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FUZE VAF-M17 ELECTRONIC BLOCK TEST SOFTWARE

NEMANJA DEURA
Metropolitan University, Vlatacom Institute, Belgrade, nemanja.deura@vlatacom.com

DRAGAN DOMAZET
Metropolitan University, Belgrade, dragan.domazet@metropolitan.ac.rs

SREĆKO NIJEMČEVIĆ
Metropolitan University, Vlatacom Institute, Belgrade, srecko@vlatacom.com

Abstract: *Detailed explanation of the test procedure for the aviation fuze vAF-M17 is described. The fuze vAF-M17 main purpose is to be implemented inside aviation bombs such as MK-82, MK-84 and BLU-109 penetrator bomb. Complete block schematic of hardware and software architecture of the system is covered in this paper, which is designed to simulate real-time conditions of an aviation bomb drop from an aircraft from the viewpoint of electronics. Required parameters that are measured during testing are amplitude and length of the arming, that is detonating impulse, which is used for activating certain electro-explosive devices for aligning the explosive train (arming position). System, which is described in this paper, is capable to simulate initiator vFI-M17 function essential for providing environmental conditions for activating the fuze. More than 10 various test scenarios are implemented which are going to be described further in the paper.*

Keywords: *fuze, simualation, software, millitary, vlatacom.*

1. INTRODUCTION

The fuze is a device that detonates a munition's explosive material under specified conditions. In addition, a fuze will have safety and arming mechanisms that protect users from premature or accidental detonation. The fuze may contain only the electronic or mechanical elements necessary to signal or actuate the detonator, but some fuzes contain a small amount of primary explosive to initiate the detonation. Fuzes for large explosive charges may include an explosive booster. [1] [2]

The fuze is essentially a binary state mechanism. In the context of weapon system hardware, a fuze and warhead are unique in that they are expected to remain functionally quiescent until a bona fide target is encountered, and then to function as intended in a fraction of a millisecond. Guidance systems may recover from transient malfunctions; target-tracking radars may experience numerous false alarms without significantly compromising their utility; and missile airframes may flex and recover, but the fuze-warhead process is singular and irreversible. [2]

The warhead usually contains a powerful but relatively insensitive high explosive that can only be initiated by the heat and energy from a primary explosive. The primary explosive is a component of the fuze subsystem and is normally loaded in the detonator. If the detonator is designed properly, it can only be activated by a unique fire signal received from the target-sensing device. A detonator can be designed to activate when it receives either electrical energy (high voltage) or mechanical energy (shock or stab) from the target sensor. [2]

The fuze vAF-M17 and the initiator vFI-M17 that have been developed are a sub-system designed for use with standard general purpose aircraft bombs such as the MK-81, MK-82, MK-83 and MK-84 as well as penetration aircraft bomb BLU-109.

Each individual component of the vAF-M17 fuze and the vFI-M17 initiator is subjected to functional tests before being installed on the final product, after which the complete product is subjected to certain tests. These tests can be factory (FAT) or site (SAT) tests whose test requirements are obtained based on MIL standards. This paper will describe a small segment of these tests, with an emphasis on the software that was developed for the purpose of testing the main electronic board of the vAF-M17 fuze.

Functional testing of the fuze vAF-M17 main board is performed using equipment shown at Figure 1.

Testing equipment:
1. vAFMainB PCB completely assembled (Electronic block of the fuze, EBAF)
2. Referent PCB board vAFRSW,
3. Computer with 2 USB ports,
4. Application software v*AFM17 Fuze Test software*
5. National instrument Data Acquisition Module (DAQ) USB6361, NI DAQ
6. Interface vAF USB-UART
7. Driver for vAF USB-UART interface: (Silicon *Labs CP210x USB-UART Bridge)*
8. Power supply, adjustable from 5V to 15V
9. Interface box vAFM17-EBAF-NI-INT with appropriate cables.

