View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by NASA Technical Reports Server

N89-20352

Transmitter Data Collection Using Ada

B. L. Conroy

Radio Frequency and Microwave Subsystems Section

This article describes a data collection system installed on the 400-kilowatt X-band transmitter of the Goldstone Solar System Radar. The data collection system is built around off-the-shelf IEEE 488 instrumentation, linked with fiber optics, controlled by an inexpensive computer, and uses software written in the Ada language. The speed and accuracy of the system is discussed, along with programming techniques used for both data collection and reduction.

I. Introduction

The system described in this article is the result of two separate goals. The first goal was to instrument the Goldstone Solar System Radar (GSSR) transmitter to start building a base of operating data that could be used for statistical analysis. The second goal was to demonstrate the feasibility of a data collection system that used only readily available, easily calibrated instruments. This article is concerned with the extent to which this second goal has been realized.

The Ada language was chosen for a number of features: (1) multitasking is provided within the language, (2) it embodies a number of software engineering disciplines such as modularity, strong typing, and levels of abstraction, which will result in robust and more maintainable programs, and (3) the federal government maintains a standard for the language, and enforces conformity to the standard, which will contribute to maintainability of Ada programs.

II. Hardware Description

Figure 1 is a block diagram of the entire system, as installed at DSS 14. The control computer and one data collection unit are located in Room 105. This data collection unit has been wired into the Local Control Console (LCC) to provide access to 26 analog values, 53 interlocks, 40 indicators, and 9 warnings. The second data collection unit is located in Module II, just below the tri-cone area, and connected to Room 105 by a fiber-optic link. This unit monitors 18 resistive temperature detectors (RTDs), 4 turbine flow meters, and 8 paddle-wheel flow meters, all of which were added in the radar feedcone during the 70-meter upgrade period.

A. Control Computer

An IBM industrial AT computer was chosen as the controller. This computer is similar to the standard AT, but is rack-mounted and provided with an air filter and vibration damping mounts for expansion cards. It has an IEEE 488 interface card, which allows a wide range of instruments to be monitored.

B. Data Collection Units

The HP 3852S Data Collection Unit is a rack-mounted card case, with local programming capability and a wide range of plug-in cards. The cards used in this system include a 5½-digit voltmeter (option 44701A), a 5-channel counter (option

44715A), and several multiplexer cards. Reference 1 contains a summary of cards available, and their capabilities.

C. Fiber Optic

The data collection unit in the cone area is linked to the pedestal by a pair of HP 37204A fiber-optic bus extenders. These units are completely transparent to the control computer, and use internal protocols to ensure error-free data transmission. The maximum data transmission rate of 60,000 bytes per second is adequate for this application.

III. Software Description

Figure 2 is a "Booch" diagram of the overall structure of the controlling software at a high level of abstraction. This style of diagram is introduced in [2], which is an excellent introduction to Ada. The central unit is the HARDWARE_DEFINITIONS package, which contains most of the information specific to the transmitter. This package provides a list of all the parameters available (an ENUMERATION type), functions that return the current value and status of each parameter, and an internal task that periodically reads the data collection units. Figure 3 is the declaration of the type PARAMETER, with explanatory comments. The names chosen for the parameters are abbreviations descriptive of the function. For example, Filament Time Delay on klystron 1 becomes FIL_TD_1 (an interlock) and Alidade Heat Exchanger On becomes ALI_HE_ON (a warning because the main heat exchanger should be adequate). Some other abbreviations used are UC for Under Current, CB for Crow Bar, IGN for Ignatron, IL for Interlock, RPA for Reflected Power Amplifier, COLL for Collector, V for Voltage, I for Current, and UA for Microamps.

The GSSR program contains the operator interface. It contains three display tasks, each of which can be directed to display a different view of the data, and a keyboard watching task that switches the views based on operator inputs. The DATA_LOG package monitors the measured data and writes it to disk.

