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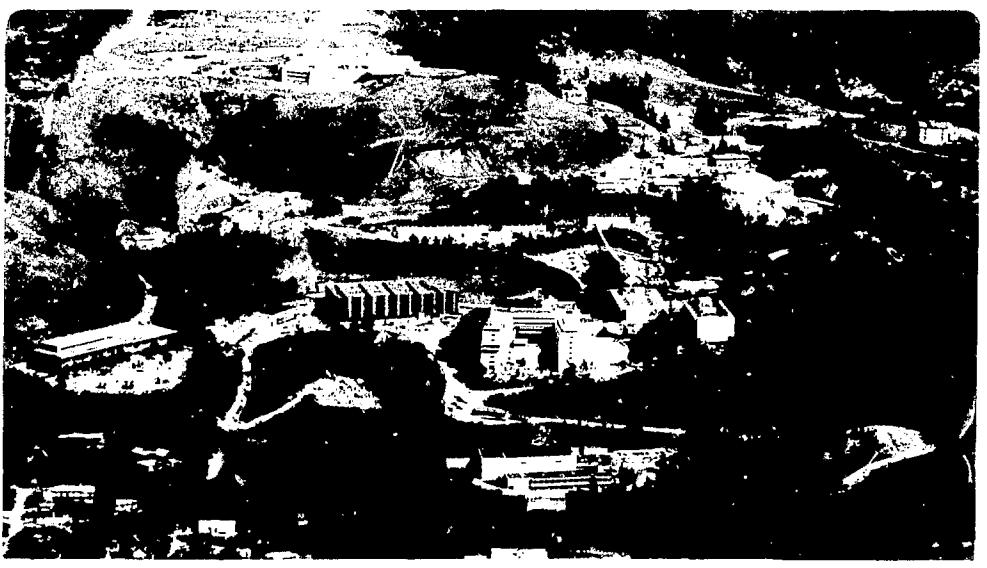
Engineering & Technical Services Division

CAMAC SYSTEM FOR COMPUTER CONTROL OF MICROWAVE SPECTROMETERS

George Zizka, Bojan Turko, and Bill Kolbe

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MASTER



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CAMAC System for Computer Control
of Microwave Spectrometers

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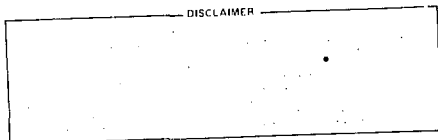
Abstract

An interface between a microwave spectrometer and a computer is described. It consists of three CAMAC modules and uses standard CAMAC crate and controller. The hardware, in conjunction with appropriate software routines was designed to synchronize measurements, to collect data, and to control the microwave frequency and other experimental parameters.

Introduction

Microwave spectrometer data are ideally suited to numerical calculation, but sheer quantities of data involved make the task quite time consuming. It is evident that it would be highly desirable to automate a spectrometer for this job. This automation can also improve the sensitivity, resolution and accuracy of the spectrometer through digital signal processing techniques.

A prime consideration with microwave spectrometers is how to improve the signal-to-noise ratio in order to increase their capability for handling very weak microwave absorptions. In conventional spectrometers, (1) this is



done by employing Stark-effect modulation, phase sensitive tuned detectors and an output noise filter. A second method of signal-to-noise improvement is digital filtering which is simply mathematical curve smoothing applied to data after it has been taken. A final method is the averaging of repeated scans. By automating the instrument, much more precise signal averaging and digital filtering is possible. A computer controlled microwave spectrometer was described by White (2) which demonstrated some of these advantages. It automatically searched for and recorded all major resonance lines found during a scan and computed their frequencies and intensities.

For a Microwave Spectroscopy Program at the Lawrence Berkeley Laboratory, a spectrometer for the detection of gaseous pollutants has been developed, (3-8). The spectrometer operates at frequencies in the vicinity of 70 GHz and incorporates a Fabry-Perot resonator (9,10) and uses superheterodyne detection to obtain high sensitivity at low microwave power levels. For the reasons just discussed, the spectrometer was automated with the aid of a PDP 11/34 computer. A description of the interface between the spectrometer and this computer follows. The software routines are also briefly explained.

CAMAC Hardware

The electronic hardware constructed to provide the interfacing between the spectrometer and the computer consists of three CAMAC (11) modules. These are shown together with the other major components of the system in Fig. 1. The modules were mounted in a Standard Engineering model PCS/a half-size CAMAC crate together with a Borer model 1533 Controller and additional modules of commercial design not described in this report. Figure 2 shows the front panel of the CAMAC system.

The three modules constructed consist of a synthesizer controller (MS SCU) to control the frequency of a General Radio model 1062 frequency synthesizer, an 8 channel analog-to-digital converter (MS ADC) to collect analog data and a real time clock (MS RTC) to provide timing information. The design of each of these modules is described below.

