Creating an Oscilloscope Driver

Roland Szabó, Aurel Gontean, Ioan Lie, Mircea Băbăiță

***Abstract*—In this paper a driver is created for the HAMEG HM 407 oscilloscope. This equipment is controlled with PC via the RS232 serial port. This oscilloscope has no driver provided by the manufacturer, so all the necessary control has been developed according to the SCPI instructions provided in the datasheet. Due to the fact that the core microcontroller is relatively old, these instructions are not so simple and a lot of binary calculations are needed to make it all work.

***Keywords*—Communication equipment, control equipment, driver, oscilloscope, protocol, remote handling, serial port.

I. Introduction

THIS paper presents the creation of an oscilloscope driver. To test the driver, the HAMEG HM 407, 40MHz, 100MS/s cathode-ray tube oscilloscope (Fig. 1.) is connected with the PC to be controlled via the RS232 serial port. The oscilloscope is an analog/digital oscilloscope. It has an RS232 serial port and a microcontroller with implemented SCPI (**S**tandard **C**ommands for **P**rogrammable **I**nstruments) commands. Its commands are presented in the product datasheet. Some commands are quite complicated and need a lot of binary calculation to make them work. Some of them are not complete or not well explained and need programming tricks to make them fully functional. Some commands are related to other commands. These dependencies are explained in an other datasheet, so to command this equipment, a lot of prior study is needed.

The oscilloscope has a quite old microcontroller and this makes it a little more difficult to program, then other equipments.

Its commands are not standardized; the commands are closer to binary code.

This equipment was chosen, because it's not common equipment, like the Agilent equipments, which quite really simple to program and most of them have drivers for all common communication ports present on an equipment, like GPIB, RS232, USB or Ethernet.

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II. Problem Formulation

The most often used functions needed to be implemented in the computer interface of this HAMEG HM 407 oscilloscope.

Some functions that are not possible without a computer, like saving a graph from the oscilloscope, or sending a graph to the oscilloscope, were the main target.

On the computer interface the buttons needed to have similar name as those present on the oscilloscope.

III. Problem Solution

A. Programming Language Presentation

The goal was clear, to make a simple, but efficient computer interface for the oscilloscope via RS232 interface.

The software used for programming was MATLAB. This software is simple and powerful. MATLAB has also a graphical interface, which was very useful for our oscilloscope's user interface creation. The only inconvenience is that MATLAB has only Windows style controls, like sliders, buttons, check boxes and radio buttons. When, for example, a TIME/DIV. dial is needed, we had to use slider, not so suggestive, but functional.

Maybe for a better user interface some National Instrument's software can be more convenient, like LabVIEW, LabWindows/CVI or Measurement Studio for Visual Studio, because these software packages have dials, LEDs, graphs and other controls and indicators which look like the ones on electronic equipments.

MATLAB has its own advantages too. The thing that is very useful in MATLAB graphical interface is that any change on button makes change immediately a change in the MATLAB *.m code file. No need for generate callbacks like in other programming languages like Visual Studio or LabWindows/CVI. This can be very useful when a complicated code is made.

B. MATLAB Graphical Interface

MATLAB graphical interface can be accessed when the "guide" command is introduced at the command prompter.

This command will open a window like the one in Fig. 2. Here the user can drag-and-drop buttons, sliders and other Windows style controls and indicators needed.

In the oscilloscope interface sliders, Push buttons, pop-up menus controls and edit text, axe indicators were used.

