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THE CHROMONITOR, A COLORFUL DYNAMIC GRAPHIC DISPLAY TERMINAL

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Summary

The Bevatron has associated with its acceleration cycle many parameters which vary in a dynamic manner throughout that cycle. Control and monitoring of such parameters is now done largely by computer, so that many variables formerly in the analog realm and easily observed on the conventional oscilloscope are now in the digital realm and not easily observed. The Chromonitor is a device which has been developed to accept inputs from computers or the analog realm and display on a TV screen any or all of sixteen different parameters which may be associated with particle acceleration and delivery, or which may be pertinent to monitoring a computer process in progress. Each of the parameters may be displayed in any of seven colors.

Introduction

Control philosophy at the Bevatron shifted a few years ago from manually set closed loop analog systems to automatically set closed loop digital systems in the areas of main guide field control [1], accelerating system control [2], and transport magnet control [3]. Interfacing between the human operators and the digital systems has been one of the more challenging tasks, not yet complete, and the Chromonitor was designed to equip the operator with a display terminal capability which includes a high visibility multi-trace device capable of quasi-real time monitoring of both analog and digital processes occurring during a Bevatron acceleration cycle. Both on-line graphic displays and text lines are available.

For maximum convenience to the operator, the Chromonitor has available sixteen traces in seven colors, any trace being selectable at the flip of a switch. Each trace may be adjusted in position and amplitude independently from all others. Trace color is under computer program control and may be changed easily, allowing color grouping of signals if it is desired. Our experience in the past with monochrome displays is that more than two or three traces on the face of a cathode ray tube lead to confusion and loss of operator confidence in monitoring. The multi-color system allows a large number of traces to be presented simultaneously.

Common to all traces is horizontal positioning and relative sweep speed control.

Design Philosophy

A genuine multi-color display dictated the use of cathode ray tube system employing standard color-TV picture tubes rather than the layered phosphor tubes which give a choice of three or four colors. A result of selecting a standard TV-type tube is that raster scan techniques must be used in order to keep deflection power requirements resonable and to avoid the use of specially designed magnetic deflection yokes. In addition, the Sony Trinitron tube was chosen because it is slightly less sensitive than the RCA type dot-matrix tube to the stray pulsed magnet fields which exist in the Bevatron control room. Therefore, to get a display on the face of the tube, an intensity-modulated NTSC raster-scan technique is used.

Intensification information is stored in a core memory module having capacity of 8192 words and 9 bits per word. Data is brought into this core from any of our computers and an analog-to-digital converter which is part of the Chromonitor. Each of the sixteen traces available for display has its own set of 512 core locations, one location for each scan increment.

Our standard Trinitron monitor was turned on its side for the Chromonitor project. Quasi-real time displays imply an update rate fast enough to keep pace with one per millisecond at the Bevatron. The fastest possible display update rate is achieved if the display abscissa is incremented at the horizontal sweep rate of the television monitor, about 1 per 63.5 micro seconds. If the display abscissa is incremented at the rate of the vertical scan, then some 17 milliseconds must elapse between up-dates, too long a time for observation of some processes at this accelerator. For maximum convenience in this presentation, "horizontal" and "vertical" will have TV usage definitions, unless it is obvious from the context that standard usage should apply.

Satisfactory text and graphic display definition has been obtained with a 512 x 512 array of dots on the face of the TV tube, therefore a 9 bit word which contains intensification information for one horizontal line is adequate. Of the 525 horizontal lines allowed for in raster-scan TV, 512 are used in the Chromonitor. In point of fact, not all 525 lines are normally visible and the loss of 13 unassigned lines is no hardship.

The core memory has been divided into 512 cells of 16 words each for storage of information on display. Figure 1 is simplified block diagram of the Chromonitor. Information from the digital and analog sources is written into core during the horizontal sweep time and is read from the appropriate core locations to the output registers during horizontal blanking intervals. Figure 2 contains timing interval information. A standard horizontal interval is shown, along with the necessary modification for use with the Chromonitor. The standard vertical interval is also shown. During a standard horizontal blanking pulse there is an interval of about 11.5 microseconds within which information may be obtained from core. Because the core memory cycle time is 900 nanoseconds

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and 16 words need to be extracted, the blanking interval was extended to about 16 microseconds, at the cost of some extra display margins on the viewing screen.