A. Utility Packages

The SCREEN_IO package provides facilities for multiple screen windows, each with its own attributes. These windows are used by the display tasks to present independent views of the measured data. It also provides functions to monitor the keyboard. Although they are not used in this application, it provides control over the screen modes and graphics capability for both color graphics and enhanced graphics adapters.

The IEEE_488 package provides facilities for sending and receiving ASCII or binary data, sending bus commands, serial or parallel polling, and detecting service requests. It contains an internal task for resource control. This is needed in a multitasking environment to ensure that different tasks cannot send conflicting messages.

B. Update

The UPDATE package encapsulates all the information about the data collection unit configurations. Several techniques are used to minimize the number of transactions on the IEEE 488 bus. First is the use of downloaded subroutines in the scanners. On startup, this package loads each scanner with a program that will take all the required measurements. This allows a set of measurements to be taken with the command "CALL DOMEAS" rather than a repetition of what measurements are to be taken. The second technique is the use of block transfers in binary rather than individual data values in ASCII. This reduces the number of bytes sent by about a factor of 3. A third technique is preprocessing the interlocks and indicators (which are either 0 or 28 volts) and sending only the numbers of the channels that exceed a threshold (2 bytes) rather than the actual values (8 bytes). Fourth is overlapping the measurement time of one scanner with the data transfer time of the other scanner.

C. Calculated Parameters

In addition to the parameters measured directly, there are a number of calculated ones. Thermal techniques as described in [3] are used to calculate the power in the water loads on each of the two klystrons and the waster load on the four-port power combiner. In addition, a 4-foot section of the waveguide between the power combiner and the feedhorn has been calibrated and instrumented for a thermal determination of the total power being delivered to the antenna. The time remaining in the present cycle (transmit or receive) is calculated from the round-trip light time (entered by the operator) and the time of the last change in the beam status. This module also determines the correct scale factor for the vacuum-ion-pump current on each klystron from the range indicators.

D. Data Log

The DATA_LOG package contains a set of limits on each parameter, and a task that records all analog parameters whenever one or more of the limits is exceeded.

When the program is started, the operator is prompted for the name of the target, the round trip light time (used to calculate the TIME_LEFT parameter) and a file name for the data. The file name is passed to the LOG task, which creates the file and writes a header consisting of the data, the target, an optional smoothing factor, and the names of the parameters that will be recorded. The LOG task waits until all parameters have been measured, then writes their initial values to the data file. One of the parameters recorded is the measurement time, which time tags the data record. The format used for recording is Comma Separated Values (CSV) that is, the ASCII representation of the values, with commas separating them.

The decision on when to record data is based on a "record on change" algorithm. The DATA_LOG package contains a limit on the absolute value of change for each measured parameter. Every time the data is updated, the LOG task compares the change in each parameter from the last value recorded. If the change on any parameter exceeds the limit for that parameter, it sets a flag. If no parameter has changed more than its limit, the data is kept in temporary storage. When a change does occur, two sets of data are recorded: the last measurement that did not show a change and the measurement that did show a change. This technique simplifies the plotting of the data.

IV. Data Reduction

Supercalc 4 is used for data reduction. One of its options is reading CSV data files, and it allows keyboard macros that can import data, set the scales and labels, and plot the data with a few keystrokes. Figure 4 is a graph of the transmitter output power during a recent experiment. This graph plots the total output power (P_TOT), along with output powers of each klystron (P_OUT_1 and P_OUT_2). Since all operating parameters are recorded, additional graphs, such as beam voltage and drive power, can be produced to determine the source of the variations in the output power. The output power can also be supplied to the scientists for calculation of target albedo or cross section.

V. Results and Discussion

A. Speed and Accuracy

The data collection system reads four turbine flow meters with 1-hertz accuracy. The actual frequencies range from about 900 hertz to 1200 hertz, so this is about 0.1 percent of the actual reading. There are 18 RTD temperature sensors, which are read to about 0.1°C accuracy at a rate of 25 readings per second. The system measures 32 dc voltages with 5½-digit precision (100 readings per second) and 120 dc voltages with 3½-digit precision (160 readings per second). Using the overlapping techniques described above, it makes a measurement of every parameter every 3.5 seconds.