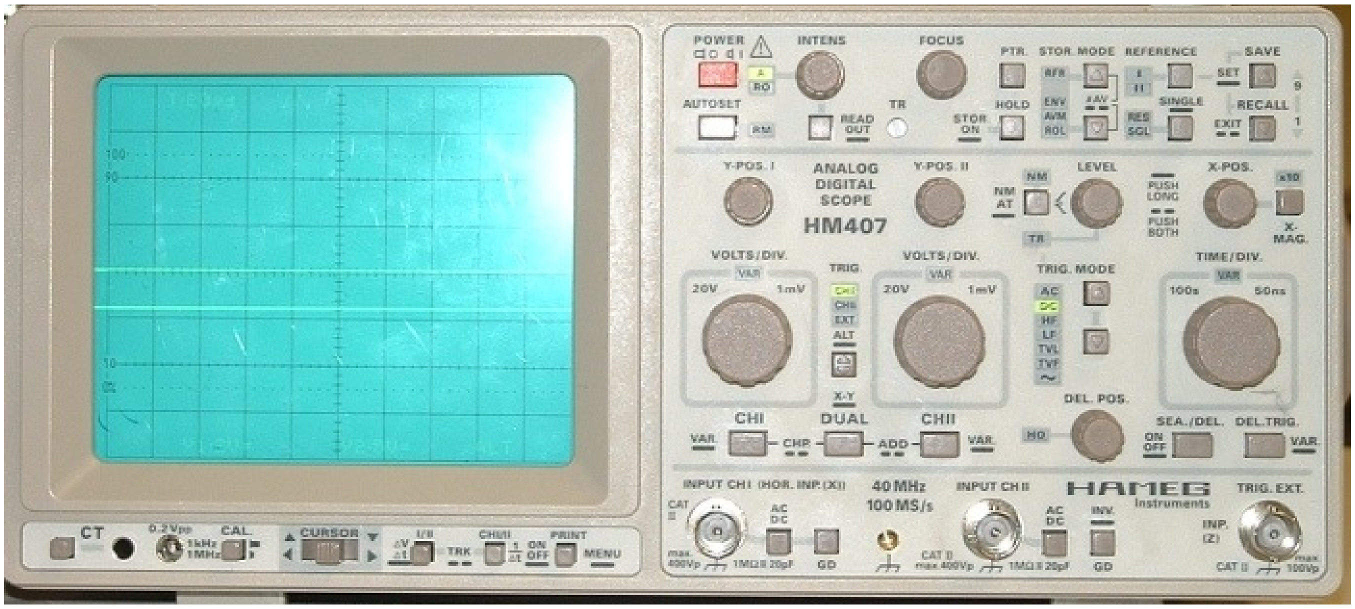


Fig. 1. HAMEG HM 407 oscilloscope's front with display and control buttons.

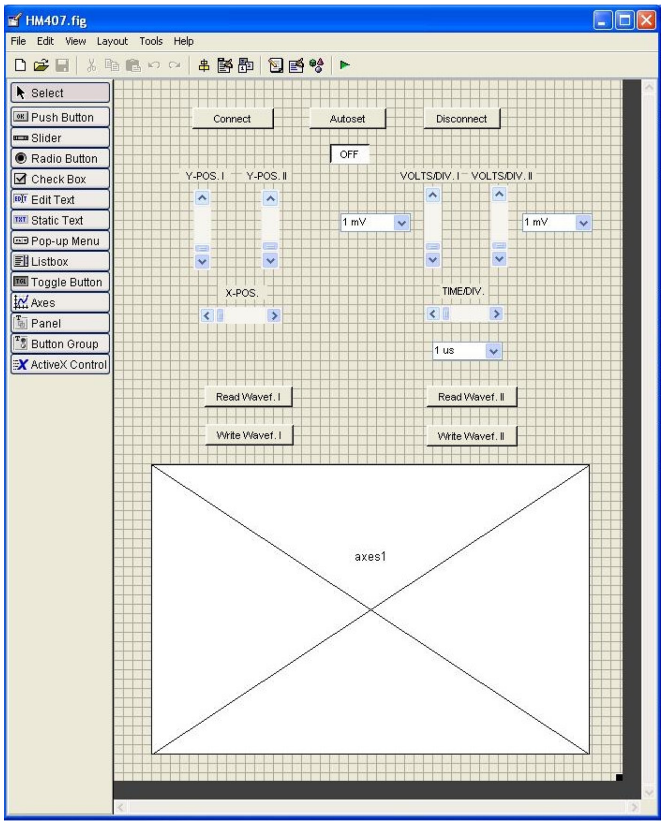


Fig. 2. Front panel creation of the oscilloscope in MATLAB. This window can be accessed when the "guide" command is introduced to the command prompter.