Corresponding to each trace there is a register/down—counter which is loaded during the horizontal blanking interval with the conditioned output of core. At the end of the horizontal blanking interval a 10.08 MHz clock is gated into the register/down—counters. When the counters become empty a pulse is forwarded from them through a color decoding block to the color gun circuitry of the Sony TV monitor. In addition, the write circuitry for the core memory is enabled. The conditioning on the core word consists of a left—right scaler which provides a virtual gain adjustment of the displayed trace, and an adder in which a reference position is summed with the scaled core output, so that trace placement on the TV tube may be adjusted. Semi—conductor memories are used to contain gain and position words for each trace; these memories are modifiable from the control panel of the Chromonitor.

Additional features available to the viewer are abscissa positioning and abscissa delay, both obtained by presetting counters during a vertical blanking period. These features, combined with address skipping on reading the core (an apparent increase in sweep speed) and display hold, allow detailed examination of a set of traces, the equivalent of a multi—color storage oscilloscope.

Data is exchanged on a serial basis at a nominal 1 MHz rate, which means that data input to the Chromonitor is acquired at approximately 20 microseconds per word. (Sixteen—bit words are used for transmission, a standard which is now obsolete). To input a single word to core in the Chromonitor three transmitted words are required: a function word, an address word, and the data word, for a total of time required of about 60 microseconds, or one horizontal line time. Similarly, the Chromonitor ADC is a 20 microsecond unit, for 10 bit resolution. Consequently, on the average, the core may be loaded at the rate of 16 traces in about 700 to 800 mircoseconds, just within the update time of our process controllers. This is a worst case situation, with one computer sending two control words and one data word. Better conditions obtain when one computer sends a string of data words which are preceded by two control words, so that the overhead is reduced dramatically.

Of the twelve bits of data available from a PDP—8, the most significant nine are stored in sign-magnitude form in the Chromonitor core. The three lowest bits are discarded. The exact Chromonitor core address is determined by a twelve bit address word and one bit of a five—bit instruction block in the twelve bit function word.

Boundary conditions on clock rates and timing considerations consisted of, a) the clock rate on the output registers required for 9 bit resolution on the TV tube, and b) the cycle time of the core memory used in this project. An additional refinement consisted of synchronizing the master clock with the horizontal sweep frequency of the TV sync generator. Nine—bit resolution, when translated to time increments on a horizontal sweep line meant that the 50 microseconds duration of the sweep had to be split into 512 segments, requiring each segment to be about 100 nanoseconds long. The master clock frequency was thus set at 10 MHz which, when synchronized to the horizontal sweep frequency, became 10.08 MHz (the 640th harmonic of 15,750 Hz). For logic operations relating to servicing the core memory the 10.08 MHz master clock was divided down to a 5 phase, 1.008 MHz, service clock.

The Chromonitor has been designed using TTL logic throughout, implementation of the design being carried out with Control Logic Coporation cards and in—house cards made for general and special use at the Bevatron.

Color

Seven colors are used for display: red, green, blue, yellow, magenta, cyan and white. Each color is obtained by turning on one, two, or all three electron guns in the TV monitor. The only color balance required for this application is to make white appear as white. The other color combinations are sufficiently distinct from each other for easy discrimination. Were more than seven colors desired, color balance would become important so that similar hues could be distinguished easily.

Color information is transmitted from a computer into sixteen three—bit color registers which control gates at the output of the Chromonitor. This color transmission is normally done only when the Chromonitor is turned on, or when a color change is desired by the operators. However, it is possible to create special effects by altering the color information as the display is being generated.

Software Control

A set of 10 instructions is available for control of the Chromonitor:

1. Clear core;
2. Read from address in lower half of core and transmit;
3. Read from address in upper half of core and transmit;
4. Enter color data into registers;
5. Write in specified lower core address(es);
6. Write in specified upper core address(es);
7. Write in next lower core address(es);
8. Write in next upper core address(es);
9. Write in next core address(es);
10. Disable ADC.

If one and only one computer has access to the Chromonitor, then instructions 7,8, or 9 would be used and the Chromonitor would keep its own tally of addresses already used. If several computers have access, then each computer must keep track of addresses being used, and instructions 5 and 6 would be employed. Instructions 2 and 3, and the necessary hardware, have been included to allow this core memory to serve in an emergency as auxiliary storage unit for other services, in which case the Chromonitor ceases to function.

Text display is accomplished either by using a portion of one of our PDP—8's as a character generator operating on one or two of the sixteen traces, or by using an external character generator, as shown in Figure 1, which operates directly on composite video and sync signals to the TV monitor. In the first method, a 34 character alphabetic message is available. In the second method a 256 alpha—numeric character message is available.

