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TWO MICROCOMPUTER-CONTROLLER APPLICATIONS AT SLAC*

W. C. Struven and K. B. Mallory
Stanford Linear Accelerator Center
Stanford, California

The SLAC Accelerator Control and Monitoring System as originally implemented, was a manual (non-computer) control system with provisions to add computers at a later date. Since operation began in 1966, we have added a PDP9 with a PDP8/e "front end" in the accelerator control room, and most recently, eight PDP8/f's in the two mile Klystron Gallery which are linked to the 8/e front end. A data link was added between the PDP9 and an SDS 925 in the Main Control Room. Touch panel interfaces were provided so that the Accelerator and Beam Switchyard could be controlled and monitored from one console.

The number of required beams has increased steadily so that the present six beam capability is not adequate to handle the experimenter load. The accelerator was initially built with a minimum of pulsed steering and focusing magnets. During the past year, pulsed magnets requiring new controllers were installed in four sectors. Diverse beam requirements had required the implementation of "six level" beam guidance equipment throughout most of the accelerator. When the addition of more levels was proposed, it was clear from a cost and maintenance point of view, that microprocessors (if they could be built and installed for about $1000 per sector) were the way to go. The Klystron Gallery, with the dirt-dust problem and wide temperature variations, is a bad environment for electromechanical equipment. Microprocessors, it was felt, would work better in that environment.

In 1975, Motorola announced their 6800 evaluation kit with a PC board which contained the MPU and clock circuitry, a TTY interface, a 16 bit I/O chip and a UART for a bargain price of $149. The kit came complete with ROM operating system and software-hardware manuals. A kit was ordered and mounted in an inexpensive chassis. The power was applied to the PC board in very short order. In the interim, a cross assembler was written for the 6800 which ran on our triplex system. When we had this unit operating for a short time, a simple steering magnet program was written and checked out. Within a period of three weeks, the unit was installed in the Klystron Gallery and successfully operated the steering in that sector. The operating program at that time was in RAM, so if a power dip occurred, the paper tape of the operating system would have to be used to reload the program. Fortunately, no power dip occurred, so the reliability was 100%.

More I/O chips were required to handle all Beam Guidance functions in a sector, so the next step was to fabricate a "kluge board" which was the same size as the Motorola kit board. At this point, it appeared that we could add more I/O facilities and an EPROM without buffering the address and data lines. Subsequent models confirmed this decision. We now have a Motorola CPU board, a memory-communications board, an input board (all inputs are optically isolated), and an output board. This group of four boards plus chassis and power supplies is called our Beam Guidance Controller and, as presently designed, will provide for fifteen Beam Guidance "levels" in a sector. On a pulse-to-pulse basis, the program reads the "pattern" which defines which experimental beam will be accelerated on the next pulse, selects corresponding values from a table, and writes them to an output register driving a DAC. The DAC output directly replaces the former electronically switched motor-driven potentiometers which controlled the pulsed supplies. Every 24 pulses, the program reads bits from the local command, decodes and increases or decreases a selected table value (raise-lower commands). Link software to the PDP8 allows patching a value into any table location ("SET") or reporting a value ("READ") and to read or restore the entire table as a single block of data.

Cost reductions in this system were achieved by using a simple SLAC chassis which is available in many sizes of panels, plates, bars and covers, and can be assembled in "erector set" fashion. Since a TTY is not needed to operate each microcontroller, the power supplies required for the TTY interface have been mounted on a portable TTY. The basic operating program is contained in an EPROM which also has a copy of the Motorola "MIKBUG" monitor. The CPU board still contains the original "MIKBUG" ROM which is easily reconnectable if the CPU board is to be checked in a stand-alone situation. The mem-comm, input and output boards have been provided with test points and a pair of push buttons have been installed to use some of these test points as "local control" points to facilitate maintenance and trouble shooting. Our philosophy, in general, is to isolate trouble on a board-by-board basis and replace the malfunctioning board. Board repair is then accomplished at a maintenance location which is off-line. Appropriate test boxes and diagnostic software facilitate rapid diagnosis of the trouble.

We recently have defined a second type of microcontroller to control the triggers in each sector. The same basic configuration is being used as described above with the addition of a second input board. This controller uses virtually the same program as the Beam Guidance controller, with added logic for folding pattern, rate and modulator interlock data into output registers defining "accelerate" or "standby" pulses for each of the eight klystrons in the sector. A third unit, a Beam Monitoring Processor, is in the design stage now, which again will utilize the same complement of boards. The difference will be in external hardware which, it appears, can be added to the existing microcontroller chassis.

We are starting production of 30 beam guidance units now, and as soon as the pre-production prototype is tested, we expect to produce 30 sector trigger units also. The Beam Monitoring Processor will be a one-off quantity. To reduce costs, we will use automatic wire wrapping of the "kluge boards" and we will use as many "SLAC stock" chassis parts as practical to avoid the high fabrication costs of special metal parts. We expect that in production, we can achieve a price of about $1000 for units which have 384 bytes of RAM, 64 I/O bits, a 2400 baud UART, and 1000 bytes of EPROM.

To facilitate EPROM programming (Intel C2708), we have constructed a PDP8/e interface which will program, copy and read an EPROM. The program to be "burned" is assembled on the IBM Triplex and is transmitted by wire line to the core of the 8/e. The program in the PDP8 which manages the EPROM programming is also capable of punching the program in paper tape. This facility enables rapid software changes when testing new programs.

We have developed party line link hardware so that each microcontroller will communicate with the nearby PDP8/f. This will enable reading and presetting of values in RAM.

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L22 At this time, we have six Beam Guidance Controllers installed in as many sectors. We also have a developmental model of a sector trigger controller operating. The failure rate of these seven units has been zero (the six Beam Guidance units have been operating since the middle of last year). When all 30 Beam Guidance Controllers are installed, later this year, we will have expanded the number of guidance beam lines from six to fifteen and, in addition, will be able to store and later preset the focussing and steering currents for as many beams. The sector trigger controller when installed, will provide similar upgrading of the trigger system in the Klystron Gallery. By this time next year, we expect to have almost 100 microprocessor-controllers installed in the Klystron Gallery in dedicated controller functions.