The following can be tested using this equipment and software:

a) Functionality of Arming delay rotary switch
b) Functionality of Detonation delay rotary switch
c) Battery voltage at load with the current greater than 5mA
d) MP1 switch functionality
e) MP2 switch functionality
f) Arming capsule activation sequence (all scenarios are performed to check the operation of the microcontroller)
g) Accuracy of arming time
h) Firing pulse from the output of the arming capsule driver- waveform, amplitude and width
i) Detonation capsule activation sequence
j) Firing pulse from the output of the detonation capsule driver - waveform, amplitude and width
k)Accuracy of Detonation delay time

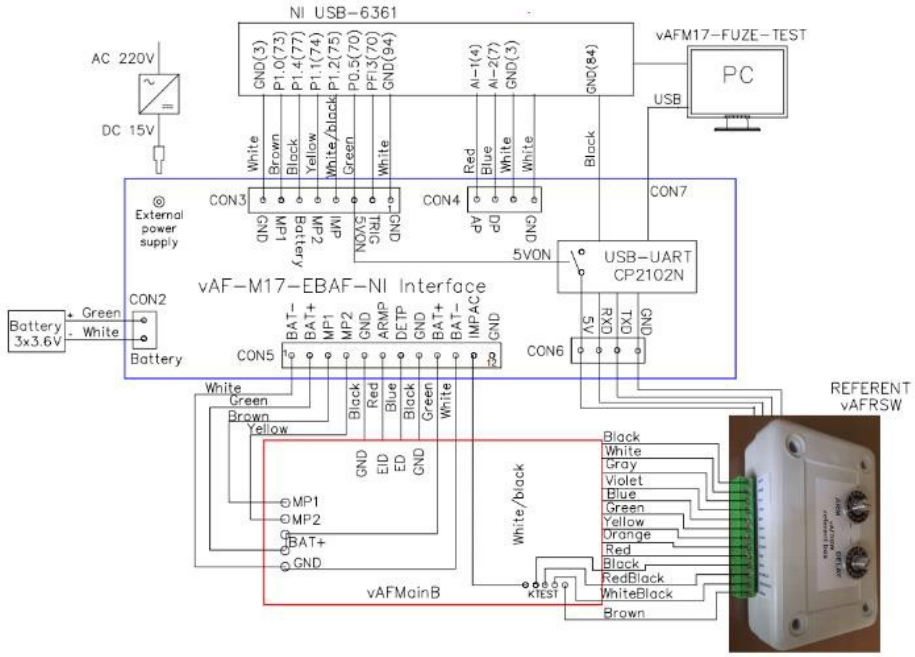


Figure 1. Fuze vAF-M17 main board testing equipment diagram

2. SOFTWARE DESCRIPTION

The purpose of the developed software is to test the operation of the electronics of the fuze vAF-M17 in factory before assembling of the fuze.

The fuze microcontroller (uC) has two modes of operation (Functional or normal mode of operation and Test mode of operation mode). If the uC is powered up by USB connection it goes to test mode of operation – otherwise, if it is powered up by MP1 signal, it goes to normal functional mode.

In Normal operation mode, the following can be tested:

a) Launch sensor (MP1 switch) functionality
b) Environmental sensor, MP2 signal, functionality
c) Arming capsule activation sequence (all scenarios are performed to check the operation of the microcontroller)
d) Accuracy of Arming time
e) Arming pulse characteristics: waveform, amplitude and width
f) Detonation capsule activation sequence
g) Detonation impulse characteristics: waveform, amplitude and width.
h) Detonation delay time accuracy.

Table 1. List of signals and NI DAQ ports

No.	Signal	Analog /Digital	Input/ Output	NI DAQ Port	Description
1	MP1	Digital	Output	P1.0	Simulates switch MP1 inside the initiator
2	MP2	Digital	Output	P1.1	Simulates signal From pressure Sensor located inside the initiator
3	Impact	Digital	Output	P1.2	Simulates impact the bomb; After this signal detonation delay time begin.
4	Battery	Digital	Output	P1.4	Disconnects power supply from the EBAF; Reset EBAF
5	AP	Analog	Input	AI-1	Puls generated by arming capsula driver
6	DP	Analog	Input	AI-2	Puls generated by detonation capsula driver (ED)

Test results can be saved into Microsoft access DB, and report of testing generated after performing the test.

