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Applying Virtual Oscilloscope to Signal Measurements in Scintillation Detectors

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Abstract: A virtual oscilloscope was designed by using the LabVIEW software. Signals supplied by a pulse generator and background radiation signals from a NaI(Tl) scintillation detector were displayed in a real and a virtual oscilloscope, respectively. Amplitude, maximum voltage, rise time and fall time values through the oscilloscopes for both type signals were measured. They were acquired in different time/div. values to test and compare their performances. Obtained results and the signal shapes from them were meticulously compared. It was observed that they were highly comparable to each other. Results indicate that the developed virtual oscilloscope would reliably be able to be used for data acquisition as well as a real oscilloscope.

Keywords: NaI(Tl) Detectors, LabVIEW Software, Virtual Oscilloscope and GPIB

1. Introduction

LabVIEW software is one of the virtual instrumentation software platforms. LabVIEW expanded as Laboratory Virtual Instrumentation Engineering Workbench. It provides an easy-to-use application development environment designed specifically with the needs of engineers and scientists. It is a powerful graphical development environment for signal acquisition, measurement analysis and data presentation [1].

The new way in the design of computer-based measurement systems can be seen in the use of up-to-date measurement, control and testing systems based on reliable devices. Digital signal processing (DSP) is used to replace conventional analog systems [2]. The virtual instrumentation technique performed in LabVIEW is used for nuclear DSP system realization [3].

A virtual oscilloscope is composed of two parts in that hardware and software. The hardware includes a general computer and a data acquisition (DAQ) device [4]. The DAQ devices typically connect directly to the computer's internal bus through a plug-in slot. Some DAQ devices are external and connected to the computer via serial, GPIB (General Purpose Interface Bus) or Ethernet ports [5]. GPIB facilitates the communication between computer and instrument. It is simply the means by which computers and instrument transfer data. Its purpose is to provide computer control of test and measurement instrument [6]. Their software include their driver programs also [4].

An oscilloscope is a device for recording and visualizing the instantaneous value of alternating voltage [7]. It can be used in order that amplitude, maximum voltage, rise time and fall time values of a signal are determined. Amplitude is a difference between max. and min. voltage values of a signal. Maximum voltage is a value of positive peak voltage [8]. Rise time is the passed time to rise from 10 to 90% of the signal amplitude. Fall time is the passed time to fall from 90 to10% of the signal amplitude [9].

A NaI(Tl) scintillation detector is widely used to particle detection in nuclear physics. The scintillation can be converted into electrical pulses which can be analyzed and counted electronically to give information concerning the incident radiation. A preamplifier amplifies its input signal from a detector by filtering it from the electronic noise together with the impedence matching. A main amplifier amplifies the output of the preamplifier and shapes it to a convenient form for further processing [9].

A multifunctional virtual oscilloscope was designed by Gong and Zhou using LabVIEW software [4]. A virtual oscilloscope was designed with LabVIEW by D. ShengLi et al. Voltage and time parameters were determined from a signal generator to design the test signals by ShengLi et al. [10].

In this study, a generator signal was compared with a real oscilloscope and a virtual oscilloscope developed with LabVIEW. The quantities containing voltage and time values of the signal and the signal shapes were compared with each other. These processes were repeated for the background signal from a NaI(Tl) scintillation detector.

2. Materials and Methods

In this work, a GW Instek Model 2204 oscilloscope and a pulse generator (Ortec 419) as a signal source were used. The virtual oscilloscope was operated in a desktop PC by generating a virtual instrument (VI) through LabVIEW. The connection between the computer and the real oscilloscope was performed by GPIB interface. Pulse generator output was first sent to the real oscilloscope, then, the signal was transferred to the virtual oscilloscope through GPIB cable. The real oscilloscope's interface has a USB port, RS232C and GPIB port. Due to the fact that data transfer rate via GPIB is fast, GPIB cable was preferred. A block diagram of the used setup is given in Figure 1.