Real Time Clock (MS RTC)

The Real Time Clock provides synchronization of analog measurements. This double width module contains logic designed to produce trains of programmable time periods, during which the spectrometer system performs its various functions.

The cycle of periods starts with an interval, T1 and is followed by a sequence of N programmable T2 periods. During T1, experimental parameters, including the microwave frequency, are changed. Within each T2 period the data is collected, using the ADC module, and stored in the computer memory.

The unit is provided with its own crystal controlled clock which generates a 1 MHz timing signal. The length of T1 is determined by software by means of register T1, which can be loaded with up to 24 bits. The T2 and N registers are 16 bits wide. All three counters are down-counting and their overflow causes self-reloading, so it is not necessary to load registers every cycle. The module can also be programmed for single cycle operation.

At the end of each complete cycle, the RTC module generates a LAM (look-at-me) signal thereby enabling the computer to respond during the coming T1 interval. Upon completion of the appropriate action, the computer clears the LAM, providing a handshake. If the LAM is still set at the end of T1, the clock enters a T1 overrun mode and will wait until the handshake is completed before proceeding.

The T1 interval can be interrupted by a software command and continued again. The status of T1 can be tested to determine whether the module is in a T1 period or not. A normal mode of operation is shown in Fig. 3. At the beginning of each T2, a strobe is generated to initiate conversion in the ADC module. Also an internal flag is set. Upon completion of the conversion, the ADC module, returning the EOC signal (or a software command) clears the flag, completing the handshake. If either one is missing before the time the next T2 should start, it will cause an overrun condition to exist and the RTC will wait in its T2 overrun mode. Operation resumes only after the overrun is cleared.

Figure 4 shows a block diagram of the module illustrating the major components. The CAMAC function codes controlling the module are tabulated in Table I.

Analog-to-Digital Converter (MS ADC)

The ADC unit is built around a Datel Model MDAS-8D Data Acquisition System featuring 8 multiplexed differential channels, sample and hold, and a 12 bit ADC (see Fig. 5). The total acquisition and conversion time is 20 μ s. The system is wired for a random addressing mode.

The input signal amplitude is ± 10 V (each channel). Output (12 bits) two's complement binary is extended to 16 bits to produce a signed (2's compl.) number. All functions can be controlled manually or via CAMAC commands. These commands are shown in Table II.

MS SCU-Synthesizer Control Unit

The Synthesizer Control Unit is shown as a block diagram in Fig. 6. To control the frequency synthesizer (Gen Rad 1062) 9 digits of BCD information are needed. The necessary information for this unit is presented in

Table I

RTC - CAMAC Function Codes

COMMAND	ACTION
N.F(0).A(0)	Read N Register (16 bits)
N.F(10).A(0).S2	Enable LAM
F.F(24).A(0).S1	Disable LAM
N.F(8).A(0)	Test LAM
N.F(16).A(1).S1	Load (overwrite) T1 Register (24 bits)
N.F(16).A(2).S1	Load (overwrite) T2 Register (16 bits)
N.F(16).A(0).S1	Load (Overwrite) N Register (16 bits)
N.F(9).A(0).S2	Reset RTC Except LAM Latch
C.S2	Reset RTC Except LAM Latch
N.F(10).A(0).S2	Reset or Clear LAM Latch
Z.S2	Initialize RTC
N.F(24).A(1).S1	Disable Clock During T1 (set T1 Interrupt Latch)
N.F(26).A(1).S1	Enable Clock During T1
N.F(27).A(0)	Test T1 Status (Q response for T1 in Progress)
N.F(26).A(1)	Test T1 Interrupt Latch
N.F(25).A(0)S1	Start RTC
N.F(25).A(0)S1	Stop RTC (at the ned of the cycle)
N.F(25).A(2)S1	Initiates one cycle operation
N.F(11).A(0)S2	Clears T2 overrun

Table II

MS ADC CAMAC Function Codes

- F(16).A(0) - loads MUX (channels 0 thru 7).
- F(16).A(1) - loads MUX as above and strobes ADC initiating a conversion.
- F(25).A(0) - initiates a conversion of previously selected channel.
- F(0).A(0) - reads out results of ADC conversion.
- F(2).A(0) - reads out results of ADC conversion and clears register.
- F(0).A(1) - reads out channel number selected by MUX.
- F(24).A(1) - inhibits analogue inputs to MUX and front panel strobe of ADC.
- F(26).A(1) - enable analogue inputs to MUX and front panel strobe of ADC.
- F(25).A(0) - disable LAM Latch (no interrupts produced).
- F(26).A(0) - enable LAM Latch (interrupts produced).
- F(8).A(0) - test LAM A = 1 if LAM set
- F(10).A(0) - reset LAM.
- F(9).A(0) - reset.

the form of two 16 bit blocks via CAMAC commands. The upper block represents (in binary form) the most significant 5 BCD digits and the lower block contains (in binary form) the 4 least significant digits. In the case of the most significant 5 digits, the largest number to be converted is 49999_{10} and hence can be contained in 16 bits (unsigned). For the least significant digits, the largest value is 9999.