The major limit on the time for a measurement cycle is the integration time of the precision voltmeter. Because one scanner is transmitting its data while the other is making measurements, an increase in the data transfer rate would not decrease the cycle time. The counter card needs 1 second of integration time to get 1-hertz accuracy, but it reads all channels simultaneously, and is independent of the voltmeter, so it is not limiting the overall speed.

If necessary, some speed improvement is possible in the future by using a higher-speed voltmeter (option 44702A) for some of the less critical measurements. This unit has only 12 bits of resolution (plus sign) and a maximum input voltage of 10 volts, but can read up to 100,000 channels per second.

B. Problems

During the initial phases of the development, efforts were made to allow the system to function with bad or missing sensors by marking individual data items as "UNKNOWN," but measuring and recording the rest of the data. This effort was only partially successful. At present, it can detect and allow for problems in the RTD temperature sensors and failures of an entire data collection unit. A problem at the card level within a data collection unit prevents reading of other cards, and a failure of the fiber-optic link prevents reading of the local data collection unit.

C. Open Items

Not yet implemented in the system are: (1) better techniques of detecting and flagging hardware failures, (2) more precise limits on parameters used in the "record on change" algorithm, (3) other tools for data reduction, and (4) real-time graphical representation of certain parameters.

References

[1] Hewlett Packard, HP 3852S, *Data Acquisition and Control System Data Book*, 1986.

[2] G. Booch, *Software Engineering with Ada*, Second Edition, Menlo Park, California: Benjamin/Cummings, 1986.

[3] B. Conroy, H. Schleier, and T. Tesarek, "Thermal Evaluation Method for Klystron RF Power," *TDA Progress Report 42-88*, October–December 1986, Jet Propulsion Laboratory, Pasadena, California, pp. 91–95, February 15, 1987.

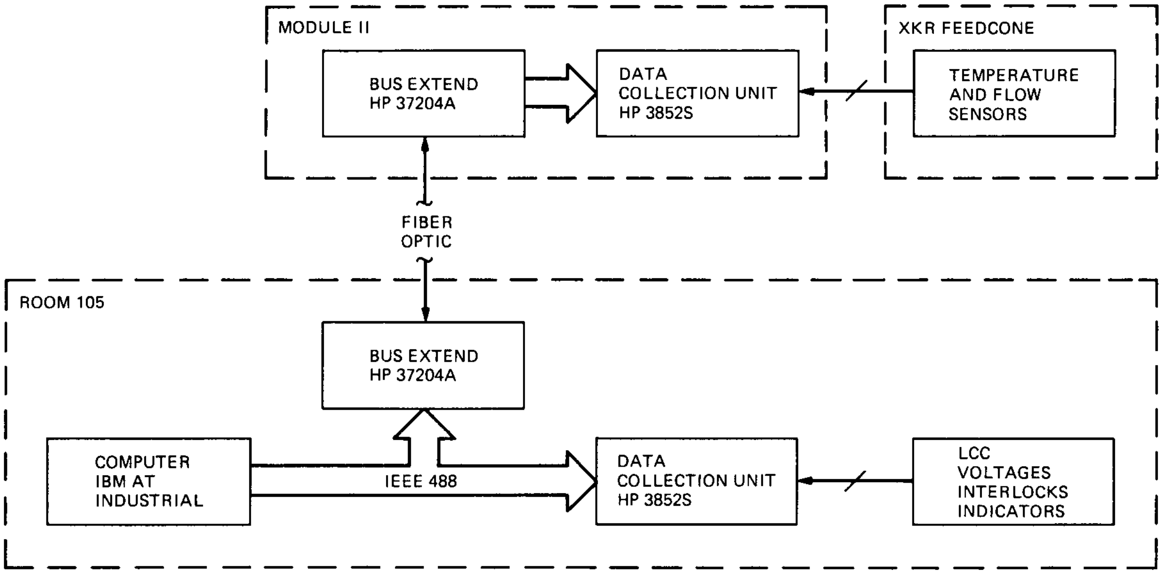

Fig. 1. Block diagram of data collection system.

