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Authors
Kolbe, W.F.
Turko, B.T.

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Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

Engineering Division

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W.F. Kolbe and B.T. Turko

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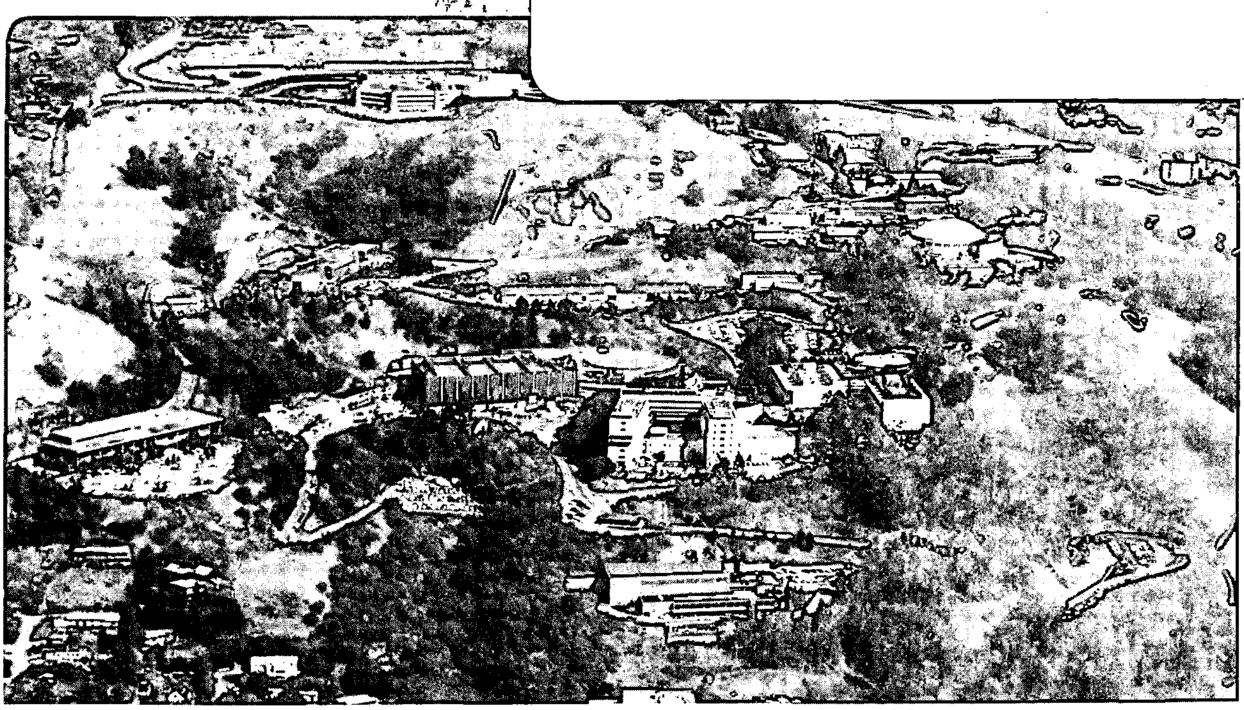

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AUTOMATIC TESTING OF HIGH RESOLUTION TIME DIGITIZERS

William F. Kolbe and Bojan Turko

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720 U.S.A.

ABSTRACT

An automated system for the testing and performance evaluation of high-resolution long-range time digitizers is described. The test system employs an IBM PC/XT or PC/AT personal computer together with appropriate hardware interfacing modules to control the digitizer under test. Precise timing intervals for testing are generated by a pulse calibration module driven by a programmable low phase noise frequency synthesizer. The time intervals measured by the digitizer are then compared under computer control with the actual intervals produced by the synthesizer for a sufficient number of cases to establish the digitizer performance. The hardware and software components used are discussed.