3. SOFTWARE OPERATION

Figure 2 shows the main screen of the software

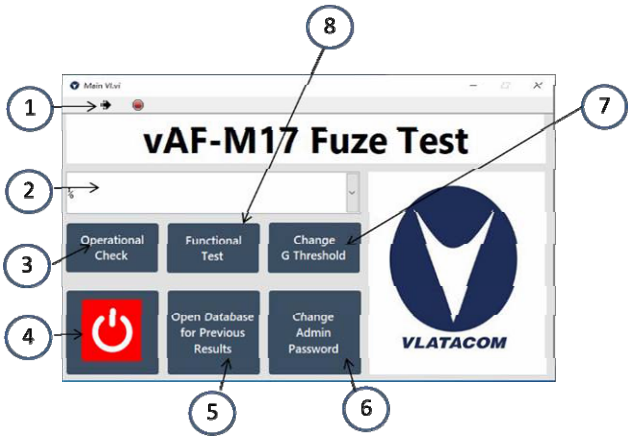


Figure 2. Software main screen

Table 2. List of control and indicators of the main screen

No.	Control/indicator
1)	Toolbar (Run, stop or pause running). When the user launch the software the application will run automatically
2)	VISA Resource name of the USB-UART interface. The user must select this from the dropdown list before starting any test.
3)	***Operational Check:*** activate uC in test mode of operation. (USB should be connected) and get uC response of several parameters (as listed in software requirements in test mode of operation)
4)	Stop running the application.
5)	Open Database for Previous Results: possibility to see, and/or print previous UUT Results.
6)	nge Administrator password, (the only privilege of the administrator, is that he can change "g threshold" value)
7)	Change 'g' threshold
8)	***Functional Test:*** activate uC in normal, fuze functional mode of operation to test EBAF regular functionality.

3.1. Operational check

When user clicks on "Operational Check" button on the main screen, DAQ device activates (vAF-M17 NI-USB-UART adapter) to connect USB to the uC via USB-UART adapter. Then SW keep sending a query command to the uC "[R]" and receive response string (see table 5-2), parse this string, and display different parameters on the operational check screen.

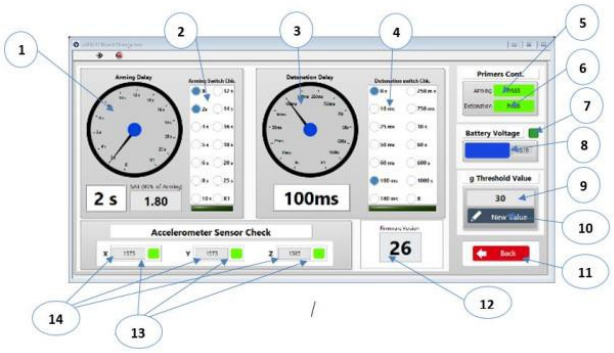


Figure 3. Operational Check Screen

Table 3. List of control and indicators of the operational check screen

No.	Control/indicator
1)	Arming Rotary Switch indicator
2)	Arming Switch position check
3)	Detonation delay Rotary Switch indicator
4)	Detonation Delay Switch position check
5)	Arming primer continuity indicator
6)	Detonation primer continuity indicator
7)	Battery voltage check indicator
8)	Battery voltage measurement indicator
9)	'g' threshold value indicator
10)	Open window to allow administrator user to change the 'g' threshold
11)	se the screen, go back to the main menu
12)	Firmware version indicator
13)	Accelerometer sensor check indicators (X, Y, and Z)
14)	Accelerometer's voltage indicator (X, Y, and Z) read by uC

3.2. Functional test

Upon clicking of "Functional Test" button on the main screen, DAQ Device activates the vAF-M17 NI-USB-UART adapter to power up the uC in test mode and get the current position of the rotary switches, then wait for any user interaction.