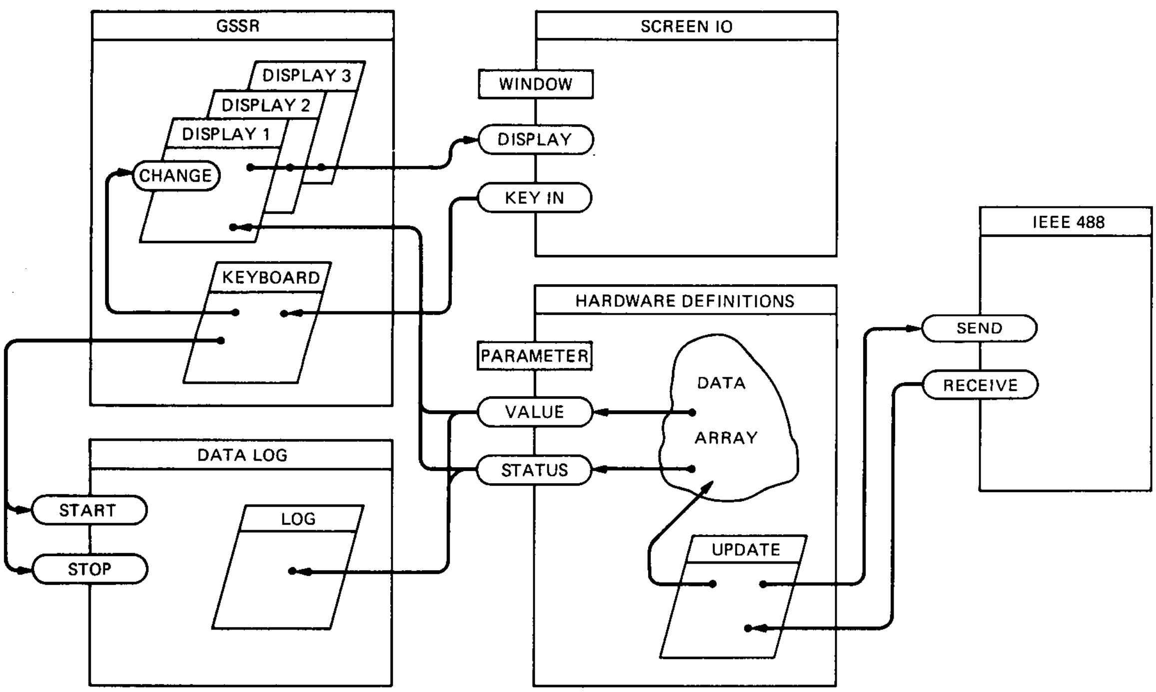

Fig. 2. "Booch" diagram of data collection system software.

