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A CAMAC BASED HIGH-RESOLUTION REPETITIVE WAVEFORM GENERATOR

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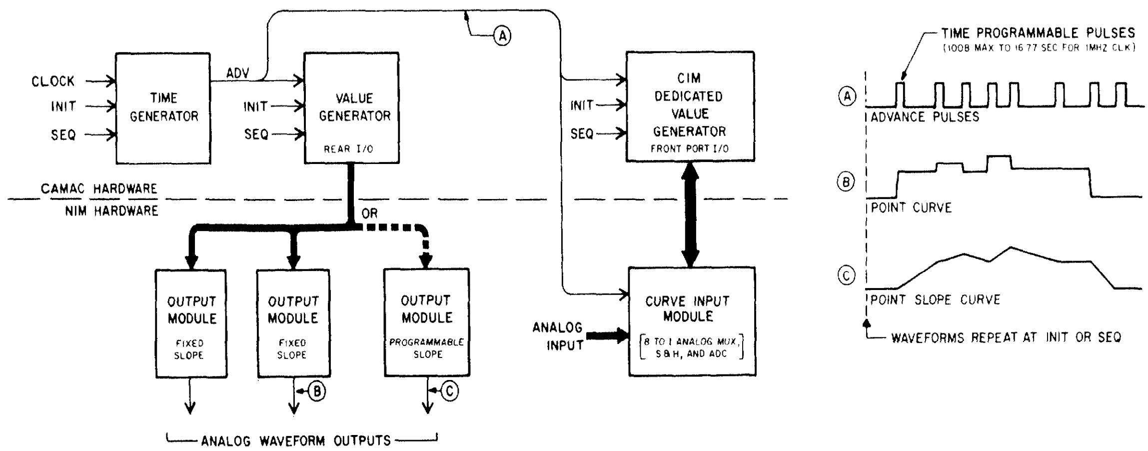

Figure 1. Block Diagram of the Waveform Generator Hardware.

INTRODUCTION

A new facility has been developed for the generation of high-resolution repetitive waveforms for the Fermilab Booster low and high-level RF Systems providing improved hardware, diagnostic, and interactive capabilities. The digital aspect of the system is implemented in CAMAC with attendant analog processing in NIM hardware. The design and philosophy developed can easily be applied to other related systems.

TIME AND VALUE GENERATORS

The nucleus of the system is separate Time and Value Generators, each a double-wide CAMAC module housing a 1K x 24 bit volatile RAM. For the Time module, the RAM stores monotonically increasing values of time referenced to the Accelerator clock. These times are continually compared to the current count of the clock with an Advance (ADV) pulse generated at every compare. ADV pulses are transmitted to the Value Generator which provides a new 24 bit word upon the receipt of each ADV.

Primary inputs to the Time Generator are clock, which may be as fast as 1 MHz, and synchronizing inputs that call for the repeating of the desired time or value program. The synchronizing inputs, Initialize (INIT) and Sequence (SEQ), also allow for execution of separate time or value programs resident in memory. The first sixteen locations of RAM store the starting addresses of up to sixteen distinct time or value programs. Upon receipt of INIT the generator vectors to the program specified by the starting address stored in memory location 0. SEQ inputs, received subsequent to an INIT, can vector the generator to other programs in memory as indicated by the starting addresses stored in locations 1 through 15.

All memory read/write operations are prioritized and appropriately buffered allowing for fully synchronous curve generation and asynchronous external interrogation or manipulation of memory data. The system is capable of generating waveforms with as little as two microseconds between points. Each generator is provided with a separate front port I/O connector for external access to memory. Two twelve bit DACs are implemented within the Value Generator for diagnostic monitoring of the generated digital word.

CURVE OUTPUT MODULE

Operation of the Booster RF Systems requires six feed-forward programs: Frequency, Radial Offset, and Radial Gain programs for the low level system; and Anode, Cascode, and Ferrite Bias programs for the high level systems. The high level programs are distributed to each of the eighteen RF accelerating systems. Twelve bit accuracy is sufficient for all programs although the Frequency and Bias programs must be especially smooth and free of transients.