Arming and Detonation pulses are monitored continuously independent on any other functionality of the software. The user will be informed and pulses will be displayed whenever any impulse is fired.

The user can perform test on the fuze board manually (MP1, MP2, and impact signals are generated manually via controls on the screen) or automatically (MP1, MP2, and impact signals are generated automatically by the software).

Switching to automatic mode will disable the control of these three signals.

3.2.1. Controls, and indicators

Figure 4 shows the Functional Test screen, and a description of every control or indicator is described below.

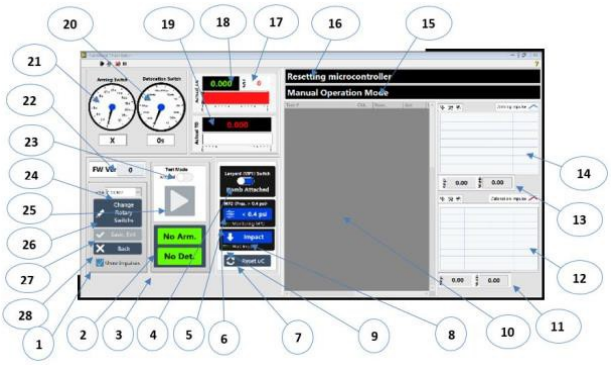


Figure 4. Functional Test screen

Table 4. List of control and indicators of the functional check screen

No.	Control/indicator
1)	Show Impulses Check box – to show/hide Impulses waveform windows
2)	Arming State indicator
3)	Detonation State indicator
4)	Lanyard (MP1) Switch simulation control (only Active in manual mode)
5)	MP2 (Press > 0.4 psi) simulation Control (only Active in manual mode)
6)	Monitoring MP2 indicator (only Active in manual mode) to indicate that uC is in the state of monitoring MP2.
7)	Reset uC Control (only Active in manual mode)
8)	Impact Simulation control (only Active in manual mode)
9)	Wait Impact indicator (only Active in manual mode) to indicate that uC is in the state of waiting impact after Arming has occurred.
10)	Test results (only Active in automatic mode) show test results of UUT in auto mode.
11)	Detonation Impulse Characteristics indicator (Amplitude, pulse width)
12)	Detonation Impulse indicator This indicator, as well as Characteristics indicator are updated every time Detonation impulse is generated
13)	Arming Impulse Characteristics indicator (Amplitude, pulse width).
14)	Arming Impulse indicator This indicator, as well as Characteristics indicator are updated every time Arming impulse is generated
15)	Program State indicator
16)	uC State indicator
17)	SAT time indicator (set according to the position of Arming time rotary switch)
18)	Arming time counter indicator (the range of this indicator is set according to the position of Arming time rotary switch)
19)	Detonation delay time counter indicator (the range of this indicator is set according to the position of Detonation delay rotary switch)
20)	Detonation Delay switch indicator
21)	Arming time switch indicator
22)	uC Firmware version indicator
23)	Test mode switch control
24)	uC VISA control
25)	Start/Stop automatic test (Active only in auto mode)
26)	Change Rotary switch, open screen to allow user change Arming, and Detonation delay rotary switches (Active only in manual mode)
27)	Save, exit – save result (shown in the result window) and exit this screen to the main screen (Active only after finishing automatic test)
28)	Back – Exit operational test screen, without saving results, and go back to the main screen

3.2.2. Performing functional test manually

If the user switches to manual mode, the software enables (MP1, MP2, and impact signals). The user can start to apply these signals to the uC, to simulate the functionality of the initiator's MP1, and MP2 signals, and accelerometer sensor's impact signal, to check the response of the uC upon different conditions.