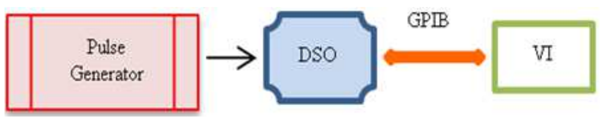


Figure 1. A block diagram for the measurement of the generator signal. (DSO: Digital Storage Oscilloscope, VI: Virtual Instrument, GPIB: General Purpose Interface Bus).

The generator signal was analyzed with different time/div. values of the real and virtual oscilloscope. During the measurements, volt/div. adjustment of both oscilloscopes was set to 500 mV. Amplitude, maximum voltage, rise time and fall time values of the signal were determined. The measurement was repeated five times for each time/div. setting. Each quantity was determined between 250.0 μs and 2.5 ms time/div. intervals since the entire signal could not be seen on the scope.

In the second part of the work, background signal from a Bicron NaI(Tl) scintillation detector (3" x 3") was displayed in both of the real and the virtual oscilloscopes. The spectrometer used for this process composed of a preamplifier (Ortec 113), an amplifier (Ortec 485) and the GW Instek 2204 oscilloscope together with the virtual oscilloscope installed in a PC via GPIB connection were used. A block diagram is shown in Figure 2.

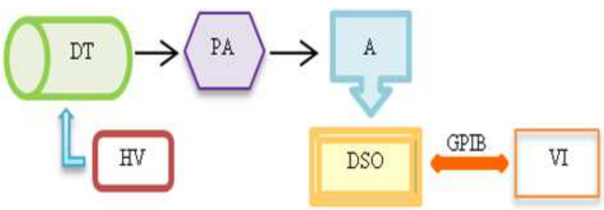


Figure 2. A block diagram for the measurement of NaI (Ti) scintillation detector background signal. (DT: Detector, HV: High Voltage, PA: Preamplifier, A: Main Amplifier, DSO: Digital Storage Oscilloscope, VI: Virtual Instrument, GPIB: General Purpose Interface Bus).

In the block diagram, the detector output was sent to the preamplifier. Its output was transmitted to the amplifier, and its output signal was displayed in the real oscilloscope. The signal was transferred from the real oscilloscope to the virtual oscilloscope through GPIB cable. High voltage to the detector, preamplifier capacitance, amplifier coarse gain and fine gain adjustments were set to 1000 V, 100 pF, 64 and 10 settings, respectively, thus, the background signal had nearly same amplitude with the generator signal to compare and test them easily.

Amplitude, maximum voltage, rise time and fall time values of the background signal were measured five times for each time/div. values from both oscilloscopes. Volt/div. adjustments of the oscilloscopes were kept unchanged. Since the signal shapes deteriorated in the time/div. under 2.5 μs and over 50.0 μs, all measurements were performed between these time values.

3. Results and Discussion

Amplitude, maximum voltage, rise time and fall time values for the generator signal and the background signal were determined from the real and the virtual oscilloscopes. To test the performance of the virtual oscilloscope signal measurements were performed at different time/div. adjustments. All measurements were performed after the oscilloscopes were stopped.

For the generator signal, time/div. setting was set to 250.0 μs, 500.0 μs, 1.0 ms and 2.5 ms, respectively. The comparison between real and virtual oscilloscopes for the generator signal is given in Tables 1-4. Background signal from the NaI(Tl) scintillation detector was analyzed for 2.5 μs , 5.0 μs , 10.0 μs , 25.0 μs and 50.0 μs time/div. adjustments. Obtained results from the oscilloscopes are given with their relative errors in Tables 5-9. Besides, signal shape comparison for the generator signal for 250.0 μs time/div. adjustment is shown in Fig. 3. Background signal shapes from the scintillation detector through both oscilloscopes are compared in Fig. 4 for 2.5 μs time/div. setting.