ORIGINAL PAGE IS
OF POOR QUALITY

```
type PARAMETER is (

-- analog parameters
   -- Klystron 1, upstairs system
   LOAD_FLOW_1, LOAD_TIN_1, LOAD_TOUT_1, LOAD_TURB_1,
   COLL_FLOW_1, COLL_TIN_1, COLL_TOUT_1,
   BODY_FLOW_1, BODY_TIN_1, BODY_TOUT_1,
   MAG_FLOW_1, WASTE_TOUT_1,
   -- Downstairs system
   COLL_I_1, FIL_I_1, FIL_V_1, MAG_I_1,
   P_OUT_1, P_DRIV_1, P_REFL_1, VAC_I_1,
   RPA_ONE_1, RPA_TWO_1,
   -- calculated parameters
   P_LOAD_1, P_WASTE_1,

   -- Klystron 2, upstairs system
   LOAD_FLOW_2, LOAD_TIN_2, LOAD_TOUT_2, LOAD_TURB_2,
   COLL_FLOW_2, COLL_TIN_2, COLL_TOUT_2,
   BODY_FLOW_2, BODY_TIN_2, BODY_TOUT_2,
   MAG_FLOW_2, WASTE_TOUT_2,
   -- Downstairs system
   COLL_I_2, FIL_I_2, FIL_V_2, MAG_I_2,
   P_OUT_2, P_DRIV_2, P_REFL_2, VAC_I_2,
   RPA_ONE_2, RPA_TWO_2,
   -- calculated parameters
   P_LOAD_2, P_WASTE_2,

   -- Common Parameters, Upstairs
   WG_TURB, WG_TIN, WG_TOUT,
   P_TOT_TURB, P_TOT_TIN, P_TOT_TOUT,
   -- Downstairs
   BODY_I, BEAM_V, BEAM_I, CB_TIME,
   VAC_V, PHASE, VDC_28, P_TOT,
   -- Misc
   P_WASTE, -- sum of two waster loads
   TIME_LEFT, -- derived from RTLT
   MEASUREMENT_TIME,
   -- calculated
   P_TOT_CALC,

-- Indicators
   -- Klystron 1
   UA_5_1, UA_50_1, UA_500_1, UA_5000_1, UA_50000_1, -- Vac Ion Scale
   FIL_RAISE_1, MAG_RAISE_1, DRIVE_RAISE_1,
   FIL_LOWER_1, MAG_LOWER_1, DRIVE_LOWER_1,
   -- Klystron 2
   UA_5_2, UA_50_2, UA_500_2, UA_5000_2, UA_50000_2, -- Vac Ion Scale
   FIL_RAISE_2, MAG_RAISE_2, DRIVE_RAISE_2,
   FIL_LOWER_2, MAG_LOWER_2, DRIVE_LOWER_2,
   -- common
   BEAM_READY, BEAM_ON, BEAM_RAISE, BEAM_LOWER,
   S_BAND_DSN, S_BAND_RADAR, X_BAND_RADAR,
   ANT_POS, LOAD_POS,
   HE_ON, MAIN_HE_ON, MG_ON, DRIVE_ON,
   PHASE_0, PHASE_180, IL_OPEN,
   PGM_MODE, COMP_IF_ON,
```

Fig. 3. Ada declaration of type PARAMETER.

```
-- Warnings
   ALI_HE_ON, AUX_HE_ON, RESIST_IN, RESIST_OUT,
   HE_TANK_LOW, HE_TANK_PRESS, HE_FANS,
   WG_PRESS, TR_FLOW,

-- Interlocks
   -- Klystron 1
   FIL_TD_1, FIL_UC_1, COLL_OC_1, FOCUS_UC_1,
   REF_PWR_ONE_1, REF_PWR_TWO_1, REF_METER_1,
   ARC_DET_ONE_1, ARC_DET_TWO_1,
   COLL_FLOW_LO_1, BODY_FLOW_LO_1,
   LOAD_FLOW_LO_1, DRIFT_FLOW_LO_1, FIL_FLOW_LO_1,
   VAC_PWR_1, CB_MAG_1,
   -- Klystron 2
   FIL_TD_2, FIL_UC_2, COLL_OC_2, FOCUS_UC_2,
   REF_PWR_ONE_2, REF_PWR_TWO_2, REF_METER_2,
   ARC_DET_ONE_2, ARC_DET_TWO_2,
   COLL_FLOW_LO_2, BODY_FLOW_LO_2,
   LOAD_FLOW_LO_2, DRIFT_FLOW_LO_2, FIL_FLOW_LO_2,
   VAC_PWR_2, CB_MAG_2,
   -- common
   ELEVATION, PS_DOOR, PA_DOOR, CB_DOOR,
   TXR_CONFIG, MICROWAVE, CB_TEST, CB_FIRED,
   FAST_BODY, SLOW_BODY, IGN_PWR, BODY_OC,
   DC_OV, DC_OC, PHASE_FAIL, TR_OIL_LOW,
   HV_ZERO, MOTOR_ST, MOTOR_LO, GEN_LO, ALI_HE_OT,

-- other parameters
   OUTPUT_TO, CONFIG,
   TARGET, TIME, DATE, UNUSED, NONE);
```

Fig. 3 (contd).