Upon clicking on the MP1 switch on the test screen, DAQ device will send MP1 signal to the uC and the battery will connect to the fuze board. At this moment, the Arming counter start to count the Arming time and "Monitoring MP2" indicator goes to high during the SAT time.

The user can click on (MP2, and/or Impact) at any time during Arming time counting, which immediately applies the corresponding signal to the uC.

The Software continuously monitors both Arming, and Detonation impulses, to be detected and displayed to the user whenever any of them is generated.

Upon detecting Arming pulse (Figure 5), Software will deactivate MP1 immediately, to check the functionality of BYPASS signal.

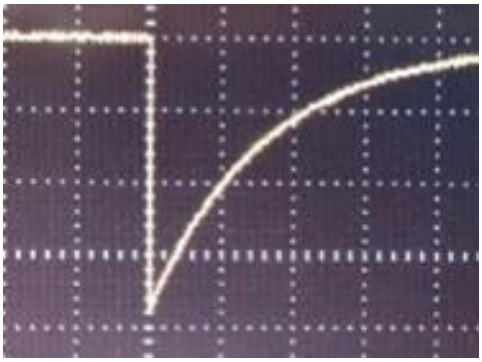


Figure 5. Arming or Detonation pulse waveform

Upon Clicking on "MP1" software disables "MP1", "Test

Mode", and "Change Rotary Switches" buttons. Because uC, at this moment is powered and running in functional mode, and cannot go to test mode unless the user resets the uC, clicking on "Reset uC" button.

Upon clicking on "Reset uC" button, DAQ device will disconnect the battery from uC, disable MP1, MP2, and Impact signals. The software will prevent the user to interact with it for 10 seconds (time for Arming, and Detonation capacitor to completely discharge). After this

time, “MP1”, “Change Rotary Switches”, and “Test Mode” buttons will be enabled again.

Upon Detecting Arming pulse, or Detonation pulse, the following sequence will be executed:

– Interface box will generate a digital signal after a delay time introduced by the interface box (Approximately 10 ms)

– This digital signal will trigger DAQ device to start acquiring data from ”Primers Impulses” task.

Note: This triggering signal is generated from the interface box if Arming impulse, or Detonation impulse is generated

– DAQ device start acquiring analog data from “Primers Impulses” task (two channels), and return acquired data from both channels to the software. Table 5 shows the detailed acquiring information of the “Primers Impulses” task

– Software will filter the acquired data and return only samples with values less than -1 V (to detect which impulse is generated), and update the waveform graph of the generated impulse.

– Software will analyze the acquired data to calculate the generated impulse characteristics (Amplitude, and Pulse width) and display this information on the related indicator, as well as Actual Arming time.

– After detecting Arming pulse, “Wait Impact” indicator will be active waiting for the user to simulate impact by clicking on “Impact” button.

– When user click on “Impact" button, DAQ device generates a pulse that goes to the Impact pin in the UUT to simulate Impact

– At this moment, Detonation timer will start counting.

– Upon detecting Detonation pulse from UUT, the Detonation timer will stop, actual Detonation time will appear at Detonation counter, Detonation pulse will be displayed at graph and pulse characteristics will be displayed at the related indicators.

– The user has to click on “Reset uC” button to be able to start the above mentioned process again

– The user can change Arming, and Detonation time rotary switches position by clicking on “Change Rotary switches” button to enable communication with UUT to acquire the new position, and update the test screen indicators.

– Acquiring Actual Arming, or Detonation delay times is acquired by DAQ device, as described in the following sub section.

Table 5. Acquiring information of "Primers Impulses" DAQmx task

Sampling Rate	500 kS/s
Sample time (Pulse width resolution)	2 us
Total No. of Samples	100 kS
Total acquiring time	200 ms
Pre trigger Samples	70 kS
Pre trigger acquiring time	140 ms
Post trigger Samples	30 kS
Post trigger acquiring time	60 ms

3.2.3. Performing functional test automatically

The purpose of automatic test is to:

– Checks UUT condition after manufacturing.