INTRODUCTION

The manual testing of high-resolution long-range time digitizers is a time consuming process. In a typical 24 bit digitizer1 2^{24} or about 16 million different time intervals can be measured. In some digitizers[2,3] as many as 48 bits of timing resolution are provided. In critical applications, as many time intervals as possible covering the entire range need to be tested in order to insure that no errors exist in an untested region. Even if it took only a few seconds for a single manual measurement, years would be required to cover the whole range.

In the conventional approach[1] for the alignment and testing of time digitizers, the digitizer is interfaced to the digital input of a multi channel analyzer (eg Tracor Northern TN-1710). Since such analyzers are essentially hard-wired computers, they are capable of very fast operation. On the other hand, they are limited to measurements over a highly restricted range of only 8192 channels at a time. They are therefore very useful for alignment and calibration of the digitizer, but are cabable of only spot checking of the digitizer performance over its wide operating range.

For the reasons discussed above, an automated system is essential for the thorough evaluation of the digitizer performance. Such a system should have the capability of generating and measuring a large number of time intervals automatically at high speed. It should be able to measure the data over the entire operating range (24 bits) of the digitizer and compare its results with the time intervals generated. Any errors that occur should be recorded for later analysis. The system described in this report is designed to have these capabilities.

MEASUREMENT SYSTEM HARDWARE

A block diagram of the measurement system is shown in Fig. 1. Because of its wide availability and open architecture, an IBM PC/AT was selected for this application. Alternatively, a PC/XT can be used if operation at somewhat slower speed can be tolerated. The computer is interfaced to a CAMAC crate using a DSP Technology (Transiac) model 6001 controller with a DSP PC004 PC interface card. The computer is also equipped with a Ziatech model ZT1488A GPIB interface.

Precision timing pulses are generated by an LBL built calibrator module[1] which is driven by an HP model 8662A low noise frequency synthesizer. The synthesizer is controlled by attaching it to the GPIB bus. The calibrator is essentially a frequency divider, producing at its output a train of NIM level pulses, separated by n clock periods of the synthesizer frequency. The leading edge of each pulse is phase locked to the clock. The resulting phase jitter is in the picosecond range and the accuracy of the time between two consecutive pulses equals the accuracy of the clock reference. The calibrator has 10 ranges, selected by a front panel switch, with each range increment resulting in an 8-fold increase in the delay time. To prevent the unlikely occurence of a false measurement while the digitizer is busy, a veto port is provided which disables the calibrator during the digitizer busy cycle.

The digitizer under test is installed in the CAMAC crate and controlled via the CAMAC dataway. As shown in the figure, it has a start input and a stop input. These are connected to the start/stop output of the calibrator using a 50 ohm matched power divider and appropriate variable and fixed delay lines. As shown, the digitizer would measure the insertion time delay between the start and stop ports generated by a single calibrator pulse. To measure the elapsed time between two successive calibrator pulses, the start and stop inputs should be reversed. In this case the digitizer will be started by the delayed pulse and stopped by the next marker pulse. The interval measured is thus the time between two successive marker pulses minus the insertion delay. In order to achive the best results it is important to provide proper system grounding and impedance matching between the calibrator and digitizer. Failure to follow these precautions can result in an abnormally large distribution in the measured times due to pulse ringing effects.

As an alternative to the HP synthesizer, provision was made for the use of a General Radio model 1062 frequency synthesizer. This option and the CAMAC interface module controlling it are shown at the bottom of Fig. 1. The configuration shown in Fig. 1 is appropriate for the testing of CAMAC based digitizers. In order to evaluate non-CAMAC digitizers some other form of digital I/O must be furnished. For this application, digital control is provided using the Ziatech ZT1488A with a SBX-30 parallel I/O interface.

SOFTWARE DESCRIPTION

The software was written in the language C and compiled using the Lattice C compiler version 2.15. The plotting routines were implemented with the use of graphics primitives supplied in the C Tools package provided by Blaise Computing Inc. Some routines were written in assembly language to provide faster response.