Table 1. Amplitude (V_{amp}), maximum voltage (V_{max}), rise time (T_R) and fall time (T_F) values of the generator signal for 250.0 µs time/div. in the real and virtual oscilloscope.

	Virtual Oscilloscope			
	V_{amp} (V)	**V_{max} (V)**	**T_R (μs)**	**T_F (μs)**
1	1.020±0.109	1.400±0.011	5.912±0.143	778.500±0.096
2	1.020±0.109	1.380±0.002	6.182±0.093	813.500±0.049
3	1.240±0.087	1.380±0.002	7.402±0.086	815.000±0.047
4	1.240±0.087	1.380±0.002	7.403±0.086	896.000±0.047
5	1.140±0.007	1.380±0.002	6.908±0.021	964.500±0.115
	Real Oscilloscope			
1	1.020±0.109	1.400±0.011	5.913±0.143	778.500±0.096
2	1.020±0.109	1.380±0.002	6.182±0.093	813.500±0.049
3	1.240±0.087	1.380±0.002	7.403±0.086	815.000±0.047
4	1.240±0.087	1.380±0.002	7.403±0.086	896.000±0.047
5	1.140±0.007	1.380±0.002	6.909±0.021	964.500±0.115

Table 2. *Amplitude (V_{amp}), maximum voltage (V_{max}), rise time (T_R) and fall time (T_F) values of the generator signal for 500.0 µs time/div. in the real and virtual oscilloscope.*

	Virtual Oscilloscope			
	V_{amp} (V)	**V_{max} (V)**	**T_R (µs)**	**T_F (µs)**
1	1.340±0.011	1.380±0.011	16.000±0.002	904.000±0.035
2	1.300±0.018	1.340±0.017	16.250±0.018	854.900±0.019
3	1.320±0.003	1.360±0.002	15.760±0.012	869.900±0.002
4	1.340±0.011	1.380±0.011	15.760±0.012	867.600±0.004
5	1.320±0.003	1.360±0.002	16.000±0.002	862.900±0.010
	Real Oscilloscope			
1	1.340±0.011	1.380±0.011	16.000±0.002	904.000±0.035
2	1.300±0.018	1.340±0.017	16.250±0.018	855.000±0.019
3	1.320±0.003	1.360±0.002	15.760±0.012	870.000±0.002
4	1.340±0.011	1.380±0.011	15.760±0.012	867.500±0.005
5	1.320±0.003	1.360±0.002	16.000±0.002	862.900±0.010

Table 3. *Amplitude (V_{amp}), maximum voltage (V_{max}), rise time (T_R) and fall time (T_F) values of the generator signal for 1.0 ms time/div. in the real and virtual oscilloscope.*

	Virtual Oscilloscope			
	V_{amp} (V)	**V_{max} (V)**	**T_R (µs)**	**T_F (µs)**
1	1.340±0.017	1.380±0.017	31.520±0.018	897.400±0.045
2	1.320±0.003	1.360±0.002	32.490±0.012	818.900±0.045
3	1.220±0.078	1.260±0.076	32.000±0.003	827.300±0.034
4	1.360±0.032	1.400±0.031	32.480±0.011	905.200±0.054
5	1.340±0.017	1.380±0.017	32.000±0.003	832.400±0.028
	Real Oscilloscope			
1	1.340±0.017	1.380±0.017	31.530±0.018	897.500±0.045
2	1.320±0.003	1.360±0.002	32.490±0.012	819.000±0.045
3	1.220±0.078	1.260±0.076	32.000±0.003	827.200±0.035
4	1.360±0.032	1.400±0.031	32.470±0.011	905.100±0.054
5	1.340±0.017	1.380±0.017	32.000±0.003	832.300±0.028

Table 4. *Amplitude (V_{amp}), maximum voltage (V_{max}), rise time (T_R) and fall time (T_F) values of the generator signal for 2.5 ms time/div. in the real and virtual oscilloscope.*

