercial beef operations often prevent frequent weighing of livestock for monitoring the weight gain performance of individual animals. With electronic identification, individual animal management becomes possible as a means of optimizing individual weight gain efficiency.

The data collected at the Jornada Experimental Range are being used to test the concept of obtaining frequent semishrunk animal weights to assess individual weight gain performance and watering behavior patterns of grazing animals. Figure 1 is a block diagram of the instrumentation. The system consists of a commercially purchased single-animal electronic weigh scale coupled to the Los Alamos electronic identification equipment. The system allows automatic collection of data from animals crossing the scale platform as they come to

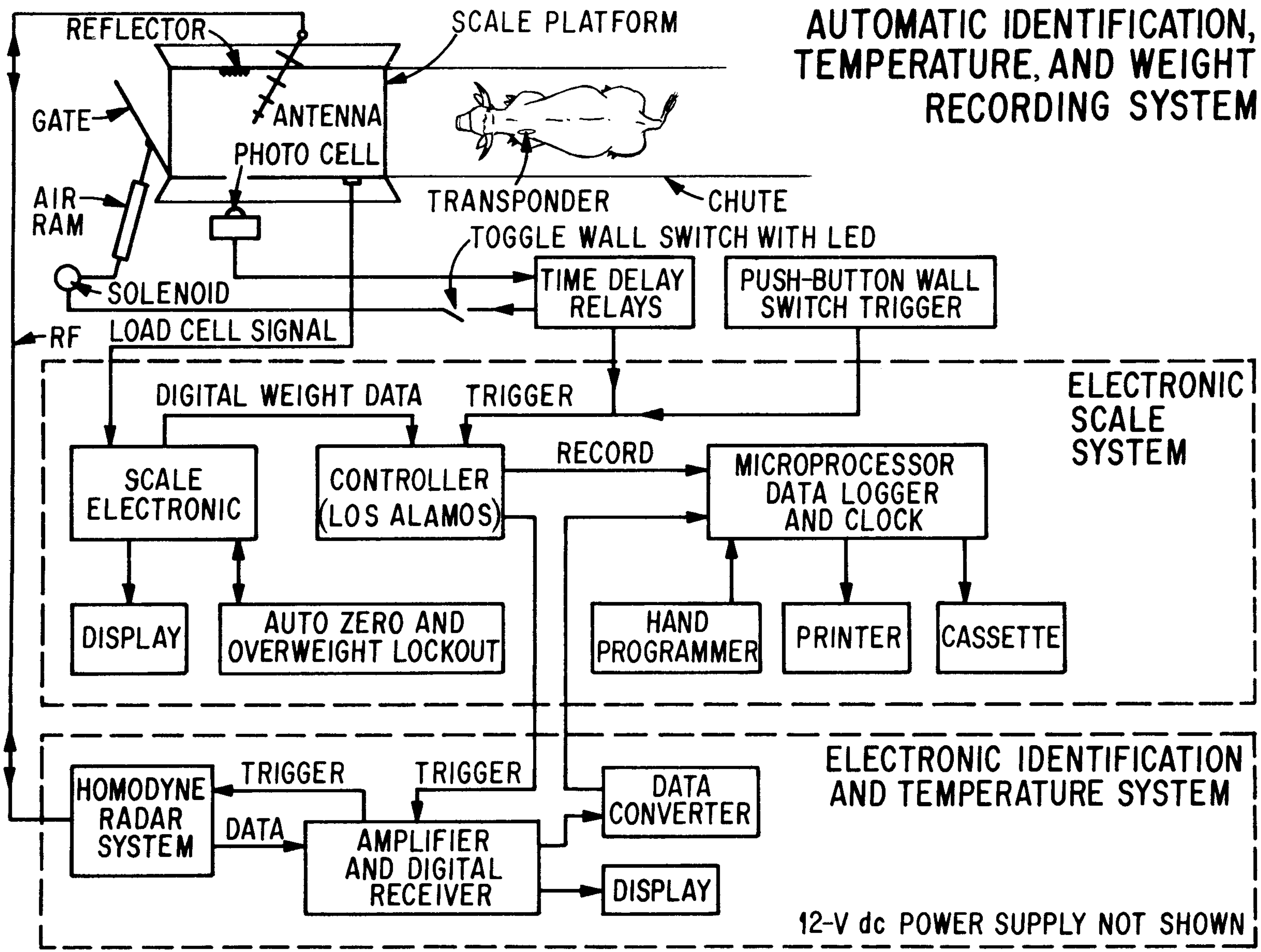



Fig. 1. Block diagram of a single-animal scale and electronic components for manual and automatic weighing, identification, and subdermal body temperature sensing in cattle.

water. The one-way maze, constructed to ensure animal weights are taken before water is consumed, is shown in Fig. 2. Data collected include Julian date, military time, animal weight, electronic identity, and animal temperature. Every 28 days, all animals are restrained and weighed manually with animal fire brand numbers, also entered by hand. These weighings allow a comparison of restrained weights with automatically obtained weights. Manual operation of the system also allows a check of transponder function. All data are stored on cassette tape and can be simultaneously displayed on paper printout.

Temperature measurements obtained from the transponders varied considerably when monitored on a spot basis through the automatic monitoring arrangement. The use of subdermal temperature measurements has not been fully evaluated; however, results are discussed in Sec. II.C.

Weight and ID data collected between Julian day 200 and 350 of 1980 are currently being analyzed. Fluctuations are evident in animal weights, some of which may by cyclical (Fig. 3). This makes it difficult to assess weight gain efficiency with only a few data points. However, repeated unattended weighings may allow the