– Checks all possible situations that may occur in reality, to ensure that UUT response to different situations safely, and operably.

– Save results for the above two checks to MS Access database

– Enable user to retrieve old data, and print test report for any UUT test event

When the user clicks on “Start Automatic test”, the following sequence will be executed:

– DAQ device activates vAF-M17 NI-USB-UART adapter to enable communication with UUT and operational check window (Figure 6) appears to test the following:
  - Proper battery voltage indication.
  - Arming, and Detonation capsules continuity.
  - Arming, and Detonation switches operations.

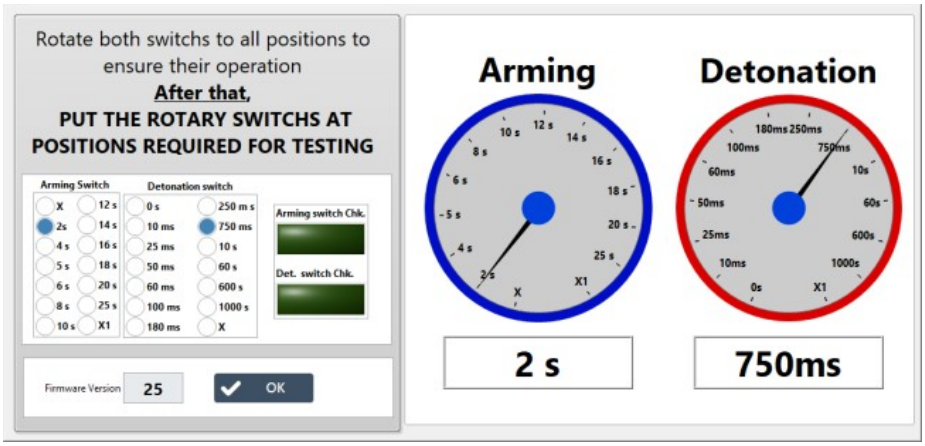


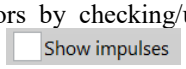
Figure 6. UUT operational check during automatic functional test

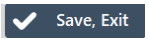
– Software reports the result of the above step, as well as ‘g’ threshold value, Firmware version, and Arming, and detonation switches positions.

– Apply ten different scenarios to UUT, to test operation of the UUT under different conditions

Table 6 displays all test scenarios description, and table 7 displays the combination of (MP1, MP2, and Impact) signals during every test.

Note: Tests number 8, 9, and 10 require change in the rotary switches positions, screen shown in Figure 7 will appear, to ask user to change the positions of Arming, and/or Detonation rotary switches according to step number.

During test execution, result window is updated according to each step result (Figure 8), the user also can show/hide the impulses indicators by checking/unchecking "Show impulses" Check box 

After executing all test steps, the "Save and exit" button 

will be activated to enable user to enter test information, to be saved in the database. (Figure 9), pressing "OK" button in this screen will save a record into DB, and return to the main screen.