In the computer, the actual frequency needed is divided by the software into two blocks of the form:

499990000 (max) floating point
9999 (max)

and the appropriate bits are masked and sent to the module. The software also handles overflow and underflow between the two blocks.

Software

The main programming including the initialization routine is written in BASIC. Subroutines, which control individual functions are written in machine language. To begin operation, the initialization routine (Fig. 7) is executed. It requests parameters for the run including:

- initial frequency
- number of steps (channels)
- step size
- number of sweeps
- step delay time T1
- ADC delay time T2
- step direction

Then the routine initializes the channel counter, sweep counter and clears the data buffers. Through the operator's console, the run begins by

starting the clock module (RTC).

Once the RTC is started, the operation of the spectrometer is controlled by means of two computer interrupt routines which are initiated by the CAMAC modules. The main program, which in Fig. 7 is simplified to include only a loop testing for completion of the frequency sweep, executes independently of these routines.

Interrupt Routines

The two interrupt routines are shown in Fig. 8. They provide for the acquisition of data at a predetermined rate. The RTCISR (RTC interrupt service routine) is called once every cycle when the RTC sets its LAM signal. An interrupt coming from the ADC module (at the end of each conversion) causes the routine ADCISR (ADC interrupt service routine) to be executed. Figure 9 shows, as an example, the frequency changes that occur during a sweep cycle.

The RTCISR first checks the channel counter and upon finding it positive, it determines the step direction and calculates the new frequency. The new frequency is then sent to the synthesizer control unit (SCU) where it gets converted in two steps into decimal numbers. Next the routine adds the sum of ADC conversion values to the data buffer.

The alternate branch in this routine is taken upon finding the channel counter to be zero (completion of one up or down sweep). Then the sweep counter is decremented, the channel counter reinitialized and the sum of ADC values added to the buffer. Finally, the step direction is complemented and the sweep counter tested. If found equal to zero, the clock is turned off, the ADC triggering is disabled, and the finish flag is set enabling the main program to proceed to the next task.

The ADCISR is very simple and short in order to minimize computer overhead. It first reads the value presented by the ADC module, and then adds it to the sum of values collected within the same step. Just before returning from this routine, the interrupt is cleared and the handshake for the RTC module provided.