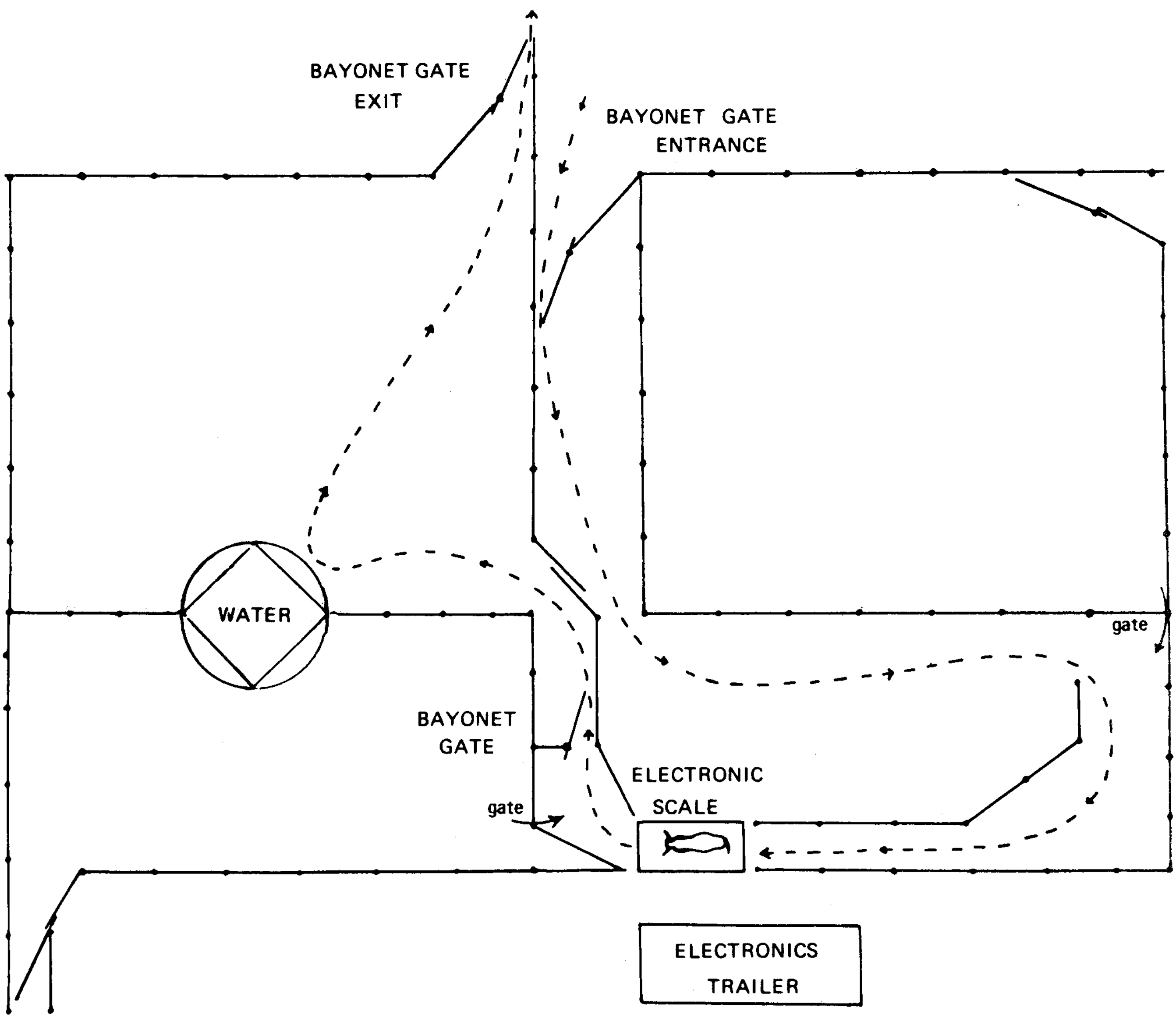



Fig. 2 One-way maze through which animals must pass as they go to water. Design of the maze ensures that the animals' weights are taken before water is consumed. Identification, temperature, and weight are automatically monitored as the animal crosses the scale.

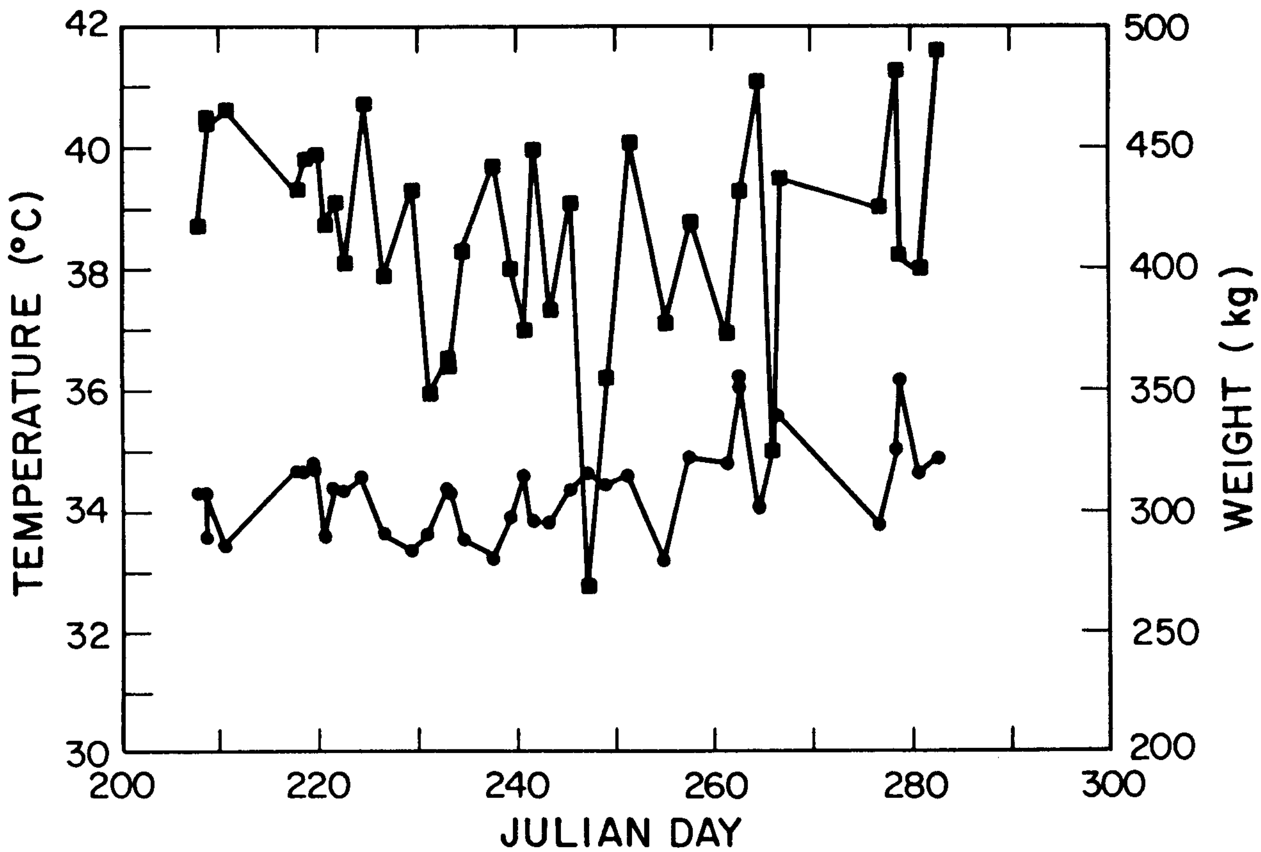



**Fig. 3. Automatically acquired weight (●, kg) and temperature (■ , °C) data obtained from a hereford cow over a 75-day period. The cow was grazing unimproved semidesert rangeland on the Jornada Experimental Range between July and October 1980.**

accurate determination of weight gain efficiency in individual animals (Table I). The ability to automatically monitor rate of gain for individual animals will make it possible to recognize and correct those factors responsible for poor performance. Increased production at a lower cost should result if management decisions can be based on individual animal records rather than a herd average.

### B. University of Illinois

For testing electronic ID, an effort was made to select those sites that encompassed different areas of cattle management, including feed lots and dairies. Also, it was important to use research facilities, that were involved in computer applications to animal management. The University of Illinois has been involved in dairy applications of computers and has pursued the use of electronic identification in dairy cattle management.[3] Los Alamos is partially supporting the effort, which offers a full test of electronic ID in a dairy environment, assessment of its commercial usefulness, and the development of new applications.

The goal at Illinois is to improve milk production through improved automated management techniques. The University of Illinois uses an ID system designed and manufactured by Identronix, Inc., which is similar to the Los Alamos design. Early transponders were not implanted but externally mounted on neck chains. Newer transponders were implanted in 20 heifers. An interrogation distance of 30 cm produced successful readings 75 to 85% of the time. The footprint pattern of the interrogation beam is elliptical with a 90- by 80-cm major-minor axis. The system operates on a 915-MHz frequency compared to 462 MHz with the Los Alamos system. The difference in frequencies between the two types of transponders produces a difference in interrogation range (Los Alamos longer) and transponder size (Los Alamos larger). The system has been equipped with 27 m of 1.25 cm foam dielectric cable between interrogator/receiver and antenna, to increase system flexibility.

