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ENERGY SIGNATURE MONITOR (ESM)

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AIC

Development of a low-cost data acquisition system.

The above photo shows the Energy Signature Monitor (the unit on the left) communicating with at a standard video terminal. The terminal is not needed during normal unattended field operation. Data is recorded on a removable EPROM data module which is located behind the front access door.

Energy Signature Monitor

December 1983

The Energy Performance of Buildings Group at Lawrence Berkeley Laboratory is developing the Whole Building Evaluation System (WBES), which addresses the data acquisition and analysis demands of test programs which require monitoring of a large sample of buildings. Such test programs have hardware and software requirements which are very different than those for detailed laboratory investigations. The Energy Signature Monitor (ESM), which is the data acquisition hardware portion of the Whole Building Evaluation System, along with the attendant data analysis software, is being developed as a novel, cost-effective system that integrates measurement, data collection, and compilation.

Based on laboratory tests and field experience with the original ESM design, which was developed in 1982, the design was refined and six prototypes were built for evaluation. Twenty more ESMs are currently under construction at the Lawrence Berkeley Laboratory for use in two research projects that are being conducted by Lawrence Berkeley Laboratory this winter. Depending on government support for this program, many additional ESMs may be needed. Although there has been no formal market survey, based on inquiries generated by a short article which appeared in Solar Age magazine, there is a very large interest in a data acquisition system such as the Energy Signature Monitor. Although Lawrence Berkeley Laboratory is building the first few ESMs, it would prefer to buy further units from a commercial supplier.

Currently, the Energy Signature Monitor system is being hand produced at Lawrence Berkeley Laboratory for about $1500 each. We estimate that with design changes and mass production techniques, the production cost will approach $500 each.

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ENERGY SIGNATURE MONITOR

Introduction

The Energy Performance of Buildings Group at Lawrence Berkeley Laboratory has developed the Energy Signature Monitor (ESM), an innovative energy monitoring system which addresses the data acquisition and analysis demands of test programs which require monitoring of large samples of buildings. Only a nominal number of sensors are required per test site, with less stringent sensor accuracy demands as compared to laboratory investigations.

The ESM development philosophy has been to produce an inexpensive ($500-$1000) and user friendly data acquisition system which can be readily used by non-technical personnel in large-scale building monitoring programs. A large number of inquiries for information were received from all regions of the country based on a short article published in the August issue of Solar Age magazine which indicated that LBL was developing the ESM.

ESM Hardware Description

The following is a description of a prototypical ESM data acquisition system which was assembled and field tested at LBL. Although the data acquisition's hardware electrical design, and its associated software, have been proven through extensive testing, the packaging has not been optimized for high volume production, and may therefore need to be modified.

Figure 1 shows the ESM as currently packaged. Because its main application will be long-term unattended operation of large samples of buildings the packaging is basically a "black box", with four status indicator lights for display. During test set-up and subsequent check-out a terminal would be connected to communicate with ESM's microcomputer. Of course, the ESM could be operated with a dedicated terminal (connected directly or via modem) if there was such a need.

The removable data module and two computer control switches, are located behind a front panel access door. The rear panel has connectors for the sensors, power supplies, and a standard RS232-C serial port. Standard modular telephone jacks are used for all the sensor connections to assure quick, positive, and foolproof field connections, thus eliminating wire stripping and matching of the correct wires to proper terminals.

Data acquisition and communication are controlled by a 6502 CPU microprocessor. Data acquisition program memory is contained in 8K bytes of erasable programmable read-only memory (EPROM). An additional 4K bytes of random access memory (RAM) are provided for intermediate data storage.

The Energy Signature Monitor has sixteen analog input channels, which will accept a sensor output range of 0 to 4.095 volt, and one pulse count input channel, which counts the number of TTL level voltage signals it receives. A 12 bit analog-to-digital converter processes the analog input channels, for an effective resolution of 1 millivolt. Each of the analog channel inputs can be recorded either as an analog millivolt value or as a digital ("on/off") value. The "on" digital signal is defined as a sensor value that is greater than a user-defined threshold millivolt value. Each analog value (an integer value between 0 and 4095) requires two bytes of memory, while each digital value (an integer value between 0 and 240) requires one byte of memory.