As we can see we have a Connect button for connecting the computer to the oscilloscope. This buttons sends the command, which puts the equipment in remote mode. During this time, the physical buttons from the oscilloscope are not functional, it pressed they make an error beep. An LED indicator on the oscilloscope indicates that the equipment is in remote mode and can be commanded just with a computer. On the graphical interface the status of the oscilloscope is shown with and edit text indicator, where the information ON or OFF is shown, depending on the state of the oscilloscope (remote or local).

To return to local mode, the Autoset button from the oscilloscope need to be pushed for a few seconds and the oscilloscope will return in local mode. The Autoset button's secondary function is returning the oscilloscope in local mode. After this operation the oscilloscope will not be commanded eth the PC, just with the buttons physically present on the equipment and the remote LED will be turned off. To return the oscilloscope in local mode, the disconnect button from the computer interface can be used too.

The Autoset button from the user interface has the same effect as the Autoset button physically present on the oscilloscope; it sets the Time/DIV and Volt/DIV parameters most optimal to the acquisitioned signal.

For setting the horizontal (X-POS.) and vertical (Y-POS. I and Y-POS. II) positions of the signal, sliders were used. Here a little trick need to be used, because for positive vertical position was one command and for negative vertical position was another command, but only one slider was used, so the two commands needed to be merged in one.

For setting the timebase (TIME/DIV.) and the amplitude (VOLTS/DIV. I and VOLTS/DIV.), also sliders were used. Because sliders, were fuzzy, a more accurate solution was needed, to set exactly the timebase and the amplitude, this way pop-up menus were used. For timebase between 1 µs/DIV. and 0,5 s/DIV., for amplitude between 1 mV/DIV. and 20 V/DIV. The values can be set exactly. For the timebase and amplitude, both controls are functional, for exact and for fuzzy setting of the signal.

For saving the signal form the oscilloscope two buttons are used Read Wavef. I (for CH I) and Read. Wavef. II (for CH II). The signal will be shown on the axe. The acquisitioned signal has 256 samples (256 points), for larger signals more samples need to be combined. The serial interface has a buffer of 512 samples.

For writing a saved waveform from the computer to the oscilloscope, the Write Wavef. I and Write Wavef. II buttons were used. The oscilloscope has two memories and this way it can memorize to signals. The signals are saved in a text file (signal.txt) as points. This can be used for saving each signal from each channel to the computer, make some signal processing and after that send it back to the equipment. In the signal.txt file also is a signal with 256 samples (256 points). Here also a little trick is needed to make it work, the oscilloscope need to be put in STOR. MODE, so the REF bit has to be put on “1” logic by software, otherwise it will not work. This is very important to be done, because otherwise if the REF bit is not activated manually on the oscilloscope, the saving of a signal will not work and an error beep will be received.

C. *The Code behind the buttons*

In this section the code behind the buttons is explained.

Every SCPI command needs to be ended with carriage return (CR, 0D*h* or 13*d*). There are exceptions too, some of them needs only CR and other CR and LF, depends on the SCPI command.

TABLE I shows the used SCPI commands.

TABLE I
USED SCPI COMMANDS

Command	Description
AUTOSET	***AUTO SET*** function will be carried out
YzPOS=w	Sets ***Y 1/2 POS***ITION settings
XPOS=w	Sets ***X-POS***ITION settings
CHz=b	Sets ***CH1/2*** settings (like amplitude)
TBA=b	Sets ***T***IME***B***ASE ***A/B*** settings
STRMODE=b	Delivers ***STOR***E ***MODE***
RDWFMz:ww	***R***EAD ***W***AVE ***F***O***RM*** **1/2**
WRREFz:ww	***WR***ITE ***REF***ERENZ ***1/2***
RM0	Exit ***RE***MOTE mode

The functions used for write and read data from the serial port are *fwrite* and *fread*.