Conclusion

An extremely useful tool for observation of multi-variable processes has been put together and is shown in Figure 3. Specifically, in the case of the Bevatron, optimization of machine tuning for a particular experimental mode has been made easier because the interface between man and machine in this particular closed loop has been improved, effectively increasing the loop gain. We look forward to being able to monitor most processes at the Bevatron with great facility.

Acknowledgments

For philosophical discussions pertinent to the design of the Chromonitor I am indebted to Don M. Evans. Jack O'Riva was responsible for final hardware checkout and software implementation of computer generated character strings.

References

1. Don M. Evans et al.,"Bevatron Guide Field Control," IEEE Transactions on Nuclear Science, June, 1971

2. Don M. Evans and Fred H.G. Lothrop, "Digital Control of Bevatron Acceleration Cycle", IEEE Transaction on Nuclear Science, June, 1971

3. D. Evans, Bevatron Report 1016, 1969

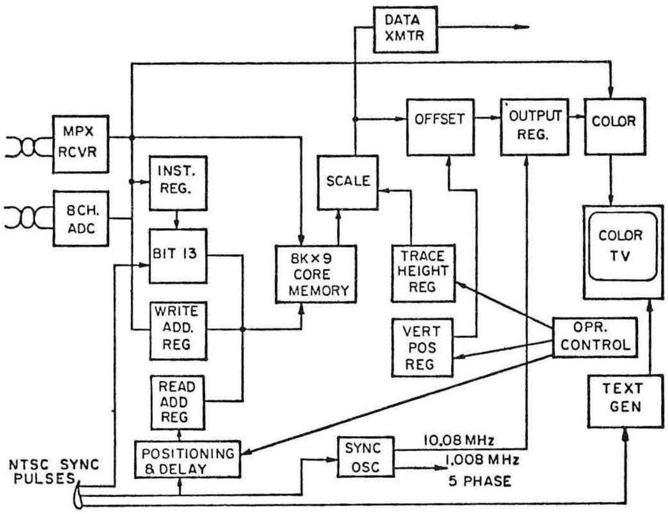

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Figure 1. Simplified block diagram of the Chromonitor. Implementation for 16 traces requires one hundred 5" x 5" circuit cards.

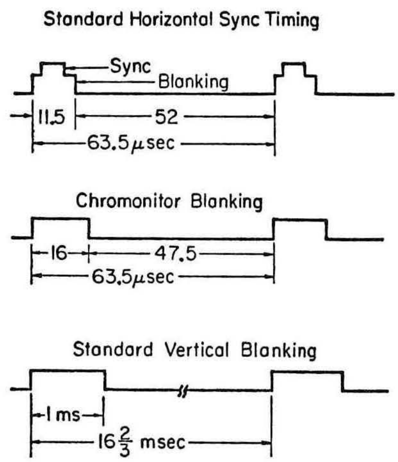

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Figure 2. TV sychronizing signals for horizontal and vertical sweep in the NTSC raster scan system. Modification for the Chromonitor is shown in the center.

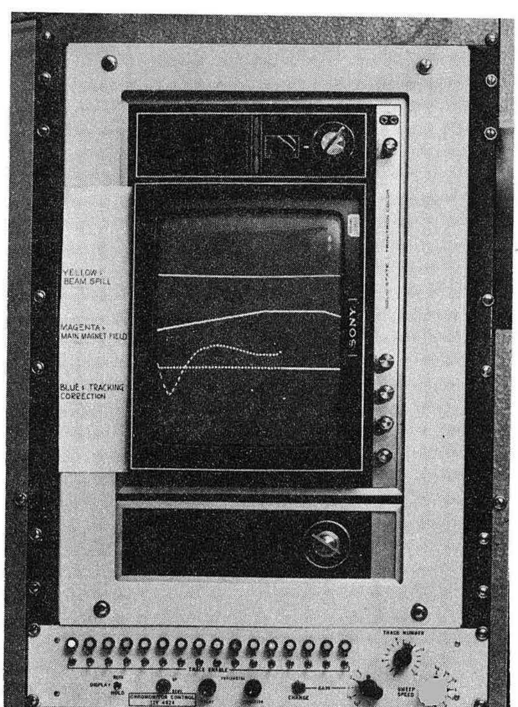

Figure 3. Display and control unit of the Chromonitor installed in the Bevatron Main Control Room. Actual trace colors are, from top to bottom, yellow, magenta, and cyan.

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