The standard data acquisition program, which is written in assembly language, monitors the pulse count channel as an interrupt and scans all the analog channels every fifteen seconds. The total number of pulses for the pulse count channel, the total number of "on" scans for each digital channel, and the average millivolt value for each analog channel are recorded in the data module at the end of each clock hour. A modification of the data acquisition program can accommodate those tests that require a scan frequency, record interval, or internal data processing scheme different than that available with the standard data acquisition program.

Data is stored in a 24K bytes of EPROM memory, which is contained on a removable 3.5 X 5 inch data module. A data module can store up to 34 days of hourly information from a typical set of seventeen sensors, which consist of one pulse count, eight analog, and eight digital channels. A fully recorded EPROM data module can be replaced in the field with an empty data module in a few seconds, without any special equipment, protocol, or interruption of an ongoing test. An ESM identical to the field units is used to transfer the full data module's recorded information to a computer at a central analysis station.

During normal operation the ESM is line powered, but battery backup power is supplied for RAM memory, clock, and short term data acquisition operation. The ESM will continue normal data acquisition operation during a line power failure until the end of the clock hour, at which time the ESM will go into a "sleep" mode. The "sleep" mode, which conserves battery power, can be continued for more than six days. The clock remains operational during a power failure, and the ESM will automatically continue normal operation when line power is restored.

A menu driven program is used by ESM to communicate with a computer terminal through a RS-232 interface. The communication program is written so that the operator does not need extensive knowledge of the program options and input requirements (user-friendly). Although a computer terminal is used to communicate with the ESM during setup at a test site, it is not required during operation of the test.

Table 1 presents a summary of the technical specifications of the ESM data acquisition system.

Sensors

Since the sensors and their interfacing properties can be a major factor in the cost and usability of a data acquisition system, some low cost sensors have been developed to compliment the ESM. Standard six wire telephone cable and modular connectors are used for connecting the sensors to the ESM. Five and fourteen volts are available on two of the six lines to power active sensors. Since there is a standard bus configuration for the six wire cables, any user developed sensors that conform to the bus can be used with ESM.

The ESM compatible sensors include electric power, temperature, and thermostat status. The electric power sensor monitors true power, including power factor, by using a signal conditioning board which is located in the ESM box. The electric power sensor's signal conditioning is automatic; the user does not have to do anything special to connect this sensor. The temperature sensor is a standard current source transducer, with the appropriate signal conditioning built into its connector. A thermostat status circuit is available to monitor the on/off status of a buildings space conditioning thermostat, with provisions for a wide range of thermostat operating voltages.

ESM Data Analysis Software

Development of data management and analysis software is also very important when a large data base is being produced. Although there are not very many sensors used per site, the large number of test sites will generate a large data base, which will quickly become unmanageable if forethought is not given to the data management. A software package which allows automated handling of such routine operations as data file management, checks for missing and erroneous data, display of data in tabulated and plotted form, merging of data from different test sites, and data transfers to other computers, will be available to compliment the ESM data acquisition hardware.

TABLE 1. ESM SPECIFICATIONS

1. INPUT CHANNELS: 16 ANALOG CHANNELS (0 TO 4.095 VOLT)
   1 PULSE COUNTING CHANNEL (TTL LEVEL, MAX COUNT IS 2^{16})

2. 12 BIT ANALOG TO DIGITAL CONVERSION (1 MILLVOLT RESOLUTION).

3. 8K BYTE OF EPROM DATA ACQUISITION AND MONITOR PROGRAM MEMORY.

4. 4K BYTE OF RAM INTERMEDIATE CALCULATION MEMORY.

