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Microprocessor Time Clock for Localized Energy Control

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MICROPROCESSOR TIME CLOCK FOR LOCALIZED ENERGY CONTROL

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Abstract

A microprocessor time clock is being developed to meet requirements for energy control in Navy buildings. The unit is designed to be a cost-effective alternative to electro-mechanical time clocks. Operating principles for both stand-alone and distributed-network modes are described.

1. INTRODUCTION

Navy shore activities are faced with the problem of high energy costs which are distributed among many buildings, often separated by miles. Because of the distances involved and reductions in manpower, centralized computer control is being considered at many of these facilities. Thus, any expenditures for energy control in the interim should be for devices with sufficient flexibility to be effective as stand-alone devices for the short term, and yet to become an integral part of a basewide control network when one is implemented.

Two microprocessor controllers are being developed to meet these specialized requirements for Navy buildings. The first, a microprocessor-based time clock, is intended to be a cost effective alternative to conventional time clocks. The second unit is a fully programmable microcomputer which can be sized and programmed to fit the energy control requirements of a particular building. Both units are designed to be compatible with a basewide energy monitoring and control system (EMCS).

The operating features of these units and a detailed description of the microprocessor time clock are presented in this paper. Other related research needs to meet the Navy's energy conservation requirements are also presented.

2. BACKGROUND

In response to the energy crisis of 1973 and resulting rises in energy costs, energy conservation targets were established for Navy shore activities. While these targets have been met in a variety of ways, most Navy bases have considered the installation of a computerized EMCS as part of the solution. The primary advantage of an EMCS is that it offers the promise of long term energy control with limited manpower resources. The primary disadvantage is the high cost for these systems, which has limited their applications to those bases with large potential energy savings, or with large physical size where significant manpower savings are possible.

The smaller activities have been forced to look to other devices such as electro-mechanical time clocks or demand controllers to accomplish their conservation goals. However, the conventional time clocks have all too often been defeated through tampering or by setting them to worst case times to eliminate complaints. The demand controllers, on the other hand, typically lack flexibility to adjust to changing demand billing structures. Demand control is generally not effective on a building by building basis since a Navy base is billed on cumulative demand. Finally, neither the time clocks nor the demand controllers are designed to be expanded or integrated into a basewide EMCS if one is to be instituted at a later date.

In FY-77, CEL engineers initiated a search for flexible, modular devices which could provide cost-effective energy control in smaller Navy buildings (<25,000 sq. ft.), while maintaining compatibility with later implementation of centralized control. Since no devices were found to fit this market, development programs were initiated for a computer compatible, intelligent time clock and a modular, programmable building controller.

3. DISCUSSION

3.1 MICROPROCESSOR TIME CLOCK

Design features of the microprocessor time clock are discussed in the following paragraphs. Emphasis is placed on the operating principles, hardware and software features, and programmability, which provide the unit with the flexibility to meet short-term and long-term requirements for Navy buildings.

3.1.1 Operating Principles

In order to overcome the shortcomings of electromechanical time clocks three key features have been designed into the microprocessor time clock; these are (1) optimized start/stop based on space conditions and outdoor temperature, (2) communication link to report status, and (3) programmability. The optimized start/stop is accomplished by sampling space temperatures and outdoor temperature and deciding when the HVAC system needs to be turned ON (or OFF). A simplified view of the morning start-up routine is shown in figure 1. The HVAC system is not started until space conditions indicate the need for heating or cooling, or ventilation is required. Parameters which affect this algorithmic determination can be entered via the front panel with the aid of a prompting command line mnemonic interpreter. Further details on programming the device can be found in section 3.1.4.

In order to minimize the effect of spurious fluctuations in temperature sensor outputs, the microprocessor performs time weighted averages for each sensor. Weights can be assigned to each sensor within a zone, so that the average temperature upon which zonal decisions are made is both time- and space-weighted.

The time clock automatically recognizes weekend periods. Holidays can be set from the front panel, and the time clock automatically reverts to its normal schedule upon expiration of the holiday period. Manual override of up to 60 minutes per setting and programmable low temperature override are also provided.