As described above, the testing procedure employs a computer controlled frequency synthesizer to generate precise time intervals which are measured by the digitizer under test. The measured intervals are listed on the operator's terminal for inspection and can be displayed graphically if desired. For automatic testing, the synthesizer can be stepped through a range of frequencies and the measurement repeated for each step. For each frequency a preselected number of interval measurements is made in order to display the statistical variation in the measured data.

In order to determine the precision of the measured results, two different tests are applied for each selected frequency: (1) the centroid of the measured interval distribution is compared to to that calculated from the known input frequency and (2) the full width (number of channels for which counts are detected) is recorded. If either of these values exceed preselected limits, the erroneous data can be written to an error file for later examination.

The program is executed by entering the command "dig" at the operator's console. The operator can then select the CAMAC or GPIB addresses appropriate to the hardware installation used or use the default values provided if appropriate. After initialization, a number of command options are provided:

parameters:	enable parameter selection.
go:	execute test sequence from start.
resume:	resume test from break point (see below).
plot:	plot of last measured data array.
file:	opening/closing of error log files.
stop:	exit from program.

By entering the command, "parameters", the operator can list the current parameter values or make any changes necessary. The available parameter commands are:

freq-low:	start frequency.
freq-hi:	stop frequency.
freq-steps:	number of steps dividing the above range.
samples:	number of time measurements per step.
time-multiplier:	scale factor converting freq to channel.
time-offset:	channel offset due to cable lengths.
max-width:	error if width exceeds this value.
max-center-offset:	error if (meas)-(calc chan) exceeded.
display-level: amount	of information displayed.
max-errors:	if exceeded error file closed+halt.
dig-sub-address:	digitizer sub-address to be tested.
list-params:	list of current parameters.
exit:	exit parameter selection.

During a measurement sequence, initiated by the command "go", the operator can interrupt the program at any time by typing the break character "b". The current measurement can then be plotted if desired. (Commands affecting the plot routine can be displayed below the plot by striking the space bar.) The <ESC> key causes exit from the plot. The sequence can then be continued at the next frequency by typing "resume" or restarted from the beginning by entering the command "go".

TEST RESULTS

The digitizer test system was evaluated using an LBL constructed time digitizer (model 10X314P-1). This unit has a 24 bit resolution in which the LSB corresponds to 78.125 ps. It has a single start input and 8 independant stop inputs each of which can be tested by setting the parameter, dig-sub-address.

In order to test the accuracy of the time intervals measured by the digitizer, correct values must be supplied for the two parameters, time-multiplier (t-mult) and time-offset (t-off). The theoretical time interval (int-calc) is given by

$$\text{int-calc} = \text{t-mult/f-syn} + \text{t-off}$$

where f-syn is the synthesizer frequency. The quantity t-mult can be computed from the following equation:

$$\text{t-mult} = \text{f-int*dig-mult*range-mult}$$

where f-int is the precise frequency (MHz) of the internal clock of the digitizer, dig-mult is a multiplier appropriate to the digitizer circuitry and range-mult is determined by the range selection switch of the calibrator module. For the particular digitizer which was tested the values t-mult = 26214214.40 and t-off = 18.40 were used.

In order to provide a printed output, the max-width parameter was set equal to 1 channel, an unrealistically small amount. Thus all the interval measurements were forced to fail test number 2 described above and were written to the error logging file. The results are shown in Table 1 in which the error file is displayed. Only 35 frequency steps and 1000 samples per step were used in this demonstration run.

The error file displays the time of creation and the parameter values employed. In the data summary, the first column shows the synthesizer frequencies used. In the second and third columns are presented the calculated intervals (based on the calibration frequency and the t-mult and t-off parameters) and the actual measured (centroid) intervals. The difference between these two values is given in the fourth column. As can be seen, the interval offset is significantly less than one channel (ie less than 78.125 ps).