Acknowledgments

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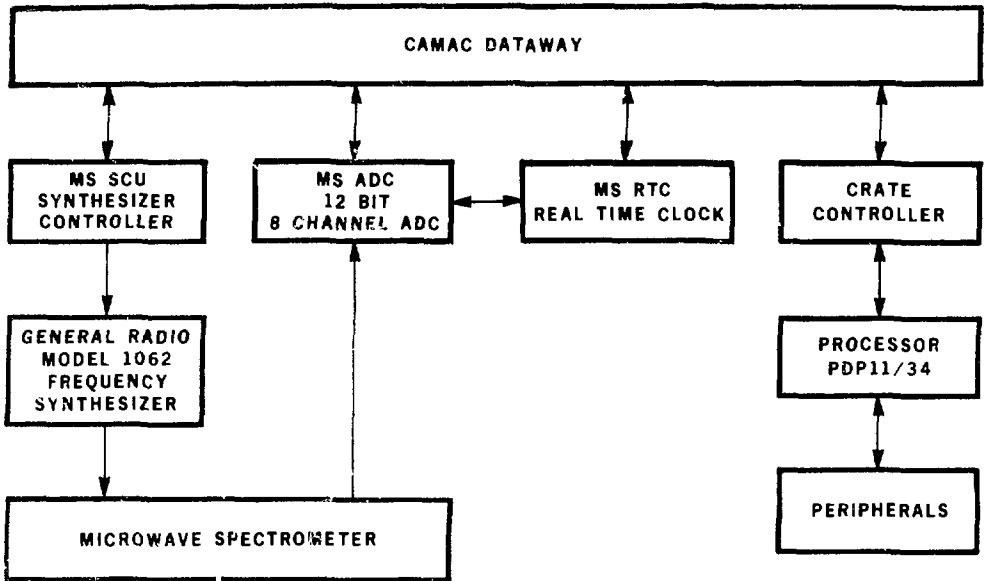
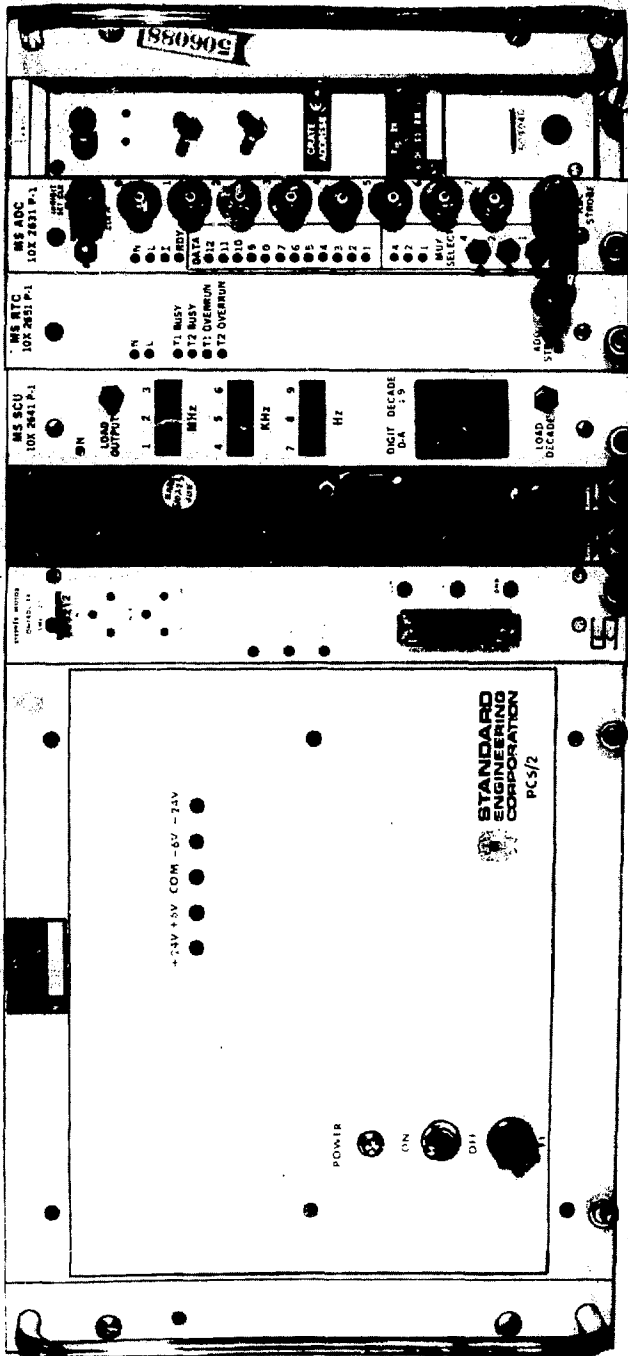