## TABLE I

### JORNADA RANGE EXPERIMENT
### LOS ALAMOS-ID ANIMALS
### 24 JULY 1980—10 OCT 1980
### PASTURE 2-NORTH

| LC ID | LOS ALAMOS ID | IMPLANT DATE | BIRTH YEAR | | DAY CONSTRAINED 219 | 220 | 233 | 261 | DAYS READ | | WGHT KGS | GAIN KGS/DAY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7417 | 900 | 06-29-79 | 1977 | S X H | OK | -- | XX | XX | 01 | 2S | | |
| 7416 | 904 | 06-29-79 | 1977 | S X H | XX | XX | XX | XX | -- | | | |
| 7304 | 905 | 06-29-79 | 1977 | H X S | XX | -- | XX | XX | -- | | | |
| 7407 | 908 | 08-10-79 | 1977 | S X H | -- | XX | XX | XX | -- | | | |
| 7302 | 909 | 08-10-79 | 1977 | H X S | XX | XX | OK | OK | 33 | ◆◆ | 406.2 | +0.181 |
| 7140 | 915 | 09-20-79 | 1977 | H X H | OK | -- | OK | OK | 27 | ◆◆ | 314.7 | +0.181 |
| 7105 | 916 | 09-20-79 | 1977 | H X H | OK | -- | XX | OK | 03 | 2S | 355.8 | -0.501 |
| 6400 | 921 | 09-20-79 | 1976 | S X H | OK | -- | XX | XX | 05 | 2S | 436.6 | +0.030 |
| 6401 | 922 | 09-21-79 | 1976 | S X H | OK | OK | OK | OK | 22 | ◆◆ | 368.4 | +0.130 |
| 7301 | 923 | 09-20-79 | 1977 | H X S | XX | -- | XX | XX | -- | 2S | | |
| 6111 | 925 | 09-20-79 | 1976 | H X H | OK | -- | OK | OK | 10 | 2S | 352.4 | +0.132 |
| 7136 | 926 | 09-20-79 | 1977 | H X H | OK | -- | OK | OK | 08 | 2S | 359.8 | -0.612 |
| 7113 | 927 | 09-20-79 | 1977 | H X H | OK | -- | XX | OK | 06 | 2S | 446.7 | +0.189 |
| 7103 | 928 | 09-20-79 | 1977 | H X H | OK | -- | OK | OK | 07 | 2S | 399.3 | -0.070 |
| 7401 | 931 | 09-21-79 | 1977 | S X H | -- | XX | OK | XX | 23 | ◆◆ | 430.6 | +0.166 |
| 7106 | 932 | 09-21-79 | 1977 | H X H | -- | OK | OK | OK | 25 | ◆◆ | 352.8 | +0.340 |
| 7402 | 935 | 09-21-79 | 1977 | S X H | OK | XX | XX | XX | 30 | ◆◆ | 377.0 | +0.098 |
| 7414 | 938 | 09-20-79 | 1977 | S X H | -- | OK | OK | OK | 22 | ◆◆ | 412.7 | -0.131 |
| 6112 | 939 | 09-20-79 | 1976 | H X H | OK | OK | OK | OK | 35 | ◆◆ | 309.4 | +0.235 |
| 6109 | 941 | 09-20-79 | 1976 | H X H | OK | -- | XX | XX | 05 | 2S | 402.3 | -0.395 |
| 7303 | 942 | 09-21-79 | 1977 | H X S | OK | -- | XX | XX | 08 | 2S | 472.2 | -0.132 |
| 6304 | 944 | 09-20-79 | 1976 | H X S | XX | XX | XX | XX | 02 | | | |
| 7132 | 948 | 09-21-79 | 1977 | H X H | OK | -- | OK | XX | 05 | 2S | 441.0 | +0.307 |
| 8119 | 949 | 02-13-80 | 1978 | H X H | OK | -- | OK | OK | 22 | ◆◆ | 271.0 | +0.082 |
| 8447 | 950 | 02-12-80 | 1978 | S X H | OK | OK | OK | OK | 11 | | 315.7 | +0.443 |
| 8121 | 955 | 02-13-80 | 1978 | H X H | XX | -- | XX | XX | -- | | | |
| 8117 | 958 | 02-13-80 | 1978 | H X H | XX | XX | XX | XX | -- | | | |
| 8438 | 962 | 02-12-80 | 1978 | S X H | OK | OK | OK | OK | 20 | ◆◆ | 372.4 | +0.340 |
| 8420 | 963 | 02-13-80 | 1978 | S X H | OK | -- | XX | OK | 22 | ◆◆ | 445.0 | +0.600 |
| 8115 | 965 | 02-13-80 | 1978 | H X H | XX | XX | XX | XX | -- | | | |
| 8300 | 971 | 02-13-80 | 1978 | H X S | OK | OK | OK | OK | 25 | ◆◆ | 352.2 | +0.337 |
| 8440 | 972 | 02-12-80 | 1978 | S X H | OK | OK | OK | OK | 30 | ◆◆ | 309.6 | +0.178 |
| 8424 | 973 | 02-13-80 | 1978 | S X H | OK | OK | OK | OK | 33 | ◆◆ | 329.1 | +0.062 |
| 8302 | 976 | 02-12-80 | 1978 | H X S | XX | -- | XX | XX | -- | | | |
| 8442 | 978 | 02-13-80 | 1978 | S X H | OK | OK | OK | OK | 15 | && | 362.1 | +0.750 |
| 8422 | 979 | 02-13-80 | 1978 | S X H | OK | -- | XX | OK | 24 | && | 374.1 | +0.621 |
| 8120 | 984 | 02-12-80 | 1978 | H X H | OK | OK | -- | OK | 27 | ◆◆ | 303.7 | +0.486 |

H -- HEREFORD
S -- SANTA GERTRUDIS
OK -- GOOD READING
-- -- DID NOT WEIGH
XX -- COULD NOT READ
◆◆ -- APPEARS TO BE GOOD DATA
2S -- IN OTHER PASTURE DURING EXPERIMENT
&& -- TRANSPONDER 978 WAS READING 979 PART TIME

The system has not been fully incorporated into the dairy operation. In November 1980, Los Alamos provided additional Identronix equipment in the form of an interrogator/receiver, a 16-position antenna controller, 16 antennae, and 115 transponders. These will be used to interrogate animals in the milking parlor. Animal temperature, milk yield, milk temperature, and milk conductivity data can then be automatically collected for each animal to assess animal productivity and health. One of the major efforts required with development of a computer system using electronic ID and automated devices has been in software development. Funds permitting, Los Alamos will provide an LSI microcomputer and support in software development and system maintenance.

## C. Temperature

Data were obtained at the Jornada Experimental Range and the University of Illinois to show the type of temperature data that are collected subdermally at the withers with the electronic ID system. These data have not been fully analyzed; however, subdermal temperatures will vary considerably within and between days (Figs. 3-6). Similar results were obtained at the University of Illinois, where an average subdermal temperature of 32.6 ± 1.5°C was determined among 20 heifers maintained in an outdoor environment. Results obtained the previous year from experiments involving radiotelemetry also indicated large fluctuations in subdermal temperatures from animals in an outdoor environment.[1] Because the livestock industry considers temperature to be an important component of the system, it was considered important to determine the magnitude of the problem and, if possible, to overcome it. However, this was pursued at reduced effort as APHIS preferred to deemphasize temperature studies.

The accuracy with which fevers could be detected from one or more subdermal sites was investigated. Radiotransmitters were implanted in the withers, dewlap, thorax, and abdomen of each animal. These sites were not selected with regard to any consideration in transponder interrogation, but rather for diverse sampling of subdermal temperatures. Animals were also equipped with ear-mounted transmitters to monitor tympanic temperature. The latter was used as a reference for deep body temperature. The experimental protocol was similar to a previous experiment.[1] Animals were maintained in an uncontrolled outdoor environment, and data were collected once every 5 min. Twenty-three days after transmitters were implanted, animals were intranasally innoculated with infectious bovine rhinotracheitis virus ($10^8$ infectious units) and monitored for 13 days to follow the course of the fever. Subdermal transmitters included Los Alamos designed transmitters and commercially available transmitters (Telonics, Inc.). Data were collected on an Intel 8010 system and the LSI physiological monitor system.[1] Once collected, data were transferred to the Los Alamos central computer facility where the analyses were performed.