In addition to gathering data for the start/stop control function, the microprocessor time clock gathers operating information such as daily space temperature profiles and cumulative hours of equipment operation. While these data may not be needed for most applications, the information is useful for validating and improving the operation of the device in research applications. These data can be printed out on a local printer or transmitted to a concentrator via phone lines and a built-in auto-call/auto-answer modem. A front panel alpha-numeric display is provided for local readout of both input and output data. This display is also used for programming the time clock.

Hardware and software are being provided to Navy specifications under contract with RADIX II, Inc.

3.1.2 Hardware Configuration

A functional block diagram of the hardware is shown in figure 2. The system is built around the National Semiconductor SC/MP microprocessor. Software is contained on 8K of PROM. Input parameters, output para-

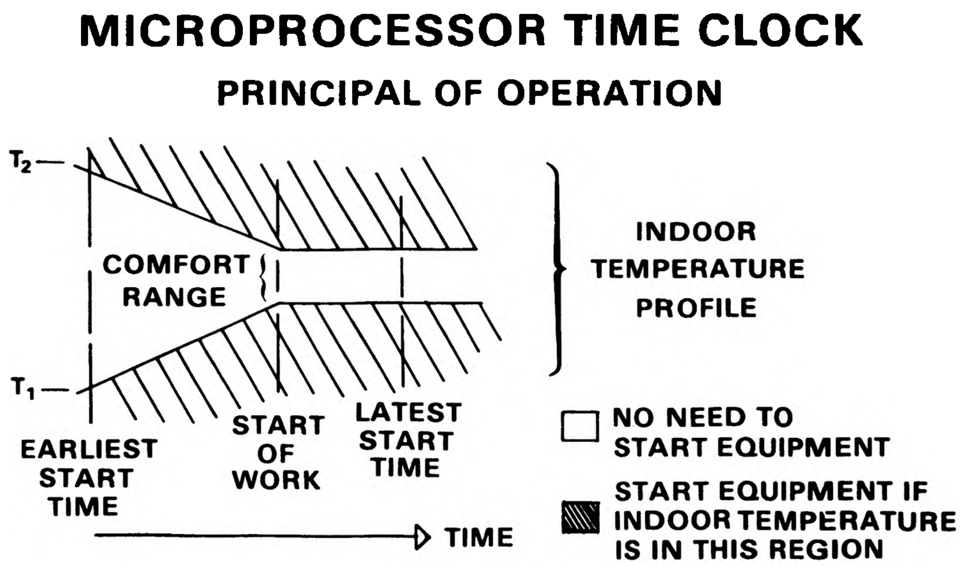

FIGURE 1. MORNING START-UP ROUTINE

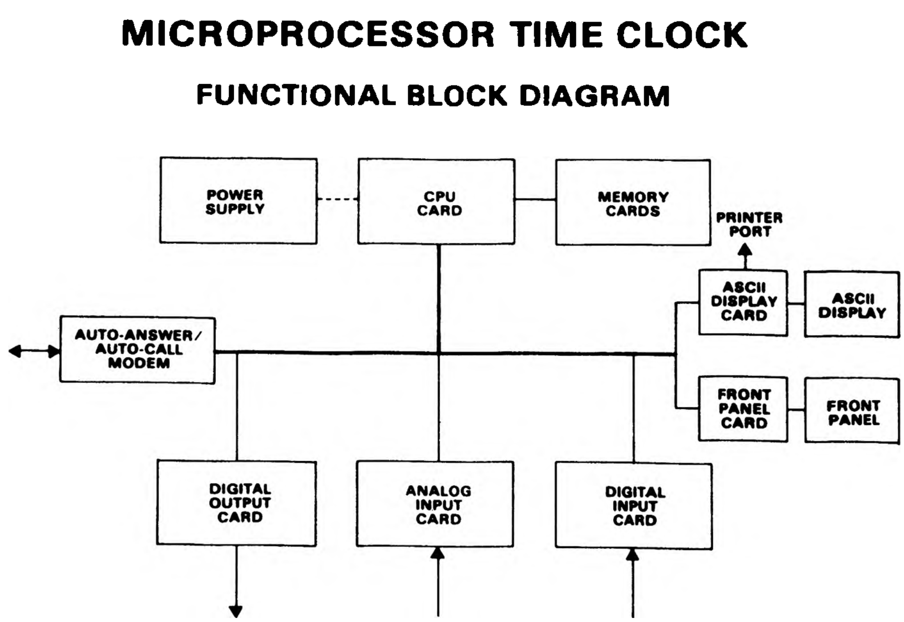

FIGURE 2. BLOCK DIAGRAM SHOWING CARD FUNCTIONS AND INPUT/OUTPUT FEATURES

meters, and scratch pad are contained on 6K of RAM. Battery backup is provided on the clock function and the 256 bytes of RAM which contain input parameters.