Fig. 1 GENERAL SYSTEM DIAGRAM

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INTERFACE MODULES



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Fig. 2 CAMAC SYSTEM FOR COMPUTER CONTROL OF MICROWAVE SPECTROMETER

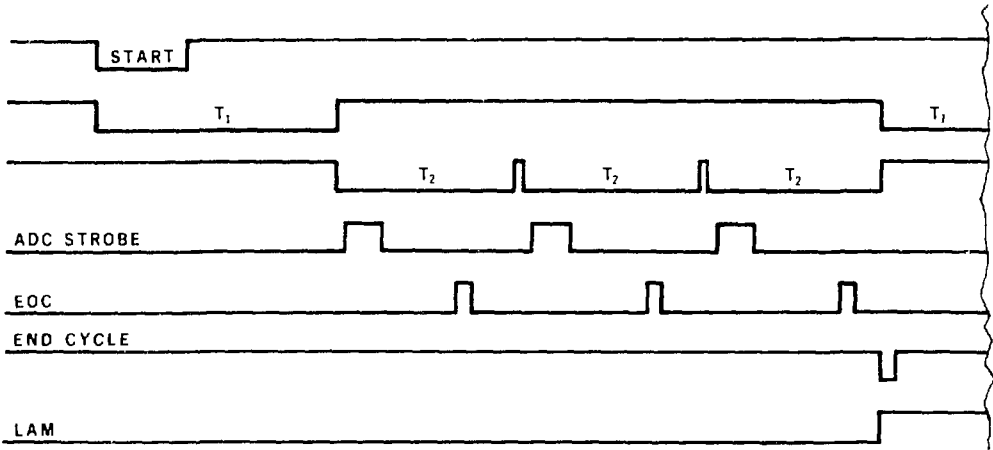


Fig. 3 RTC MODE OF OPERATION

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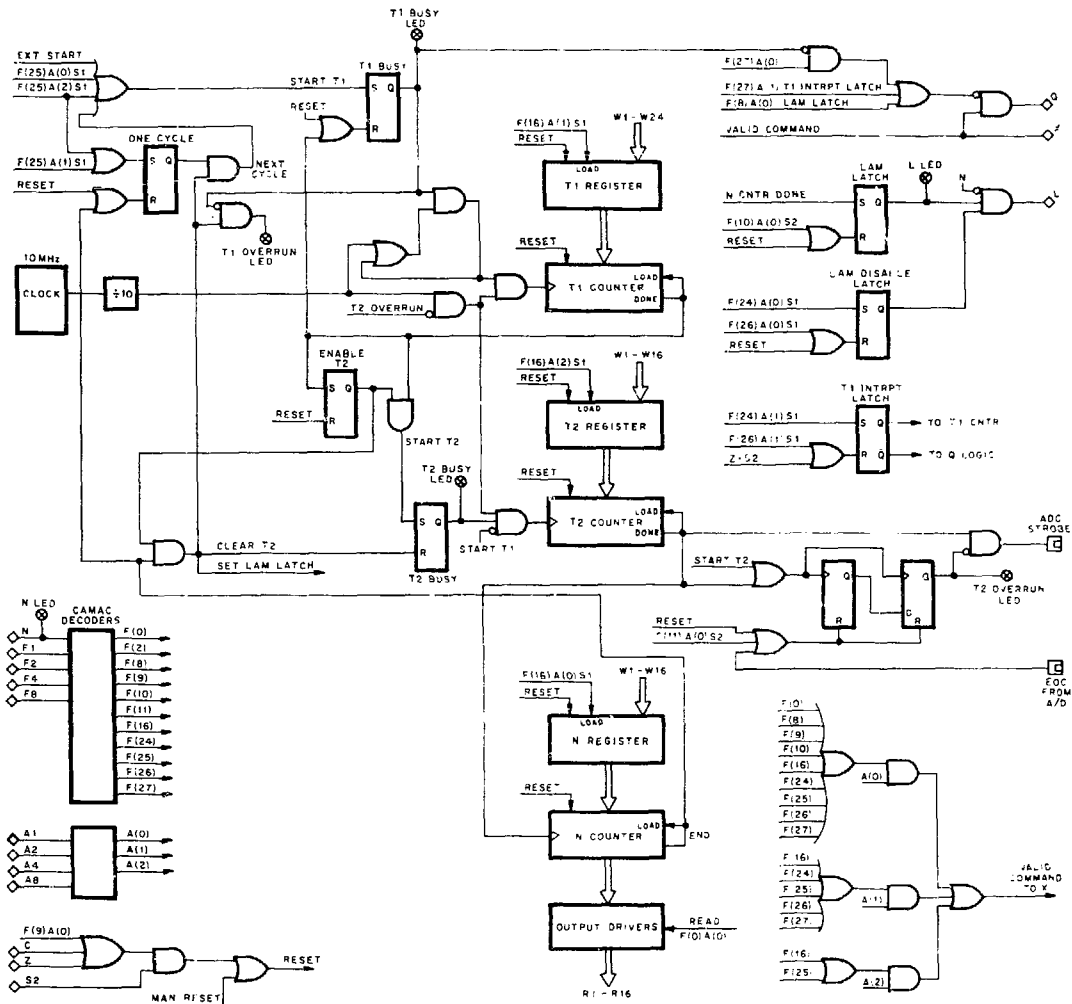