In Fig. 4, pre-injection temperature patterns are shown for four implant sites on a single animal; Fig. 5 shows the patterns obtained from a second animal during the febrile period. Visual comparisons of these patterns indicate different relationships between subdermal and deep body temperatures in different body locations. It appears from these data that subdermal temperature in the withers area is much more variable than abdominal subdermal temperature. The results of a multiple regression analysis, which compares the effects of deep body temperature and black globe temperature on subdermal temperature are shown in Table II. The data in Table II were derived from the equation

$$Y = A + B_1X_1 + B_2X_2 \ ,$$

where Y is subdermal temperature. $X_1$ and $X_2$ are deep body temperature and black globe temperature, respectively. Coefficients $B_1$ and $B_2$ denote the relative contributions of $X_1$ and $X_2$ to a predictive Y. It can be seen from Table II that contributions from deep body and black globe temperatures are less when considering abdominal subdermal temperatures in these two animals than withers subdermal temperature. The ratio of mean squares (MS) shown in Table II estimates the relative contributions of deep body and black globe temperature. For example, in animal J0780, an MS ratio of 0.36 indicates that all but 36% of the variability in withers subdermal temperature can be accounted for by variations in deep body and black globe temperatures. However, in the abdominal region, a much greater portion of the subdermal variation is unaccounted for in the multiple regression. This may indicate that, although abdominal temperature does not differ much from deep body temperature, differences that exist may not be easily reduced by environmental correction.

Results obtained at the Jornada site reinforce the data obtained in the Los Alamos study. In Fig. 6, average subdermal withers temperatures from 15 transpondered animals are shown for Julian days 206 to 284 along with the frequency of interrogation. Both are plotted relative to time of day. The diurnal pattern compares favorably with the diurnal pattern associated with withers subdermal temperature shown in Figs. 4 and 5.

Indications are that although dermal temperatures are affected by environmental factors, there are ways to minimize their effect. Alternative locations should be considered in terms of ease of interrogation and temperature monitoring effectiveness. Corrections to subdermal temperatures should also be considered. A linear multiple regression was applied to predict deep body temperature from subdermal and black globe temperature with some success, but not pursued beyond prelimnary analysis. The University of Illinois is approaching the problem by comparing the temperature of each animal relative to the average herd temperature

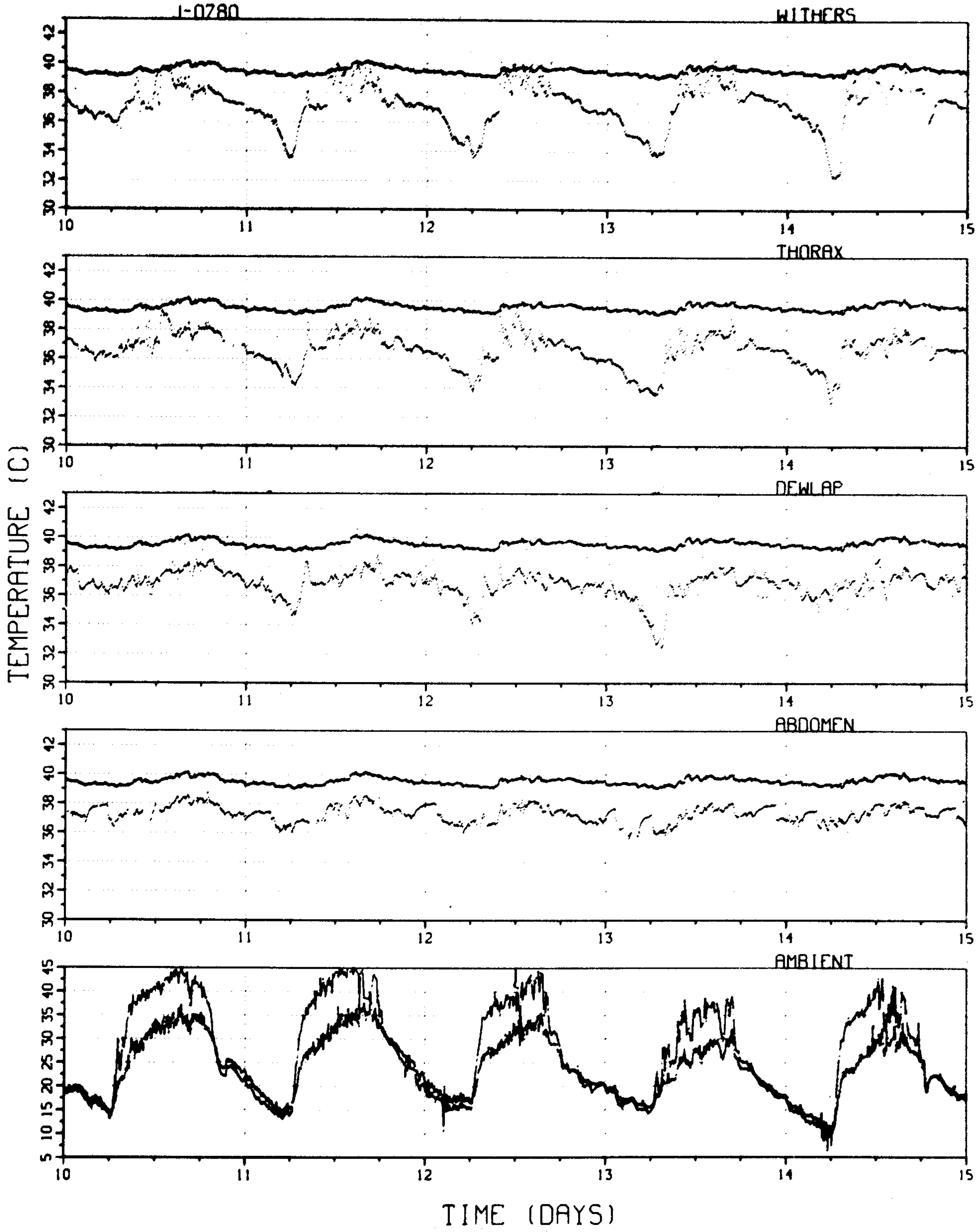



**Fig. 4.** Pre-infection subdermal temperature patterns taken from four implant sites on a single animal. "WITHERS = dorsal postscapular region; THORAX = postscapular, midthoracic region; DEWLAP = developed region central to the thoracic inlet; ABDOMEN = ventral abdominal area. Fluctuating patterns in each plot represent subdermal temperatures and the relatively stable pattern in each plot is ear-canal temperature. Indoor (lower amplitude variations) and outdoor ambient temperatures are also shown.