To further illustrate the accuracy with which time interval measurements can be made, a number of repeated measurements of the same interval were made. In order to eliminate phase jitter and other noise contributions from the frequency synthesizer and calibrator module, a single pulse generator (Picosecond Pulse Laboratories model 4000) was used with a power divider and appropriate delay line. A series of 50 independant measurements was made for each of three cases: (a) 100 samples, (b) 1000 samples and (c) 10000 samples per measurement. The results are shown in Fig. 2. In all cases the peak-to-peak variation in the measured values is significantly less than the single channel width of 78 ps and improves in proportion to the square root of the number of samples as expected. In case (c) the observed variation is approximately ±1 ps indicating that very accurate time interval measurements can be made in situations in which sample averaging is possible.

Finally, for comparison, Fig. 3 shows the linearity of the time digitizer as measured with the test system using a precision adjustable delay line as a delay time reference. In the figure, curve A shows the measured data, curve B the time differences between measurements and C the resulting integral nonlinearity.

SUMMARY

An automated system for the testing and evaluation of high resolution time digitizers has been described. With this system it is possible to make a large number of time interval measurements using the digitizer under test in a fully automatic mode without operator intervention. At the end of each measurement, the results are tested for accuracy and any errors detected are recorded for later examination. Suspicious data can be examined graphically or in numerical form as an aid to fault diagnosis.

Data are presented illustrating the measurement of a series of time intervals both with the use of a frequency synthesizer as a time interval generator and a precision calibrated delay line. In both cases comparable results are obtained. The frequency synthesizer, however permits the measurement to be made under completely automated conditions and over a very wide range. Finally, in a series of measurements of the same time interval it is shown that very precise interval determinations can be made (±1 ps) under conditions where interval averaging can be used.

ACKNOWLEDGEMENTS

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Digitizer error log file: 9:59 AM July 18, 1987

freq-low	25.000000
freq-hi	60.000000
freq-steps	35
samples	1000
time-multiplier	26214214.40
time-offset	18.40
max-width	1
max-center-offset	1000
display-level	1
max-errors	100

....

Calib Freq (MHz)	Calc Intv (ps)	Meas Intv (ps)	Intv Offset (ps)
25.000000	81920858	81920875	17
26.029412	78681106	78681117	11
27.058824	75687858	75687854	-4
28.088235	72914010	72914014	4
29.117647	70336293	70336313	20
30.147059	67934615	67934634	19
31.176471	65691538	65691537	-2
32.205882	63591855	63591852	-3
33.235294	61622240	61622237	-2
34.264706	59770971	59770979	8
35.294118	58027693	58027689	-4
36.323529	56383224	56383220	-4
37.352941	54829396	54829390	-6
38.382353	53358914	53358924	10
39.411765	51965248	51965269	20
40.441176	50642534	50642552	19
41.470588	49385485	49385489	4
42.500000	48189331	48189357	26
43.529412	47049753	47049756	3
44.558824	45962828	45962841	13
45.588235	44924991	44925009	18
46.617647	43932987	43932997	9
47.647059	42983849	42983848	-1
48.676471	42074855	42074868	13
49.705882	41203512	41203509	-4
50.735294	40367528	40367522	-6
51.764706	39564794	39564805	12
52.794118	38793363	38793376	13
53.823529	38051441	38051473	32
54.852941	37337366	37337360	-6
55.882353	36649599	36649593	-6
56.911765	35986712	35986697	-16
57.941176	35347380	35347366	-14
58.970588	34730369	34730371	2
60.000000	34134529	34134500	-29

Table 1. Sample error log file for calibration frequency range from 25.0 to 60.0 MHz.