Fig. 4 MS RTC REAL TIME CLOCK BLOCK DIAGRAM

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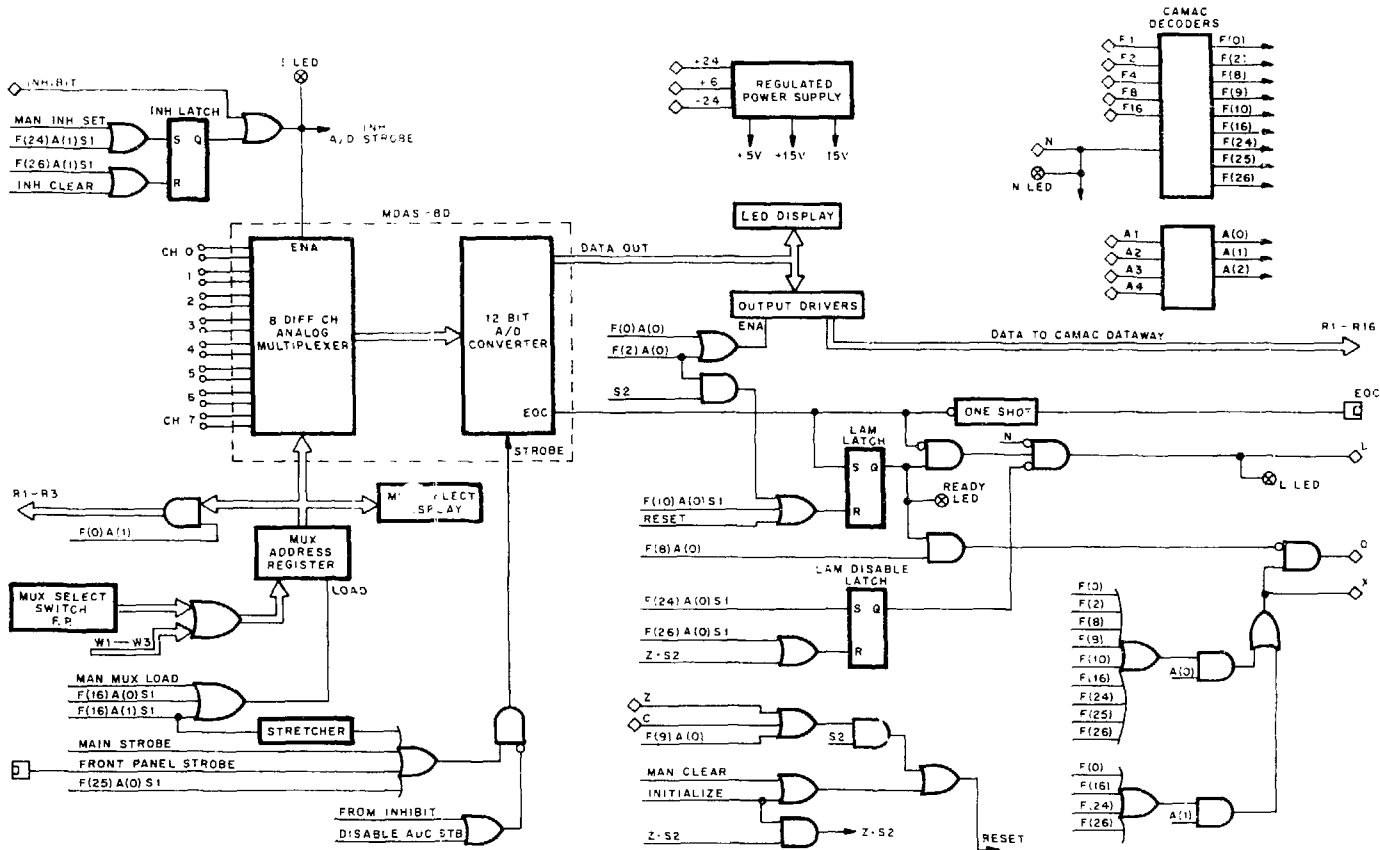