Satisfying the more stringent requirements of the Frequency and Bias programs, the Curve Output Module incorporates two twelve bit DACs for point and slope control. A bootstrapped integrator is utilized in the feed-forward path of the point program as a rate limiter. Control of the vector rate between points is achieved by variable dynamic limiting of the integrator drive voltage. Calculation of the appropriate slope program is done by the host computer from available Δt and Δv information. The other programs do not require programmable slope between points although there is provision for manual adjustment of a fixed

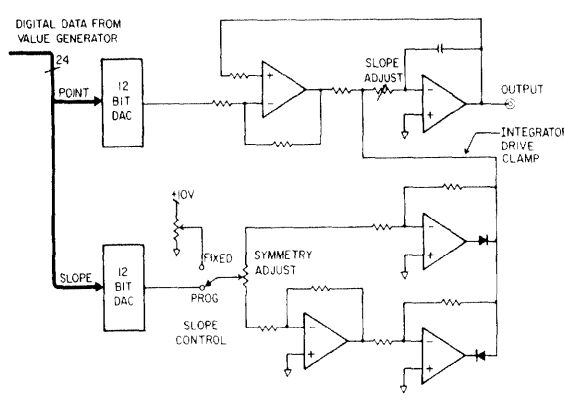

Figure 2. Simplified schematic of the Curve Output Module.

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slew rate. The Curve Output Module has provisions for dc offsetting and external gating of the output. A high power output driver is also incorporated for distribution of the high-level waveforms.

CURVE INPUT MODULE

The Curve Input Module (CIM) provides eight addressable analog inputs multiplexed to a sample and hold and a twelve bit ADC for purposes of synchronous sampling of generated curves or system related error waveforms. CIM samples are initiated by the ADV pulses of the related system waveform generators and are, therefore, in direct time overlay to the generated waveform. Sample results are stored in the memory of a dedicated Value Generator via its front port I/O connector. The CIM sample data can easily be used for waveform verification or for feed-forward curve regeneration through the use of proper mathematical algorithms.

Control of the CIM is achieved by additional coding of the starting address vector locations (0-15) of the dedicated Value Generator. The CIM, as implemented, is capable of taking and storing samples every four microseconds. The sampled data resident in the Value Generator can be displayed repetitively in analog form with the addition of an Output Module.

SYSTEM IMPLEMENTATION

The specific requirements of the Booster RF System have been satisfied by the establishment of two quasi-separate curve generator systems, LLRF and HLRF, each comprised of two Time and three Value Generators. Frequency and Bias are point/slope programs, each utilizing separate Time and Value Generator pairs. Generation of Radial Offset and Gain programs requires a similar pair of modules. Both of the 12 bit point programs are produced by a single 24 bit Value Generator. Anode and Cascode programs are similarly treated, again requiring a Time and Value Generator pair. A CIM/Value Generator combination is also part of each system. Time parameters for the Frequency and Bias programs are treated as independent variables while time programs for the other waveforms are considered fixed. Separate timing and gating modules orchestrate the functioning of both systems in coordination with Booster operations.

SOFTWARE INTERACTIVE FACILITIES

The LLRF and HLRF Waveform Generator systems are supported by dedicated application programs providing facilities for curve construction, data file manipulation, and feed-back correction. Discussion of facilities provided are common to both systems. The host computer directly services console facilities and a number of real time mini-computers, one of which interfaces the Curve Generator CAMAC hardware. Through an overlay structure, a 50K word application program is executed within a 9K partition on the host computer.

All curve data relating to a system is structured into files comprised of 8K words of time, value, and slope data stored in integer format on disk. File parts are transferred to and from the host computer as needed. The program utilizes three file types: a work file, a current-curve file, and save files. Curve manipulations are performed in the work file. The contents of this file can be either transferred to the Curve Generator or stored in a save file. The current-curve file replicates the data currently active in the Generator, and the save files provide archiving capability.

Three control functions are incorporated into the application program: direct control, indirect file manipulation, and data save/restore. Direct control provides the means for real time manipulation of the active waveforms. Indirect file manipulation allows the construction and reviewing of waveform data without altering the active waveforms. Data save/restore exercises control over several save files.