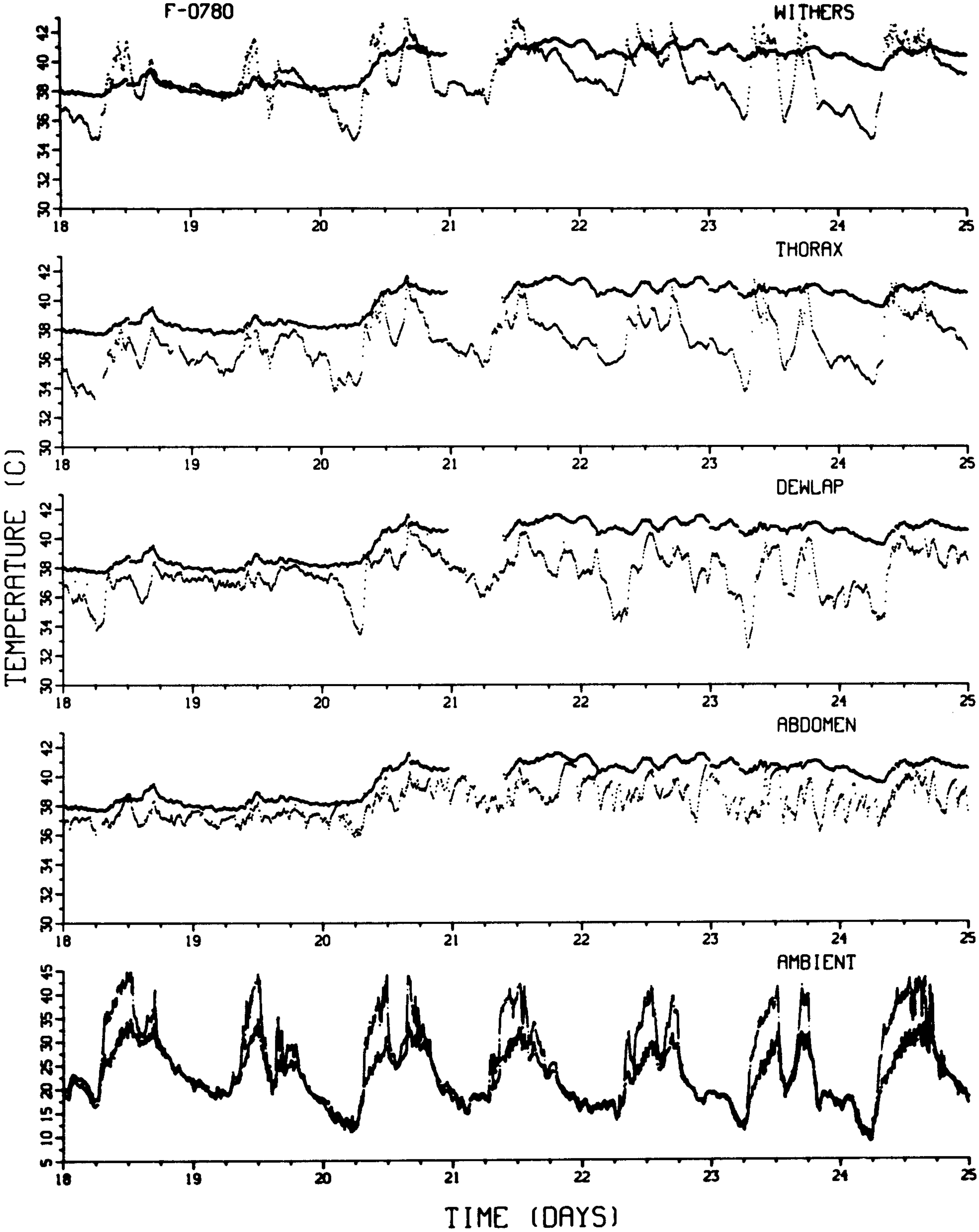



Fig. 5. Postinfection temperature patterns measured at four subdermal sites and the ear canal. See Fig. 4 caption for details.

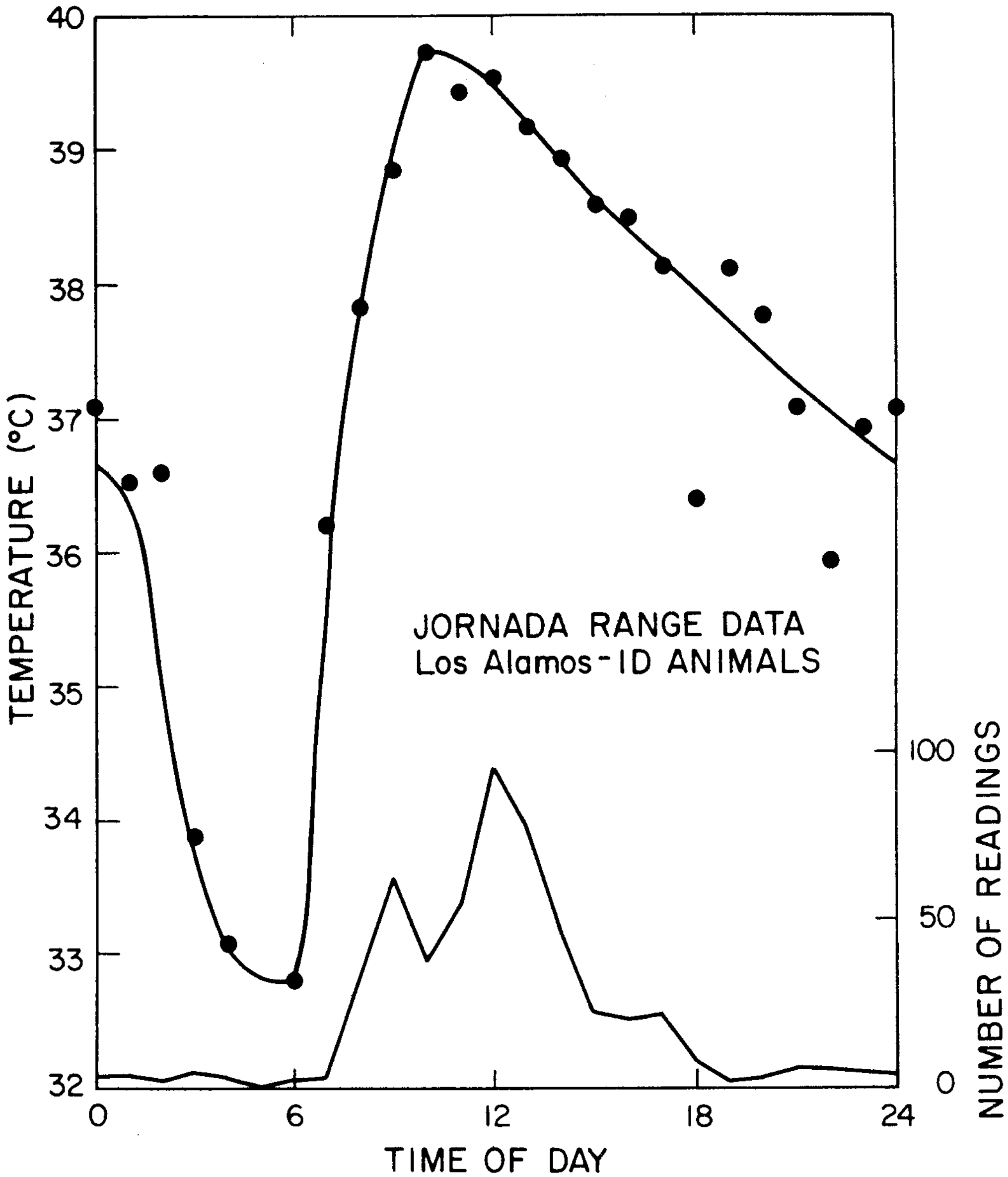



Fig. 6. Average subdermal withers temperatures from 15 transpondered cattle at the Jornada range.

with the idea that the difference in temperature will remain relatively constant in healthy animals, and changes could indicate an altered status. The amount of data collected is insufficient for an adequate test of the method and development of a management scheme must wait for the time when the ID system is incorporated into the dairy operation.