For example the Autoset button has the following code:

```
function autos_Callback(hObject,
eventdata, handles)
  cmdb=double('AUTOSET');
  b=[13 10];
  fwrite(handles.obj1,[cmdb b]);
  b1=fread(handles.obj1,3);
```

Every button has similar code to this example, *obj1* is set to COM1, the first serial port installed on the computer, but it can be set to any COM port desired with the following command:

```
handles.obj1=serial('COM1');
```

The information is sent decimal. Comments are generated automatically by MATLAB, which can be cleared. Here the SCPI command is: *AUTOSET*. The command need to be ended with carriage return (CR, 0D*h* or 13*d*) and line feed (LF 0A*h* or 10*d*) too. The *AUTOSET* command is concatenated with the carriage return and line feed bits. The number 3from the *fread* function is the number of bits read.

Modifying this function we can make the functions for all buttons, just by reading the specific SCPI command from datasheet and being attentive to some bits.

The Connect button has a similar function, but no SCPI commands are used, only sending the 20*h* (32*d*) and the CR termination character. The serial port is opened with the *fopen* and closed with *fclose* functions and set to its default values: baud rate: 9600, data bits: 8, parity: none, stop bits: 1, flow control: none:

```
fopen(handles.obj1);
...
fclose(handles.obj1);
```

The serial port is activated with the following command:

```
set(handles.obj1,'FlowControl','hardware
');
```

The ON/OFF indicator is commanded, where needed, with the following commands:

```
set(handles.sts, 'String', 'ON');
...
set(handles.sts, 'String', 'OFF');
```

Where *sts* is the indicator’s identifier and *String* is the parameter that is changed and after that is the value: *ON* or *OFF*. With this command almost every parameter can be changed, like size or position.

The whole initialization program is the following:

```
function HM407_OpeningFcn(hObject,
eventdata, handles, varargin)
  handles.obj1=serial('COM1');
  handles.output = hObject;
  guidata(hObject, handles);

function varargout =
HM407_OutputFcn(hObject, eventdata,
handles)
  varargout{1} = handles.output;

function axes1_CreateFcn(hObject,
eventdata, handles)

function con_Callback(hObject,
eventdata, handles)
  fopen(handles.obj1);
  set(handles.obj1,'FlowControl','hardwa
re');
  a=[32 13];
  fwrite(handles.obj1,a);
  a1=fread(handles.obj1,3);
  set(handles.sts, 'String', 'ON');
```

The Disconnect button is made similar, but it uses the *RM0* (remote 0) SCPI command and the serial port is closed with the *fclose* function:

```
function discon_Callback(hObject,
eventdata, handles)
  cmdz=double('RM0');
  z=[13 10];
  fwrite(handles.obj1,[cmdz z]);
  z1=fread(handles.obj1,3);
  set(handles.sts, 'String', 'OFF');
  fclose(handles.obj1);
```

For the horizontal position setting first we read the value of the slider with the following command:

```
yp1=get(hObject,'Value');
```

Then we use the *YzPOS=w* SCPI command, where *z* is the number of channel, *1*or *2* and *w* is the distance in word. The only problem is that the oscilloscope is like a coordinate system and it has positive and negative position. The goal was to change the position with only one button, so a little trick was needed.

The program that does the trick is the following:

```
function ypos1_Callback(hObject,
eventdata, handles)
  yp1=get(hObject,'Value');
  cmdc=double('Y1POS=');
  if (yp1>15)
    cyp1=yp1-15;
  end
  if (yp1<=15)
    cyp1=yp1+240;
  end
  c=[160 cyp1 13];
  fwrite(handles.obj1,[cmdc c]);
  c1=fread(handles.obj1,3);
```

As we can see the program is similar, but with *if* statement insertion. The whole idea is that the information that we have to send is 16 bits long, so we need two decimal numbers. The slider is set to the value of 15 and the minimum value to 0 and maximum to 30.