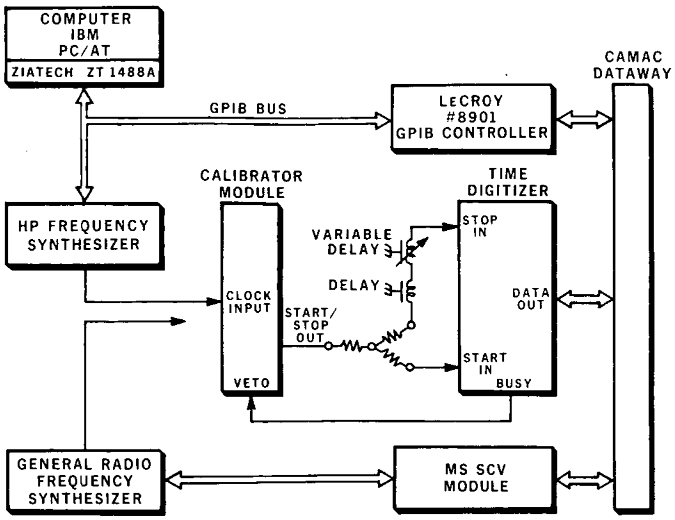

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Fig. 1. Block diagram of test system for the calibration of CAMAC based time digitizers.

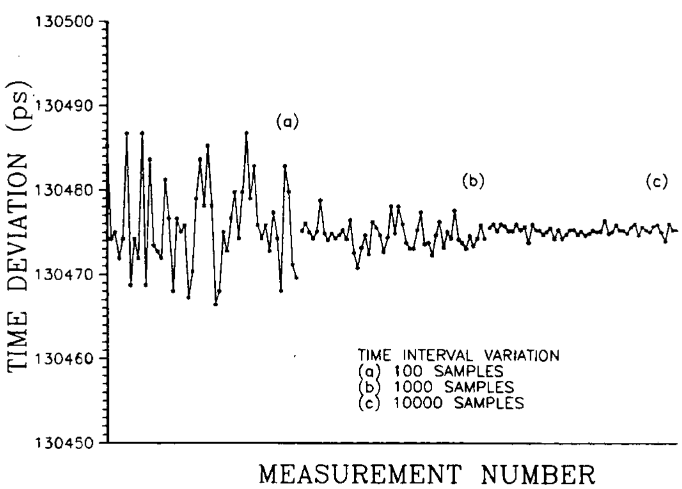

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Fig. 2. Time deviation measurements for a fixed time interval of 130475 ps as determined using (a) 100, (b) 1000, and (c) 10000 samples.

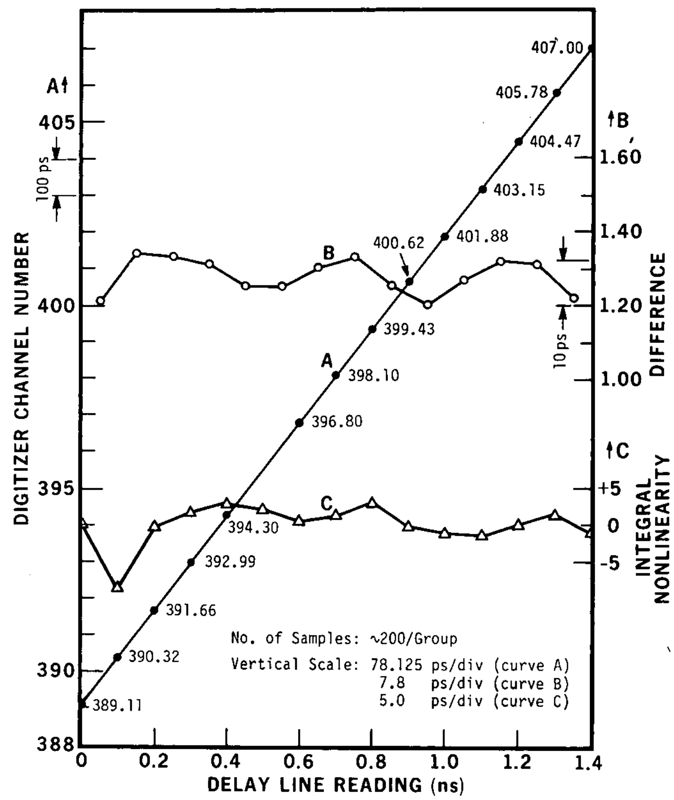

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Fig. 3. Time digitizer calibration using a precision delay line as a time interval reference.

LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720