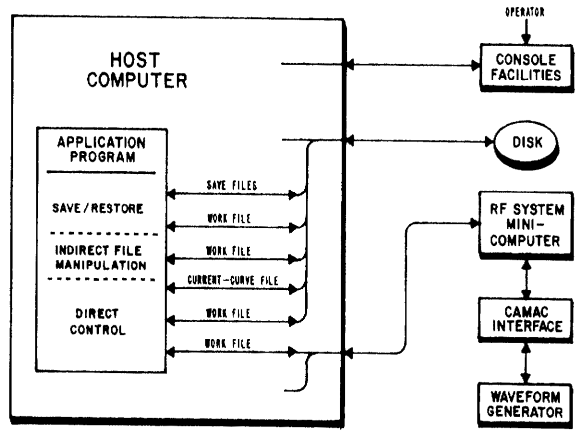

Figure 3. Operative Flow Diagram.

Direct Control

When the Curve Generator is loaded with the contents of the work file, the file data is serially transferred in 1K blocks from the host computer to the interfacing mini-computer. A three-word header, containing instructional information as to module location, type of data, and block load starting address, precedes each block. Upon successful completion of each block load, the corresponding block of the current-curve file is updated. Loading of each Curve Generator system requires the transfer of eight data blocks.

Upon request the active waveform data is read from the Generator into the work file in 1K blocks. As each block is received, the data is compared with the contents of the current-curve file. Any discrepancies are summed and displayed for the operator upon completion of the read operation.

The size of the work file prohibits simultaneous display of all the data, therefore paging is provided. Each page consists of fifteen sets of time, value, and, if applicable, slope data for a selected curve. The operator can then scan the pages for the desired portion of the curve. Keyboard or knob facilities are available for modification of current data. For curves with programmable slopes, time or value changes result in the re-calculation of slopes around the point of change. Points along a variable-time curve can be added or deleted. Adjustments to the curve values or sizes are transferred directly to the Generator and produce an immediate effect on the active waveform.

Indirect File Manipulation

Computer generated graphics provide for the plotting of individual curves from the work file, CIM samples, or differences between these. Selection of the time base allows either full curve or expanded point viewing. A graphics cursor assists in identifying time and value information for any point on the display. The option of overlaying plots allows visual comparison of active waveforms against file contents.

A curve, or parts thereof, can be constructed or altered with several available operative functions. These functions include arithmetical operations, linearization of curve values between specified points, and curve smoothing. Arithmetical operations on curve values by either specified constants or by scaled results of a CIM sample are possible. Data from synchronous CIM samples of RF System error signals can be used as software feedback for modifying the feed-forward waveforms.

Data Save/Restore

The application program also provides for the saving and restoring of up to ten sets of curve files. This feature readily adapts the RF System to the varied Booster operational modes. The save files, which are individually annotated, can be transferred to the work file for manipulation, comparison, or loading.

SOFTWARE DIAGNOSTICS

Software diagnostics aid the testing and alignment of various system components. The ability of a Time or Value Generator to load, read, and maintain data is exercised by a memory test. The entire 1K x 24 memory is loaded with either an operator selected bit pattern or computer generated random data. Upon completion of the load, the memory is read and tested against the loaded data. Comparison failures are noted and summed by the diagnostic program. The sum of comparison failures is presented to the operator upon completion of the test with the added facility of visually comparing bit patterns loaded versus the contents of each memory location.

Several diagnostic waveforms are available to a Time and Value Generator pair for local and remote verification of proper operation. Monotonic functions provide for verification of waveform linearity with discontinuities at analog monitor points indicating bit failure. The Curve Output Module's analog calibration is checked and adjusted by a second option of dc value programs. Adjusting slew rate and symmetry at the Output Module level is facilitated by two additional diagnostic programs. For modules employing programmable slopes, a program is loaded that ranges slopes from minimum to maximum values in fixed steps while generating a symmetric waveform. A square wave program is also provided for calibration of fixed slope Output Modules.

CONCLUSION

The new facility of waveform generation for the Booster RF System has been in service since May, 1978 with excellent operational experience to date. The maintainability of the system is greatly enhanced with the provision of software diagnostics and local monitor facilities. The use of the Curve Input Module as a feedback mechanism has especially simplified operator interaction with the system. The capability of storing multiple programs in Generator memory is not employed at present. It is anticipated that future applications of the Booster Accelerator may well call for the exercising of this option.

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