Fig. 5 MS ADC ANALOG TO DIGITAL CONVERTER BLOCK DIAGRAM

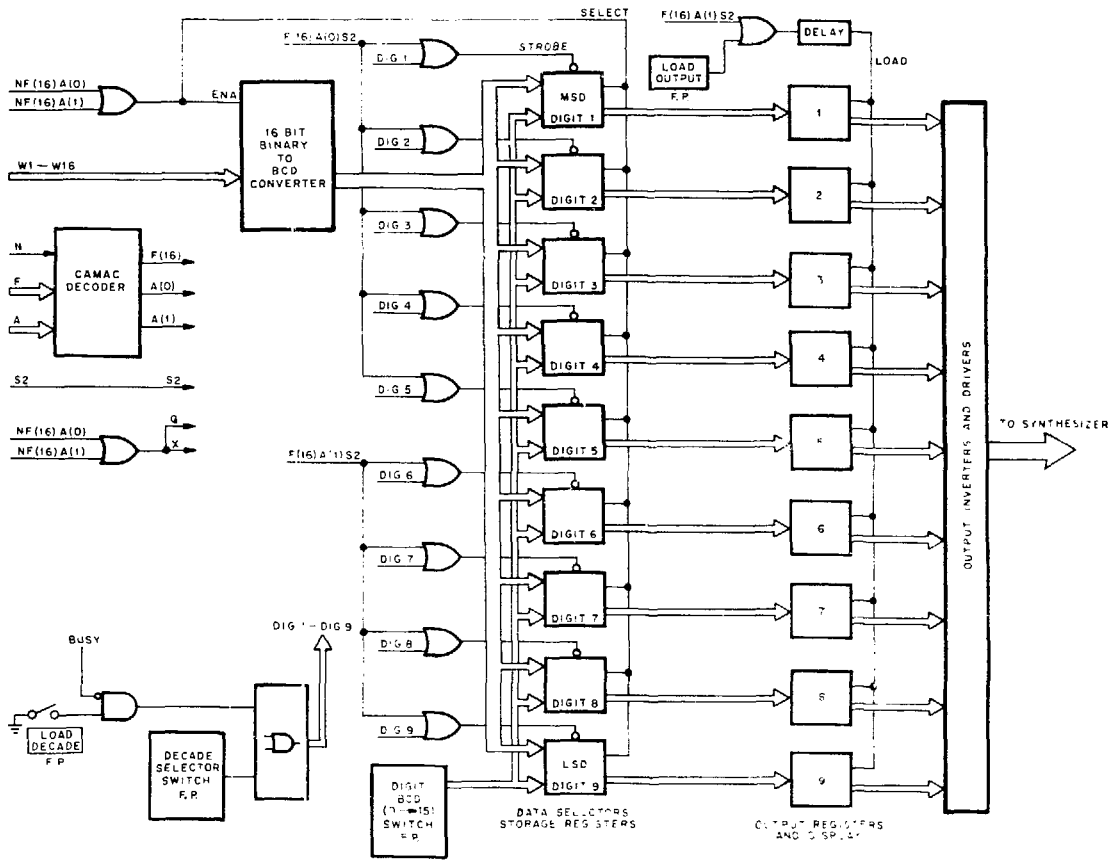


Fig. 6 MS SCU FREQUENCY SYNTHESIZER CONTROL MODULE BLOCK DIAGRAM

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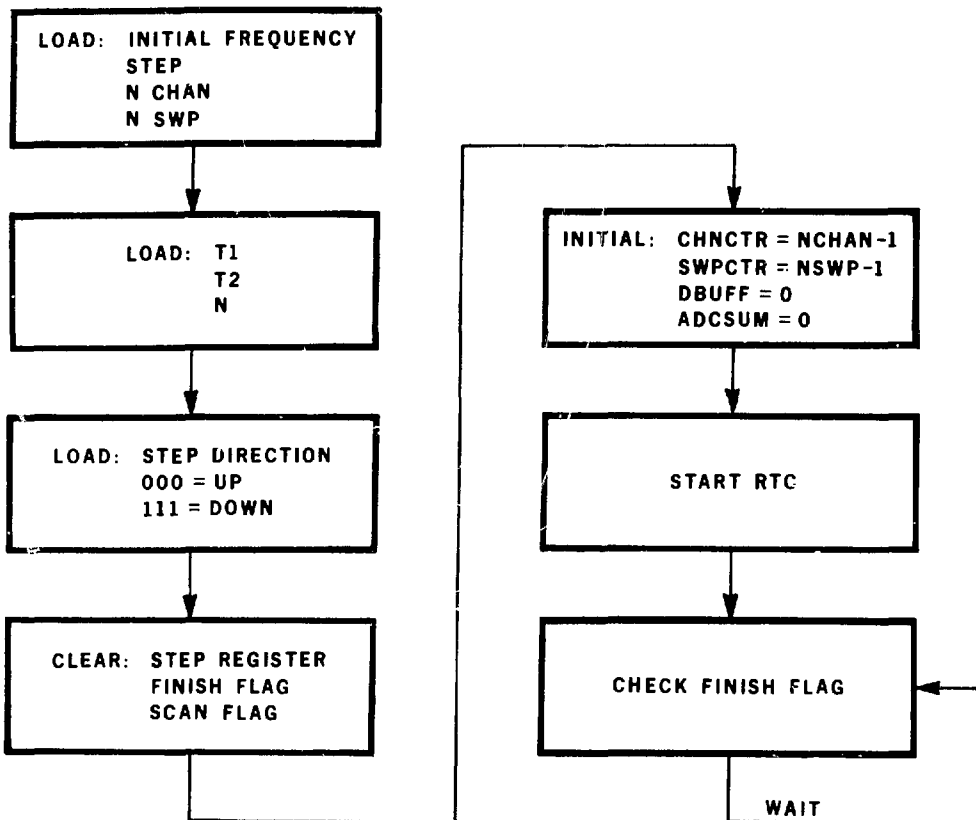