	Virtual Oscilloscope			
	V_{amp} (V)	**V_{max} (V)**	**T_R (µs)**	**T_F (µs)**
1	1.300±0.000	1.340±0.000	79.990±0.003	831.500±0.046
2	1.280±0.015	1.320±0.015	79.990±0.003	894.300±0.026
3	1.300±0.000	1.340±0.000	78.780±0.012	819.200±0.062
4	1.300±0.000	1.340±0.000	79.990±0.003	873.200±0.003
5	1.320±0.015	1.360±0.014	79.990±0.003	932.800±0.067
	Real Oscilloscope			
1	1.300±0.000	1.340±0.000	80.000±0.003	831.600±0.046
2	1.280±0.015	1.320±0.015	80.000±0.003	894.200±0.026
3	1.300±0.000	1.340±0.000	78.780±0.012	819.100±0.062
4	1.300±0.000	1.340±0.000	80.000±0.003	873.300±0.003
5	1.320±0.015	1.360±0.014	80.000±0.003	932.800±0.067

Table 5. *Amplitude (V_{amp}), maximum voltage (V_{max}), rise time (T_R) and fall time (T_F) values of the background signal for 2.5 µs time/div. in the real and virtual oscilloscope.*

	Virtual Oscilloscope			
	V_{amp} (V)	**V_{max} (V)**	**T_R (µs)**	**T_F (µs)**
1	1.120±0.025	1.220±0.049	1.215±0.002	3.590±0.343
2	1.140±0.042	1.180±0.016	1.272±0.042	5.240±0.079
3	1.180±0.074	1.220±0.049	1.315±0.073	5.938±0.187
4	1.000±0.092	1.040±0.115	1.200±0.015	5.350±0.098
5	1.020±0.070	1.140±0.017	1.088±0.119	3.992±0.207
	Real Oscilloscope			
1	1.120±0.025	1.220±0.049	1.215±0.002	3.590±0.343
2	1.140±0.042	1.180±0.016	1.272±0.042	5.240±0.079
3	1.180±0.074	1.220±0.049	1.315±0.073	5.938±0.187
4	1.000±0.092	1.040±0.115	1.200±0.015	5.350±0.098
5	1.020±0.070	1.140±0.017	1.088±0.119	3.992±0.207

Table 6. *Amplitude (V_{amp}), maximum voltage (V_{max}), rise time (T_R) and fall time (T_F) values of the background signal for 5.0 µs time/div. in the real and virtual oscilloscope.*

	Virtual Oscilloscope			
	V_{amp} (V)	**V_{max} (V)**	**T_R (µs)**	**T_F (µs)**
1	1.700±0.228	1.740±0.216	1.275±0.000	7.840±0.115
2	1.180±0.111	1.200±0.136	1.278±0.001	7.530±0.078
3	1.240±0.058	1.300±0.049	1.315±0.029	5.900±0.175
4	1.320±0.006	1.380±0.011	1.296±0.015	7.230±0.040
5	1.120±0.171	1.200±0.136	1.216±0.049	6.176±0.122
	Real Oscilloscope			
1	1.700±0.228	1.740±0.216	1.275±0.000	7.840±0.115
2	1.180±0.111	1.200±0.136	1.278±0.001	7.530±0.078
3	1.240±0.058	1.300±0.049	1.315±0.029	5.900±0.175
4	1.320±0.006	1.380±0.011	1.296±0.015	7.230±0.040
5	1.120±0.171	1.200±0.136	1.216±0.049	6.176±0.122

Table 7. *Amplitude (Vamp), maximum voltage (Vmax), rise time (TR) and fall time (TF) values of the background signal for 10.0 µs time/div in the real and virtual oscilloscope.*