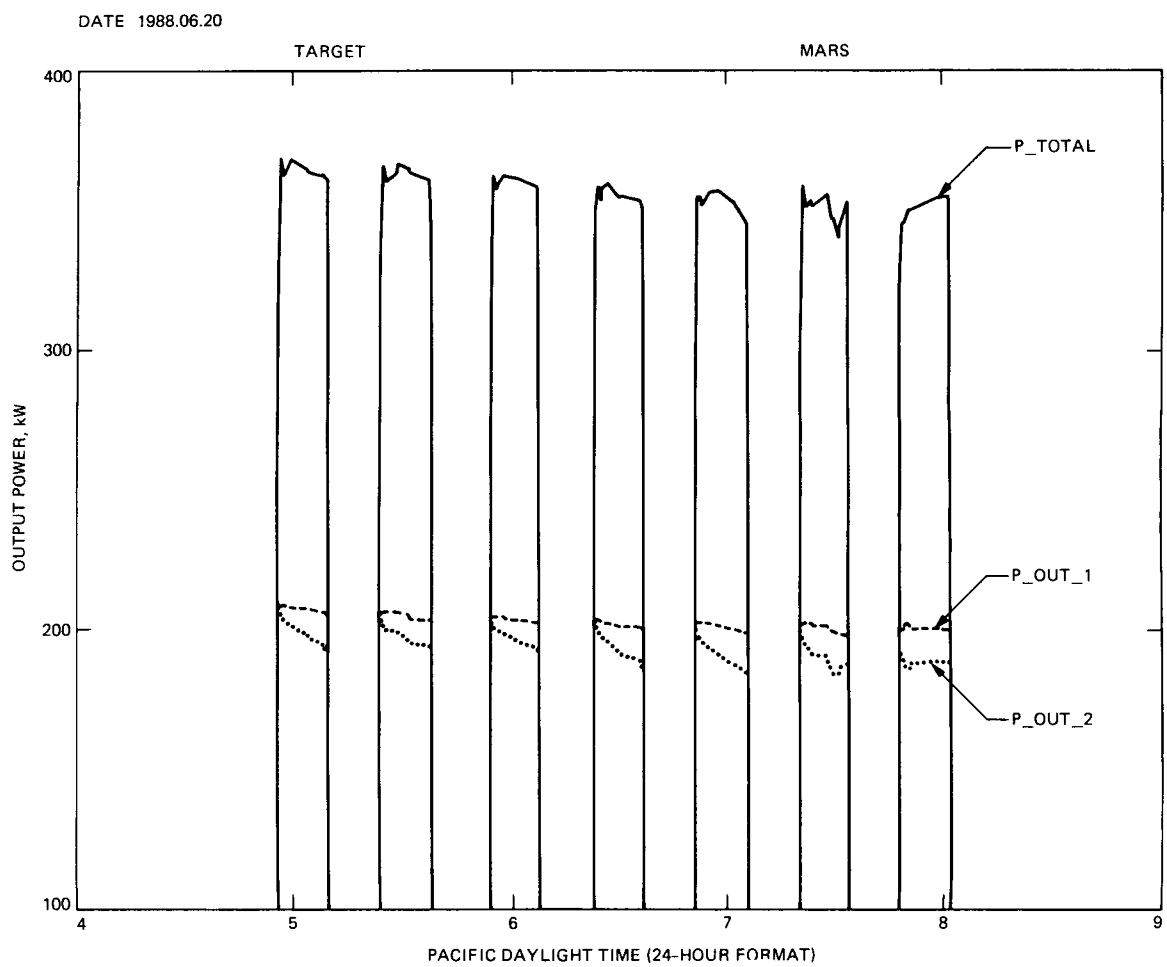

Fig. 4. Typical data plot.