## III. DISCUSSION

Within the past year, funding for the electronic ID project has been reduced to a point where full evaluation of the system will not be possible.[4] The electronics industry has been hesitant to commit itself to the concept because a market for the system has not been established and a considerable expenditure would be required to develop the market. For this reason, Los Alamos has attempted to see the development of electronic ID through to the final phase of commercial production. Over the past several years, it has become apparent that inducing commercial production is much more difficult than first presumed. However, it still appears that much of the research must be carried out through public rather than private funds. Although development of a workable system has been completed, a fully compatible system requires further refinement.

TABLE II

MULTIPLE REGRESSION ANALYSIS COMPARING THE EFFECTS OF DEEP BODY AND BLACK GLOBE TEMPERATURE ON SUBDERMAL TEMPERATURE

| | $A^a$ | $B_1^a$ | $B_2^a$ | MS Ratio |
|---|---|---|---|---|
| Animal J0780 | | | | |
| Withers | −42.35 | 1.94 | 0.10 | 0.36 |
| Thorax | −19.93 | 1.38 | 0.07 | 0.40 |
| Dewlap | −5.57 | 1.04 | 0.04 | 0.66 |
| Abdomen | 11.56 | 0.63 | 0.02 | 0.81 |
| Animal F0780 | | | | |
| Withers | −9.18 | 1.19 | 0.07 | 0.41 |
| Thorax | −14.40 | 1.31 | 0.03 | 0.57 |
| Dewlap | −10.01 | 1.24 | −0.01 | 0.75 |
| Abdomen | 17.81 | 0.50 | 0.02 | 0.68 |

[a]Multiple regression ($Y = A + B_1X_1 + B_2X_2$) of four subdermal locations for two animals.
$X_1$ = core temperature, $X_2$ = black globe temperature.

## REFERENCES

1. C. T. Araki, J. A. Landt, D. M. Holm, R. R. Brown, G. L. Seawright, R. J. Payne, and D. M. Anderson, "Electronic Identification, October 1, 1978-September 30, 1979," Los Alamos Scientific Laboratory report LA-8315-PR (August 1980).

2. D. M. Anderson, J. A. Landt, and P. H. Salazar, "Electronic Weighing, Identification and Subdermal Body Temperature Sensing of Range Livestock," in *Forage Evaluation-Concepts and Techniques*, I. L. Wheeler and R. D. Mochrie, Eds. (Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia, 1981).

3. H. B. Puckett, E. F. Oliver, S. L. Spahr, and T. J. Siktberg,"Use of a Micro- and Minicomputer System for Real Time Data Collection," Proceedings of 1980 Meeting of Amer. Soc. Agric. Eng., San Antonio, Texas, June 15-81, 1980.

4. D. M. Holm, C. T. Araki, J. A. Landt, W. M. Sanders, G. L. Seawright, and D. M. Anderson, "Present Status of Electronic Identification," presented at the United States Animal Health Association Annual Meeting, Louisville, Kentucky, November 3-7, 1980.

# APPENDIX

## TRANSPONDER CODING ALTERNATIVES

by

J. A. Landt

### INTRODUCTION

This report represents the present status of the development of an electronic identification system designed for a national disease control and traceback program for livestock. Two main items remain before electronic identification becomes a reality for the disease control and traceback function.

First, the economics of identification need to be addressed. This is the thrust of the field test experiments.

Second, the present equipment must be transformed into a commercially viable system that is suited for a national electronic identification system. This task should not be underestimated, and it involves many aspects of the equipment. The equipment must be rugged, reliable, easy to use, and economical. The ID code capacity must be increased and an efficient means of handling the extra data bits must be devised. The present Los Alamos transponders have a 12-bit binary coded decimal (BCD) format. Indications are that at least 15 decimal digits are needed for a national system. This requires 60 bits (BCD). The present Los Alamos coding design could be expanded to this number, but the coding and electronic complexities do not favor this approach. This appendix presents an alternative transponder design having a large number of bits with equipment to code and read the transponder.

This solution is an inexpensive one, designed primarily for demonstration purposes. At present, about 1 week has been devoted to the design and construction of equipment. The design philosophy and circuitry (see below) provided here demonstrate that expanding the bit requirement does not require equivalent expansions of equipment size or cost. It does, however, bring up questions of code conventions, etc.

## DESIGN PHILOSOPHY

The block diagram of an identification unit is shown in Fig. A-1. Most electronic identification schemes can be explained in terms of this diagram. For example, consider the present Los Alamos electronic identification system for livestock. An interrogating beam illuminates the transponder (identification unit). Power is derived from rectification of the interrogation beam microwave signal. The command operation is wired to the power supply and the unit operates as long as power exists. The oscillator is a temperature-dependent multivibrator (which also permits the unit to measure temperature). The code storage resides in hard-wired connections to a CMOS CD4067 multiplexer. The modulation code generator consists of a CD4040 ripply counter, an MM54C73 flip-flop, and an MM54C00 NAND gate. These three chips use the oscillator output and the code provided by the CD4067 to produce a frequency shift keying (FSK) of a biphase coded signal. This coding scheme was used to overcome problems inherent in the homodyne radar interrogation system and to provide an efficient, reliable code. The modulator of Fig. A-1 is a transistor and the output device is the same voltage doubler used to power the unit. The output signal is the resulting modulated signal scattered by the antenna from the interrogating signal. This scattered signal is received and processed in the interrogator to yield the unit's code numbers (identification and temperature).

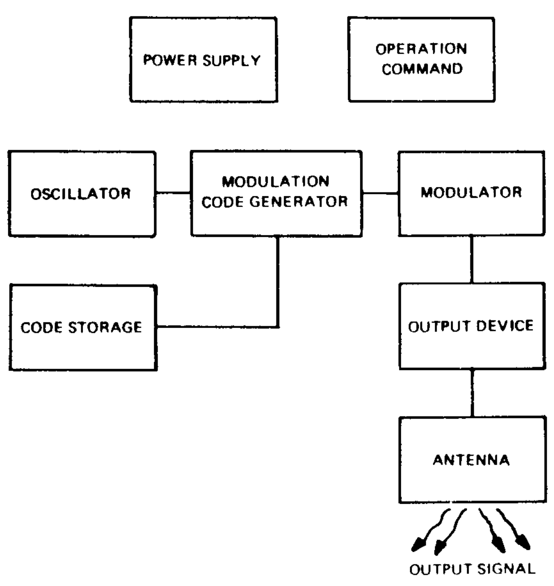



**Fig. A-1. Block diagram of an identification unit.**

The present Los Alamos scheme works very well, as evidenced by the successes of the Los Alamos field tests. However, expanding the code beyond its usable 12 bits is difficult. A 64-bit multiplexer is not currently available and even if it were, coding for 64 bits as hardware connections would make the units expensive and fragile. The interrogator circuitry would have to be modified for handling the extra bits.

The solution to these troubles must be addressed before commercialization of electronic identification. This appendix addresses the problem of expanding the code, as the basic idea of subdermal passive transponder operation has already been proven. For a demonstration unit, the following criteria were chosen: (1) at least 64 bits, (2) easy to code, (3) easy to read, and (4) simple. The resulting "proof-of-principle" design is not that of a true transponder. Work required to produce a true transponder is discussed later. In a true transponder, the transponder responds to an interrogation beam. In this demonstration unit, the unit responds when a switch is pressed (like a garage door opener). The conversion to transponder action is straightforward.

## DESIGN DETAILS

To expand the code, the bits are stored in a static shift register. For example, a MC14562 has 128 bits. The data format is standard ASCII (instead of BCD). This format uses 7 bits for data and 3 bits for parity and framing for each character. The 128 bits then give a maximum of $(2^7)^{12}$ or $1.93 \times 10^{25}$ unique code combinations. The ASCII standard includes all of the digits (0 through 9), upper and lower case letters, special symbols, and control characters. The data transfer rate was chosen at 300 BAUD so that the identification unit's code could be read on any standard ASCII terminal. An ASCII terminal can also be used for programming the identification unit's code. The major drawback of a static shift register is the requirement for a continual power supply (for example, battery). If the power supply is lost, the code is lost also.