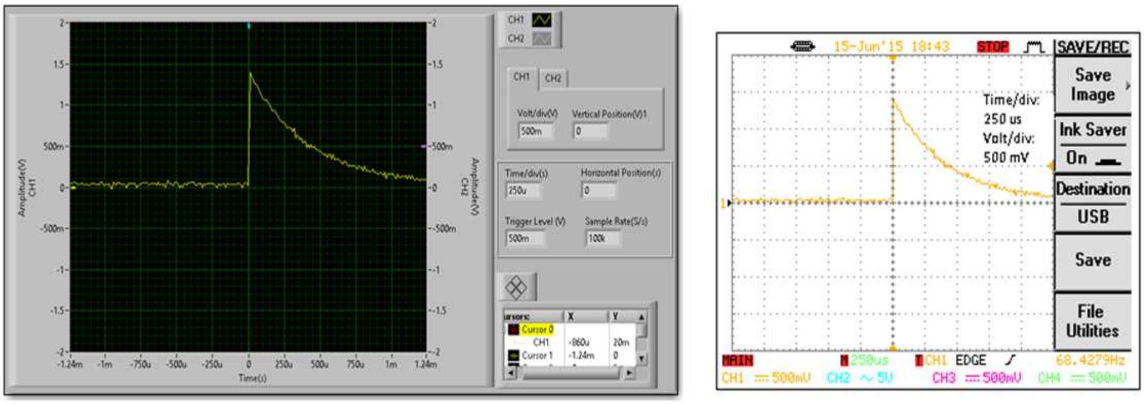
	Virtual Oscilloscope			
	Vamp (V)	**Vmax (V)**	**TR (µs)**	**TF (µs)**
1	1.120±0.250	1.200±0.223	1.173±0.034	6.853±0.225
2	1.700±0.176	1.720±0.146	1.151±0.054	6.983±0.240
3	1.440±0.027	1.520±0.034	1.279±0.051	4.442±0.194
4	1.300±0.076	1.380±0.063	1.273±0.046	3.824±0.387
5	1.440±0.027	1.520±0.034	1.191±0.018	4.421±0.199
	Real Oscilloscope			
1	1.120±0.250	1.200±0.223	1.173±0.034	6.853±0.225
2	1.700±0.176	1.720±0.146	1.151±0.054	6.983±0.240
3	1.440±0.027	1.520±0.034	1.280±0.051	4.444±0.193
4	1.300±0.076	1.380±0.063	1.274±0.047	3.825±0.387
5	1.440±0.027	1.520±0.034	1.192±0.018	4.423±0.199

Table 8. *Amplitude (V_{amp}), maximum voltage (V_{max}), rise time (T_R) and fall time (T_F) values of the background signal for 25.0 µs time/div. in the real and virtual oscilloscope.*

	Virtual Oscilloscope			
	V_{amp} (V)	**V_{max} (V)**	**T_R (µs)**	**T_F (µs)**
1	1.300±0.009	1.400±0.028	1.603±0.005	5.406±0.240
2	1.200±0.093	1.220±0.114	1.582±0.018	6.098±0.099
3	1.240±0.058	1.320±0.030	1.584±0.017	6.352±0.055
4	1.100±0.192	1.140±0.192	1.687±0.044	8.250±0.187
5	1.720±0.237	1.720±0.209	1.600±0.007	7.416±0.095
	Real Oscilloscope			
1	1.300±0.009	1.400±0.028	1.603±0.005	5.408±0.240
2	1.200±0.093	1.220±0.114	1.583±0.017	6.100±0.099
3	1.240±0.058	1.320±0.030	1.584±0.017	6.357±0.054
4	1.100±0.192	1.140±0.192	1.687±0.044	8.250±0.187
5	1.720±0.237	1.720±0.209	1.600±0.007	7.418±0.095