5. SCAN ALL THE ANALOG CHANNELS EVERY 15 SECONDS, COUNT THE PULSE CHANNEL INPUTS ON INTERRUPT, AND RECORD INFORMATION HOURLY.

   OPTION: THE SCAN TIME AND NUMBER OF SCANS PER AVERAGE CAN BE CHANGED WITH SOFTWARE MODIFICATIONS. THE MINIMUM SCAN TIME IS 2 SECONDS.

6. DATA IS STORED ON A REMOVABLE DATA MODULE, WHICH HAS 24K BYTE OF EPROM MEMORY. IT IS ADEQUATE TO STORE 34 DAYS OF HOURLY INFORMATION WHEN USING 1 PULSE COUNT, 8 ANALOG, AND 8 DIGITAL CHANNELS. ONLY 26 DAYS OF HOURLY INFORMATIN CAN BE STORED IF THE 8 DIGITAL CHANNELS ARE CONVERTED TO 8 ANALOG CHANNELS.

   OPTION: DATA MEMORY IS EXPANDABLE TO 44K BYTE TOTAL.

7. BATTERY BACKUP POWER IS PROVIDED FOR RAM MEMORY, AND CLOCK OPERATION FOR UP TO 6 DAYS. DATA ACQUISITON OPERATION IS MAINTAINED FOR UP TO AN HOUR DURING A LINE POWER FAILURE. NORMAL DATA ACQUISITIN RESUMES AUTOMATICALLY ONCE LINE POWER IS RESTORED.

8. A RESIDENT MENU-DRIVEN MONITOR PROGRAM FACILITATES ESM SYSTEM CHECKOUT AND INFORMATION INPUT DURING ON-SITE INSTALLATION.

   OPTION: THE BUILT-IN BRIEF MONITOR PROGRAM CAN BE EXPANDED TO A MORE USER-FRIENDLY PROGRAM (e.g. ON A BATTERY-POWERED POCKET COMPUTER) THROUGH USE OF ESM'S SERIAL PORT.

9. TRANSFER OF INFORMATION FROM A DATA MODULE TO A MASS STORAGE DEVICE OR ANALYSIS COMPUTER IS CONDUCTED USING A SPARE ESM. A RESIDENT DATA DUMP PROGRAM TRANSFERS DATA TO THE ESM'S SERIAL PORT.

10. HOURLY INFORMATION IS RECORDED AS:

    ANALOG CHANNELS: THE AVERAGE SENSOR MILLIVOLT LEVEL IS RECORDED. NO SOFTWARE SIGNAL CONDITIONING IS CONDUCTED DURING DATA ACQUISITION.

    DIGITAL CHANNELS: THE NUMBER OF SCAN TIMES THAT THE SENSOR INPUT LEVEL WAS HIGHER THAN A USER-SET THRESHOLD LEVEL.

    PULSE COUNT CHANNEL: THE NUMBER OF TTL LEVEL PULSES DURING THE RECORDING INTERVAL.

    WIND DIRECTION: SPECIAL SIGNAL PROCESSING FOR A WIND DIRECTION SENSOR, WHICH RECORDS THE FRACTION OF THE RECORDING INTERVAL DURING WHICH THE WIND WAS IN EACH OF FOUR QUADRANTS.

11. STANDARD 6 WIRE MODULAR TELEPHONE PLUGS ARE USED FOR ALL SENSOR CONNECTIONS

12. STANDARD TEMPERATURE, ELECTRIC POWER, AND THERMOSTAT STATUS SENSORS ARE AVAILABLE FOR THE ESM

    A SET OF 8 ELECTRIC POWER SENSOR SIGNAL CONDITIONING CIRCUITS ARE INCLUDED IN THE ESM, WHICH ALLOWS AUTOMATIC SENSOR SIGNAL CONDITIONING WHEN THE POWER SENSORS ARE CONNECTED

13. AN INTEGRATED DATA MANAGEMENT AND ANALYSIS PROGRAM WILL BE AVAILABLE TO COMPILE ALL ACQUIRED DATA