The 300 BAUD is generated in a CD 4060 clock/oscillator operating at a fundamental frequency of 2.4567 MHz. Simple pulse code modulation of the 2.4567 MHz signal is provided by a 40107 NAND gate. It is this modulated signal that is transmitted by the unit and decoded by a receiver. The command to transmit is a simple push button on the identification unit. The electrical schematic for the identification unit is shown in Fig. A-2.

The identification unit is coded by using the circuitry shown in Fig. A-3 in conjunction with a TRS80 computer program shown in Fig. A-4. To code an identification unit, it is attached to the circuit of Fig.A-3. The circuit of Fig. A-3 is attached to the RS232 port on a TRS80 computer and the program listed in Fig. A-4 is executed. Data typed on the TRS80 keyboard are entered into the shift register. CR (carriage return) and LF (line feed) characters are added to the end of the code to denote where the message ends. The code can also be read from the ID unit for verification.

Once coded, the ID unit is then detached. When the ID unit is activated, the receiver shown in Fig. A-5 can accept the ID unit's code. The line marked "data" is the decoded ASCII data received from the ID unit. This data line can be connected to any ASCII terminal for display or to a computer for data logging.

The transmission of 2.4567 MHz energy from the ID unit is inefficient and the receiver is crude. Therefore, the range of this system is about 60 cm, which is sufficient for demonstration purposes.

## EXTENSIONS AND DISCUSSIONS

The code length can be extended by increasing the size of the shift register (Fig. A-2) or by cascading registers. No other modifications are required, but clock timing requirements for the shift registers can become more demanding when the registers are cascaded.

The requirement for a standby battery is one drawback; however, the battery can be small. For example, the Panosonic lithium battery, BR-425, weighing 2.3 g, is 0.4 cm diam by 2.5 cm long, and will power the circuitry of Fig. A-2 in standby mode for 23 yr, using the stated battery capacity. Battery life will likely be more limited, but still in excess of 10 yr.

The concepts presented here could be adapted to the Los Alamos electronic identification system. The system would not be any more complex nor any larger than the present system, but would require small batteries in the transponders. Several months of design and breadboarding would be required to develop a true transponder system. This work would be worthwhile, but will not be initiated unless present funding constraints are removed. These constraints limited the present work to the simple demonstration unit presented here. The proposed development would produce a system that would be much closer to one that might attract commercial interest in electronic identification. Inclusion of the ASCII standard code may also make potential commercial developers more comfortable with the transponder design.

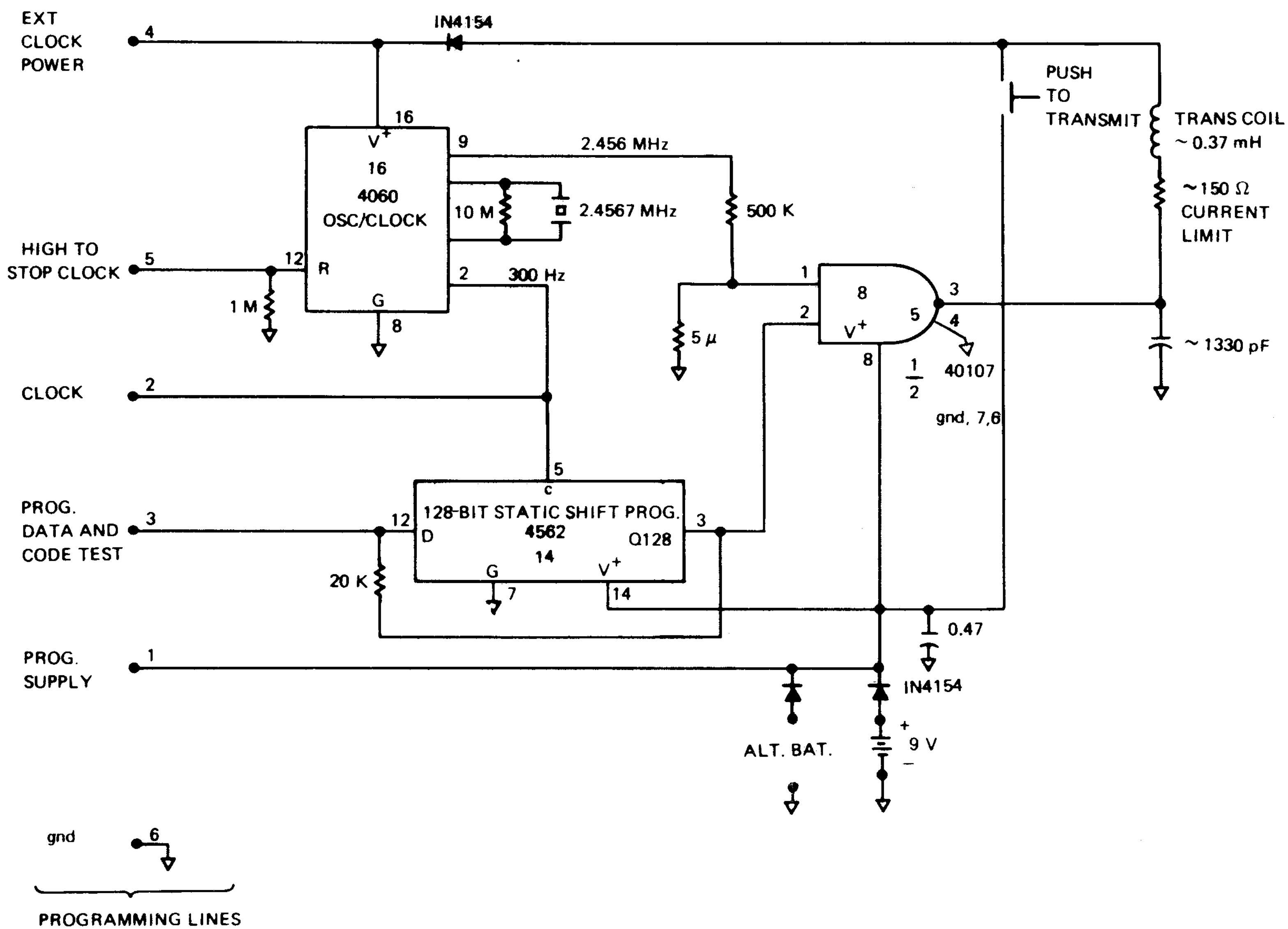



Fig. A-2. 128-bit identification unit.