In its present configuration, the time clock has the following capabilities:

(1) 32 digital outputs

(2) 64 digital inputs

(3) 32 analog inputs

The analog inputs can be assigned to zones via the front panel.

Actual hardware configuration is shown in figures 3 and 4. The hardware package is designed to be wall or table mounted in the mechanical equipment room. Physical dimensions of the cabinet are 19" x 13" x 11" deep.

The page and address lights continuously display time of day on a 24 hour clock. The push-button and toggle switches are used for selecting the desired rotating display or for programming the time clock. Certain programming functions can be inhibited with a toggle switch located behind the locked cover.

3.1.3 Software Configuration

To provide the modularity and flexibility desired for this unit, a task oriented software has been implemented. With the software structured around the tasks to be performed, future software additions or modifications can be accomplished with minimum penalty. The following list summarizes the purpose of each task. (1)

Executive. Manages, coordinates, and schedules all activities.

Panel scan task. Translates front panel commands/requests for the benefit of other tasks.

Calendar task. Calculates and maintains a 2000 year calendar, and provides an interval timer for scheduling other tasks.

Monitoring task. Continuously scans memory mapped digital input addresses to detect changes of state.

Equipment control task. Exerts digital control over connected loads.

Analysis task. Determines space weighted temperatures, maxima and minima, and daily profiles.

Command line mnemonic interpreter task. Handles all parameter and data entry using a prompt/response format.

Display task. Provides continuously updated display of input or output parameters.

Logging task. Places information in the information buffer, formats data for the transmit buffer, and supports a local printer.

Communications task. Manages the auto-answer modem and the automatic-call unit.

The front panel also provides access to the microcomputer operating system. User written programs or diagnostics can be entered and executed using this feature.

Inherent in all operator interface software are safeguards designed to prevent willful tampering. A time-out feature limits the time available to enter a command. Successful modifications to system input parameters are announced over the communication link.

While operator inputs must be accomplished via the front panel in the present configuration, software interfaces have been designed into the unit to permit modifying the time clock for remote command entry. Output data can presently be dumped as a total package, or they can be requested from a remote location in predefined blocks.

3.1.4 Programmability

In its normal operating mode, this device operates from time clock software in PROM. The parameters which determine the decision making process must be entered by the operator during system initialization, and parameter changes may be accomplished without interrupting the time clock operation.

The command line mnemonic interpreter can be accessed from the front panel. The normal time clock function continues to operate while the operator is prompted for command codes or data. The prompting feature is designed to permit data entry by an operator who has received only minimal training, aided by the appearance of easily understood requests and