Fig. 7 INITIALIZATION ROUTINE

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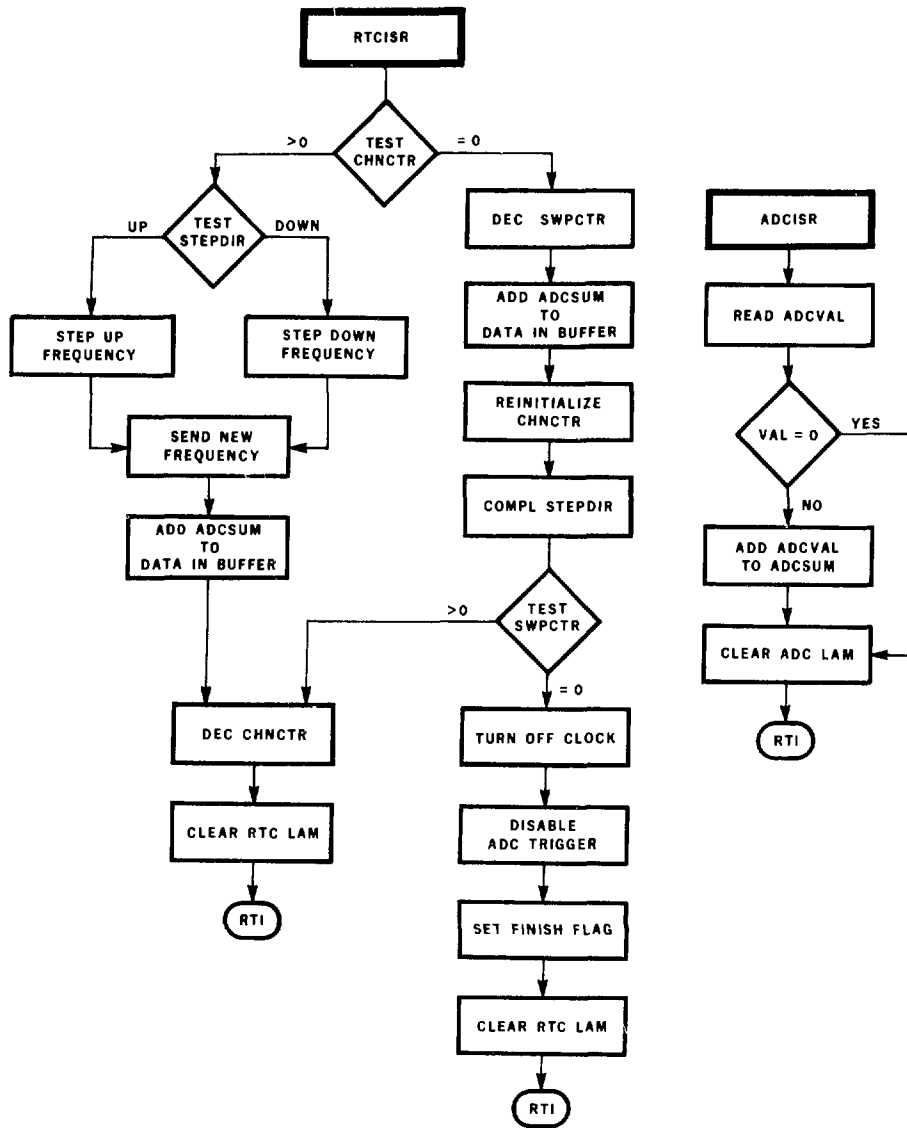


Fig. 8 INTERRUPT SERVICE ROUTINES

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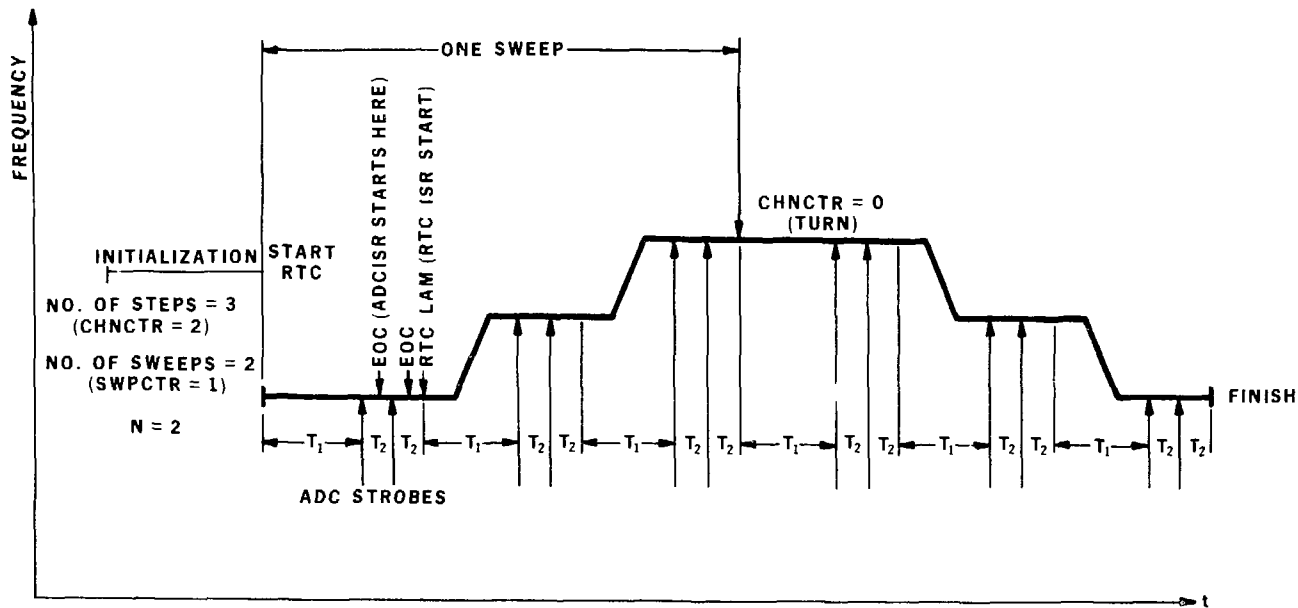


Fig. 9 EXAMPLE OF FREQUENCY CHANGES OCCURRING DURING A SWEEP CYCLE

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