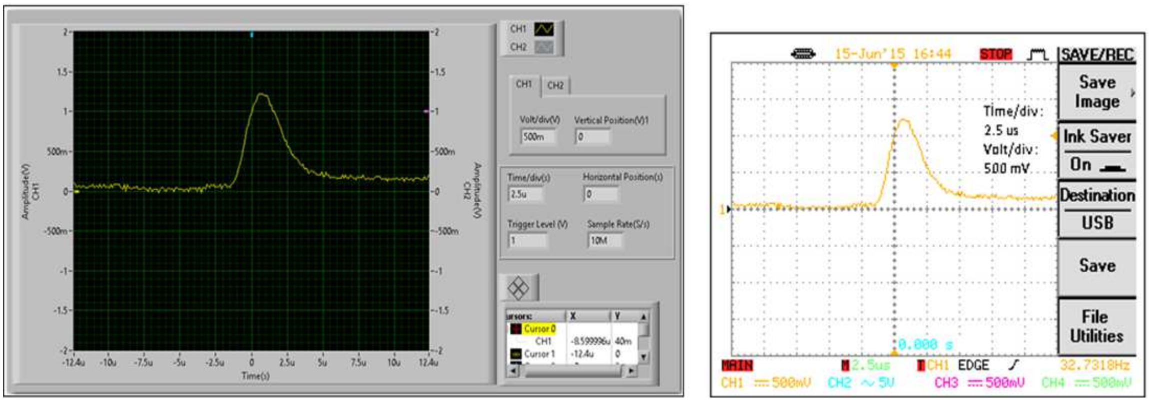
Table 9. *Amplitude (V_{amp}), maximum voltage (V_{max}), rise time (T_R) and fall time (T_F) values of the background signal for 50.0 µs time/div. in the real and virtual oscilloscope.*

	Virtual Oscilloscope			
	V_{amp} (V)	**V_{max} (V)**	**T_R (µs)**	**T_F (µs)**
1	1.700±0.174	1.700±0.157	1.600±0.334	13.960±0.020
2	1.440±0.025	1.460±0.019	1.719±0.241	15.110±0.057
3	1.160±0.210	1.200±0.193	1.657±0.288	15.910±0.104
4	1.080±0.300	1.160±0.234	2.462±0.132	12.750±0.117
5	1.640±0.143	1.640±0.126	3.236±0.340	13.510±0.054
	Real Oscilloscope			
1	1.700±0.174	1.700±0.157	1.600±0.334	13.950±0.020
2	1.440±0.025	1.460±0.019	1.719±0.241	15.110±0.057
3	1.160±0.210	1.200±0.193	1.657±0.288	15.910±0.104
4	1.080±0.300	1.160±0.234	2.462±0.132	12.740±0.117
5	1.640±0.143	1.640±0.126	3.236±0.340	13.500±0.054



(a) (b)

Figure 3. *Generator signal shapes in (a) the virtual and (b) the real oscilloscope for 250.0 µs time/div.*



(a) (b)

Figure 4. *Background signal shapes in (a) the virtual and (b) the real oscilloscope for 2.5 µs time/div.*

When compared all results from the oscilloscopes above, it can be easily realized that voltage values (V_{amp} and V_{max}) were very close to each other whereas very few differences on rise time and fall time values have been occurred in some measurements. Even so, it can be deduced from the overall results that the measurement performance of the virtual oscilloscope was quite satisfactory.

4. Conclusions

A signal generator and the background radiation signals from a NaI(Tl) scintillation detector were separately analyzed. Amplitude, maximum voltage, rise time and fall time values of both type signals were determined for different time/div. adjustments. Obtained values from the designed virtual oscilloscope were highly comparable to those of the real oscilloscope as can be seen from tables (1-9). Also, it was observed that generator and background signals in both oscilloscopes were similar in shape. Finally, our designed virtual oscilloscope (VI) showed highly good performance in comparison with the real one. It was deduced from the obtained results that the developed virtual oscilloscope would reliably be able to use for the data acquisition as well as a real oscilloscope. This helps us to analyze many types of detector signals in scintillation detectors. .

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