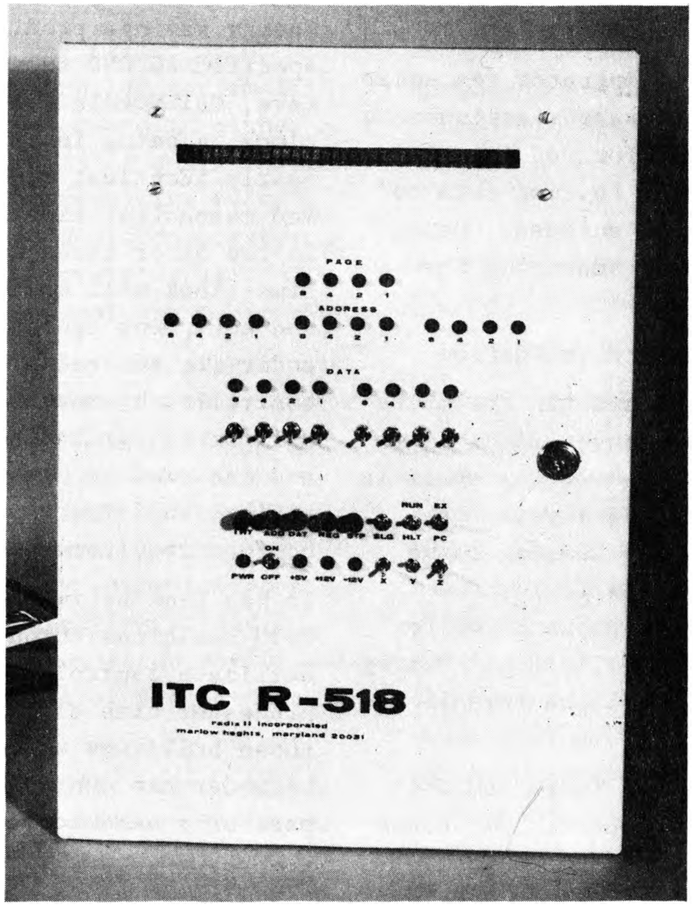

FIGURE 3. MICROPROCESSOR TIME CLOCK FRONT PANEL

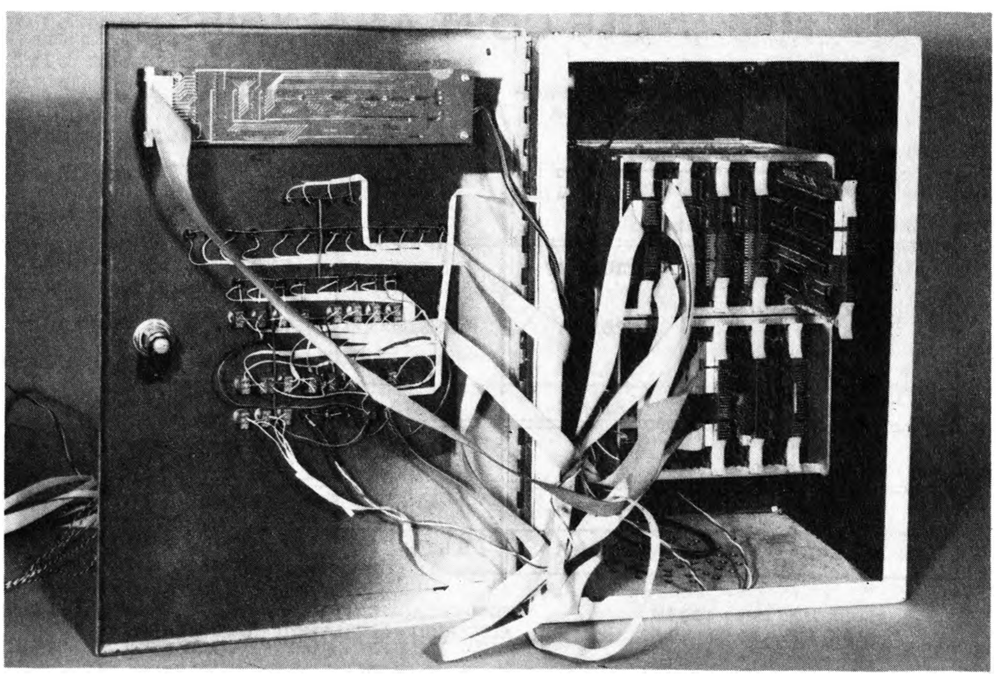

FIGURE 4. INTERIOR CARD RACK

feedback on the alpha-numeric display.

Using the front panel, the operator can enter times, temperature limits, sensor assignments and weights, phone numbers for reports, and holiday periods. A command to dump data to a local printer can also be entered. Debugging can be accomplished by accessing the operating system.

3.1.5 Cost Effectiveness and Validation

Life cycle cost analysis comparing the microprocessor time clock with conventional time clocks which have a fixed, seven day cycle is shown in figure 5. In this analysis, the microprocessor time clock is assumed to be controlling 8 of its possible 16 loads. Capital costs are estimated to be $1500 for equipment and $1000 for installation. Yearly O&M costs are based on 10% of the installed cost.

For the conventional clocks, installed cost is estimated to be $180 per unit. O&M costs reflect the costs for keeping mechanical clocks properly maintained, and for setting in and cancelling special conditions such as holiday periods.