Table 6. Automatic test scenarios

Test No.	Condition	Description
1	Dropping with lanyard attached	Apply Pressure, and Impact while not pulling the lanyard. and wait for 1.3 of (TA+TD) to ensure that there is no Arming or Detonation
2	Safe Separation	Pull lanyard, apply pressure (MP2) before "SAT Time", then Unset (MP2) for the remaining Arming time, wait for 1.3 of (TA+TD) time to ensure no Arming or Detonation
3	NormalArming Condition	Apply normal Arming condition, (Arming impulse is expected with proper impulse characteristics to activate Arming primer) without applying impact, wait for 1.3 of TD to ensure no Detonation.
4	Drop in storage	Set Impact and wait for Arming, and Detonation for 1.3 of (TA+TD) to ensure no Arming or Detonation
5	Impact Before Arming test	Apply Arming condition, and Set Impact signal until 0.8 of TA, then unset it, Arming impulse should be generated, wait for 1.3 of TD, to ensure no Detonation.
6	Arming with no impact (Soft Landing)	Apply Arming condition, with no Impact signal, Arming impulse should be generated, wait for 1.3 of TD, to ensure no Detonation.
7	Normal Detonation Condition	Apply normal Arming and Detonation conditions, (Arming, and Detonation impulses are expected with proper impulse characteristics to activate both primers)
8	'X' Position for Arming Rotary switch	Apply normal Arming and Detonation process with Arming switch set to 'X' position, wait for 1.3 of (TA+TD) to ensure no Arming or Detonation
9	'X' Position for Detonation Rotary switch	Apply normal Arming and Detonation conditions with Detonation delay switch set to 'X' position, wait for 1.3 of (TA+TD) to ensure no Arming or Detonation
10	'Inst' Position for Detonation Rotary switch	Apply normal Arming and Detonation conditions, with Detonation delay switch set to 'Inst' position (Arming, and Detonation impulses are expected)

Table 7. (MP1, MP2, and Impact) signals during automatic test steps

No	Initial state			Change				Result	
	MP1	MP2	IMP	At time	MP1	MP2	Imp	Arm	Det.
1	F	T	T	NO Change				NO	NO
2	T	T	T	0.8 * (TA)		F		NO	NO
3	T	T	F	NO Change				YES	NO
4	T	F	T	NO Change				NO	NO
5	T	T	T	0.8 * (TA)			F	YES	NO
6	T	F	F	0.8 * (TA)		T		YES	NO
7	T	T	T	NO Change				YES	YES
8	T	T	T	NO Change				NO	NO
9	T	T	T	NO Change				NO	NO
10	T	T	T	NO Change				YES	YES

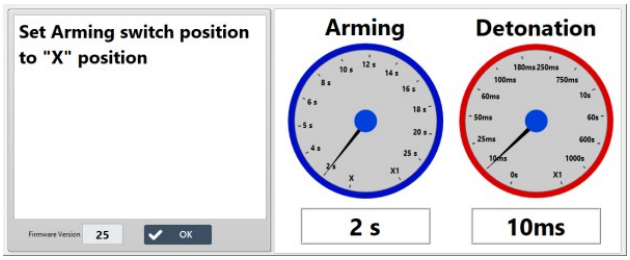


Figure 7. Change Rotary switches in step 8

Figure 8. Test result window

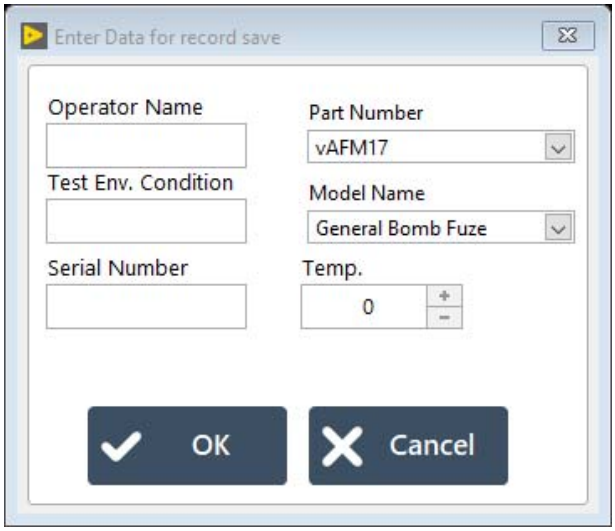


Figure 9. Save test information screen

4. CONCLUSION

Based on the test results, it can be concluded that the software performs its function. With this software it is possible to test and simulate real operating conditions of the main board of the vAF-M17 fuze and thus confirm its functionality. The test software as well as the hardware ensures better reliability of the fuze, as each individual main board of the vAF-M17 fuze is tested before assembly into the final product. This software and hardware were developed for the needs of the P126 project of the Vlatacom Institute, in order to ensure adequate testing of the manufactured products.

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