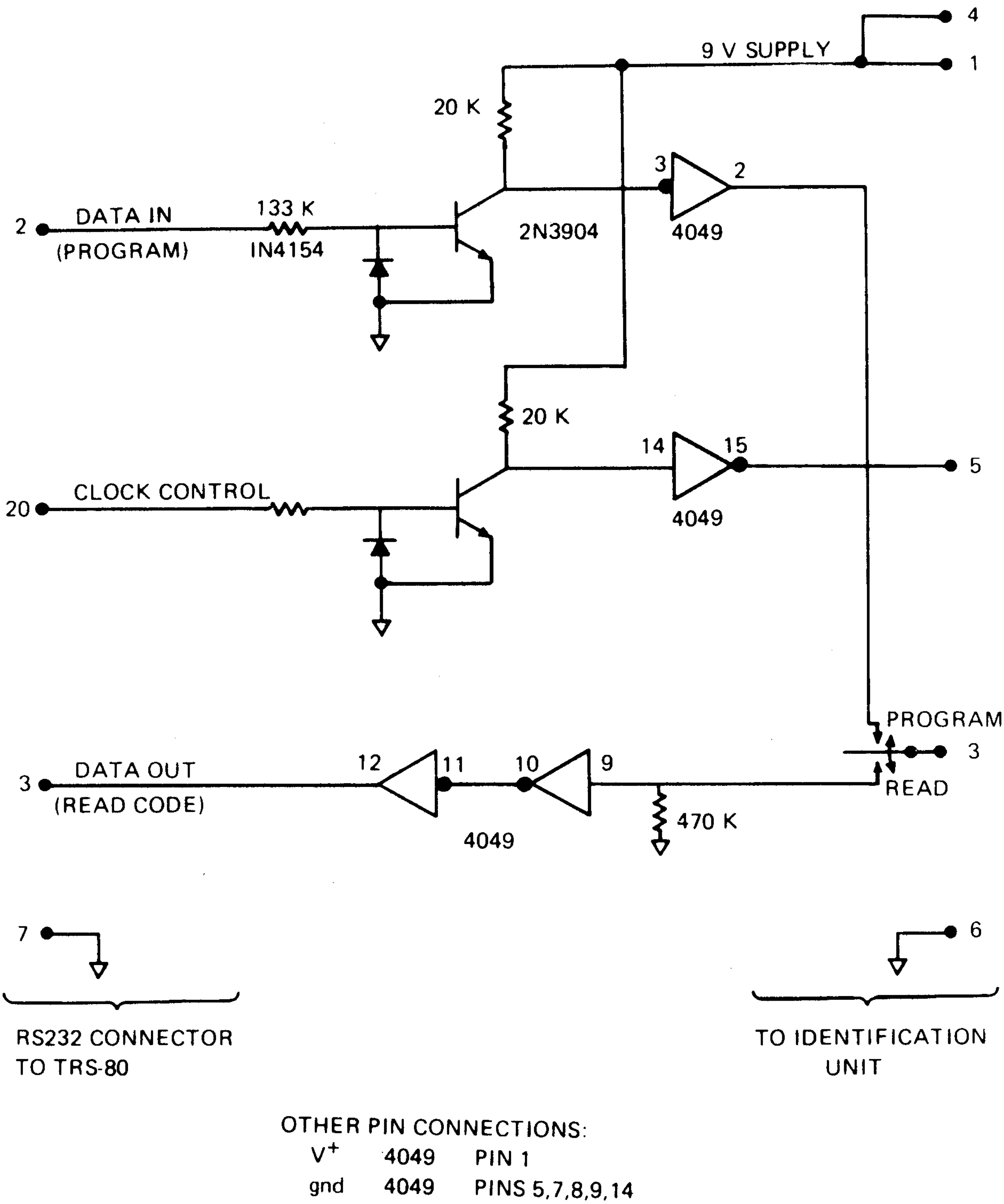


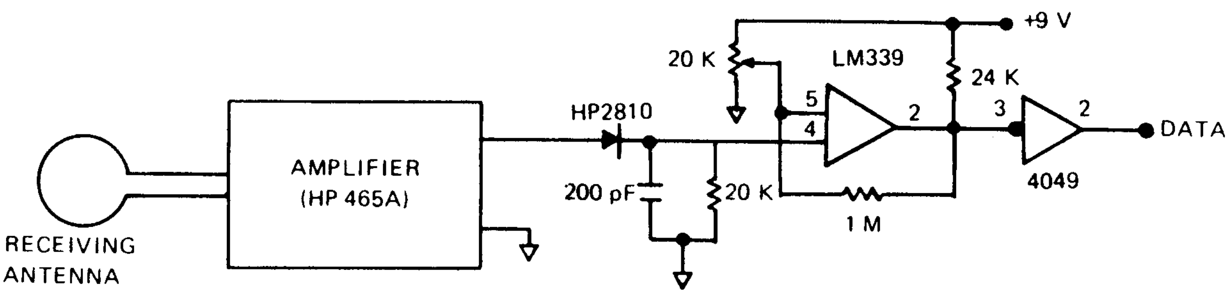

**Fig. A-3. Programmer circuitry.**

```
10 REM.◆◆◆◆◆  THIS IS FOR PROGRAMING THE 128 BIT TAGS
20 REM
30 REM ◆◆ RESET UART 300 BAUD 7 BIT WORD EVEN PARITY 2 STOP BIT
40 OUT 232,0
50 OUT 233,85
60 OUT 234,164
70 CLS
80 PRINT "CONNECT RS232 AND TAG TO PROGRAMING BOARD"
90 PRINT " "
100 PRINT "HIT # TO CLEAR TAG"
105 PRINT " OR HIT ◆ TO READ CODE"
110 T$=INKEY$
115 IF T$="" GOTO 110
120 IF T$="#" GOTO 140
125 IF T$="◆" GOTO 1000
130 GOTO 110
140 PRINT " "
150 PRINT "WAIT ........";
160 OUT 234,166
170 FOR I=1 TO 1000 : NEXT I
180 OUT 234,164
190 FOR I=1 TO 13
200 PRINT CHR$(8);
210 NEXT I
220 PRINT " "
230 PRINT " "
240 PRINT "PROGRAMING NEXT"
250 PRINT " "
260 PRINT "ENTER CODE. 9 CHARACTERS MAXIMUM"
270 PRINT " "
280 PRINT "HIT THE 'ENTER' BAR TO END"
290 PRINT " "
300 PRINT CHR$(14);
310 T$=INKEY$
320 IF T$="" GOTO 310
330 IF T$=CHR$(13) GOTO 500
340 PRINT T$;
350 X=ASC(T$)
360 IF INP(234) AND 64 >0 GOTO 380
370 GOTO 360
380 OUT 234,166
385 I=1 : I=1
390 OUT 235,X
400 IF INP(234) AND 64 >0 GOTO 420
410 GOTO 400
420 I=1 : I=1 : I=1 : I=1
421 OUT 234,164
430 GOTO 310
500 PRINT " "
510 PRINT " ADDING CR AND LF.  WAIT ....."
```

**Fig. A-4. TRS80 program for entering the code into the identification unit.**

```
520 IF INP(234) AND 64 >0 GOTO 540
530 GOTO 520
540 OUT 234,166
545 I=1 : I=1
550 OUT 235,13
560 IF INP(234) AND 64>0 GOTO 575
570 GOTO 560
575 I=1 : I=1 : I=1 : I=1
576 OUT 234,164
580 OUT 234,166
585 I=1 : I=1
590 OUT 235,10
595 IF INP(234) AND 64>0 GOTO 605
600 GOTO 595
605 I=1 : I=1 : I=1 : I=1
610 OUT 234,164
620 PRINT " "
630 PRINT "DONE.....    REMOVE DATA LINE BETWEEN TAG"
640 PRINT "             AND PROGRAMING BOARD BEFORE"
650 PRINT "             REMOVING TAG."
660 END
1000 OUT 234,166
1010 IF INP(234)>127 GOTO 1030
1020 GOTO 1010
1030 PRINT CHR$(INP(235));
1040 GOTO 1010
1050 END
```

**Fig. A-4 (cont).**




OTHER BIN CONNECTIONS:

| | | |
|---|---|---|
| $V^+$ | LM339 | PIN 3 |
| $V^+$ | 4049 | PIN 1 |
| gnd | LM339 | PINS 6,7,8,9,10,11,12 |
| gnd | 4049 | PINS 5,7,8,9,11,14 |

**Fig. A-5. The receiver.**