Energy savings predictions are based on a specific 20,000 sq. ft. building at China Lake, California. The microprocessor time clock is being installed in one of four nearly identical zones within this building, and mechanical time clocks are being installed in the other three zones. The microprocessor time clock will monitor temperature profiles and equipment operating hours for the zone under its control as well as for the zones controlled by mechanical clocks. These data will be transmitted to CEL on a daily basis, and analyzed to determine actual energy savings and effectiveness in meeting space comfort requirements.

It has been estimated that there are over 6000 buildings throughout the Navy which can utilize a control device such as the microprocessor time clock. This figure excludes those buildings which are already slated to be under the control of a microcomputer as part of a basewide, distributed EMCS.

3.2 SINGLE BUILDING CONTROLLER

A second contracted study has recently been completed by Harvey Mudd College Engineering

LIFE CYCLE COST ANALYSIS*

	MICROPROCESSOR TIME CLOCK	CONVENTIONAL TIME CLOCK (8 UNITS)	BASELINE
CAPITAL COSTS (INCLUDING INSTALLATION)	$2,500	$1,440	---
FUEL COST	30,682	35,061	43,820
ELECTRICITY COST	20,651	24,800	41,396
OTHER O&M	1,995	3,192	---
TOTAL O&M	53,328	63,053	85,216
TOTAL LIFE CYCLE COST	55,828	64,493	85,216
SIR	12.76	15.39	---
PAYBACK	0.63 YR	0.52 YR	---

*ECONOMIC LIFE = 15 YRS
BLDG. SIZE = 20,000 SQ.FT.

FUEL ESCALATION = 8%/YR
ELECTRICITY ESCALATION = 7%/YR

FIGURE 5. LIFE CYCLE COST COMPARISON OF CONVENTIONAL TIME CLOCKS AND MICROPROCESSOR TIME CLOCK

Clinic. A clinic team was tasked with developing a modular controller for small buildings which can be operated in either a stand-alone mode or as part of a distributed processing network. The resulting system, based on the Motorola 6800 microprocessor, has an on board BASIC interpreter written especially for energy control and monitoring.

The design philosophy behind the single building controller is modular growth from a microprocessor time clock to a distributed processing basewide control system. This feature has been accomplished by utilizing an easily expanded remote board concept for I/O, and by providing a two-way communications port for data output and software loading. This port can be left unconnected, or it can be connected to a terminal or another computer.

Estimated production cost for this unit including installation is $4000. Software can be customized to the individual application.

3.3 OTHER RESEARCH REQUIREMENTS

The Civil Engineering Laboratory is conducting extensive research into other potential improvements to energy monitoring and control. Specific needs which are being addressed include (1) use of commercially available microcomputer components and programmable controllers, (2) development of inexpensive and easily installed computerized metering, (3) development of intelligent sensors, (4) development of modular software for energy control, and (5) improving the energy efficiency of the local HVAC control loop.

4. CONCLUSIONS

Energy consumption at Navy shore activities is generally distributed among many buildings in a large geographical area. In order to provide the flexibility to meet resulting Navy requirements for energy monitoring and control, a microprocessor based time clock has been developed as the basic unit in a modular approach to building energy control. Although industry is beginning to respond with microprocessor based control systems, most still lack the flexibility of this modular approach, which provides significant energy savings at low cost without sacrificing future growth to full computer control.

5. REFERENCES

1. "Intelligent Time Clock" (DRAFT), Radix II, Inc., August 1978

6. BIOGRAPHIES

Roger I. Staab is a research electrical engineer with the Electrical and Electronic Systems Division of the Navy Civil Engineering Laboratory. His current assignment is principal investigator for development and applications of energy monitoring and control systems (EMCS) at Navy Shore Facilities. In this role he has conducted research on localized control loop modifications, microprocessor applications, and minicomputer/microcomputer networks for reducing Navy energy consumption and costs. He received his B.S. and Ph.D. degrees in electrical engineering from Montana State University.

Dallas M. Shiroma is a research electrical engineer at the Navy Civil Engineering Laboratory, Port Hueneme, California. He has been involved in the development of stand alone intelligent building controllers for energy conservation, and in the development of control algorithms. He is currently the senior project engineer in the development of microprocessor based single building controllers. He received his B.S. and M.S. in electrical engineering from the University of Hawaii.