The whole screen height is FF0*h* (4080*d*), the inserted string is the LF (0A*h*), so this way we have FF0A*h*. We split the word in two bytes and get FF*h* and 0A*h*, we reverse them and get FF*h* (255*d*) and A0*h* (160*d*), and these need to be sent in reversed orders.

With the implemented algorithm we will be able to change the vertical position in brute values (changing the MSB). In binary the positive values for the second byte are between 00000000*b* – 00001111*b* (00*h* – 0F*h*, 0*d* – 15*d*) and the negative values between 11110000 – 11111111 (F0*h* – FF*h*, 240*d* – 255*d*), the negative values are in the complement of 2, so the lowest value is FF*h* (255*d*) and the highest is F0*h* (240*d*).

A same program can be made to the channel 2, but using *Y2POS=w* SCPI command and for horizontal position with the *XPOS=w* SCPI command.

For the amplitude the used SCPI command is *CHz=b*, where *z* in the number of channel, *1* or *2* and *b* is the value in byte. There are 4 bytes for other settings to the channel and 4 bytes for setting the amplitude. D7 = GND, D6 = AC, D5 = INV, D4 = ON, D4 ÷ D0 are the setting for amplitude between 0000*b* – 1101*b* (0*d* – 13*d*). All bits can be “0” logic, but the ON bit must be at “1” logic, so the number we need to send are between 10000*b* – 11101*b* (16*d* – 29*d*). This way the slider’s value is set to 22 and the minimum value to 16 and the maximum value to 28.

The same thing can be made for the channel 2, but with the *CH2=b* SCPI command and a similar function will work for the timebase, but with the *TBA=b* SCPI command, where *A* is the A timebase, because this model has no B timebase.

The program for the amplitude is the following:

```
function vdiv1_Callback(hObject,
eventdata, handles)
  vold1=get(hObject,'Value');
  cmdf=double('CH1=');
  f=[round(vold1) 13];
  fwrite(handles.obj1,[cmdf f]);
  f1=fread(handles.obj1,3);
```

The program for the timebase is the following:

```
function tdiv_Callback(hObject,
eventdata, handles)
  timed=get(hObject,'Value');
  cmdh=double('TBA=');
  h=[round(timed) 13];
  fwrite(handles.obj1,[cmdh h]);
  h1=fread(handles.obj1,3);
```

For pop-up menu the programming is a little more complicated, because we ne exact amplitude and timebase. For amplitude, we have 14 values between 1 mV/DIV. and 20 V/DIV, this way 1 mV/DIV. means 1, but we need to send 16, and 20 V/DIV. means 14, but we need to send 29, so we have to add 15 to every value. Same thing for TIME/DIV. but we have 26, values between 1 µs/DIV. and 0,5 s/DIV., so we need to add 3 to every value.

Maybe a little more complicated is the reading of the waveforms, the used SCPI command is *RDWFMz:ww*, where *z* is the number of channels, *1* or *2* and the first *w* word is the offset and the second is the length. The offset we will set to 0, so the first two bytes are 00*h* and 00*h*. The length we will set to 256 samples (256 points), the serial has a 512 sample buffer. 256 = 0100*h*, we split the word in two bytes and we get 01*h* and 00*h*, after all we need to send it in reversed order, so 00*h* and 01*h*. All the numbers from the offset and length in reversed order, in decimal and with CR termination character is: 0 0 0 1 13.

Where we plot the information from the 12th sample, because these samples in the start are information about the waveform, but the waveform data starts from 12 and ends at 267.

For this signal acquisition to work we have to be careful with the STOR. MODE bits using the *STRMODE=b* SCPI command. D7 = REF2, D6 = REF1, D5 ÷ D3 = PRE TRIGGER (011 = 0%) and D2÷D1 STOR MODE (000 = REF). This way for signal acquisition we need no reference memory, so we have 11000*b* (24*d*), for sending signals to reference memory 1 we will have 1011000*b* (88*d*) and for reference memory 2 we will have 10011000*b* (152*d*). This way we don't need to push the reference button manually all the time and stop the program.

After it we need to lot de received data to the axe, so the program section will be:

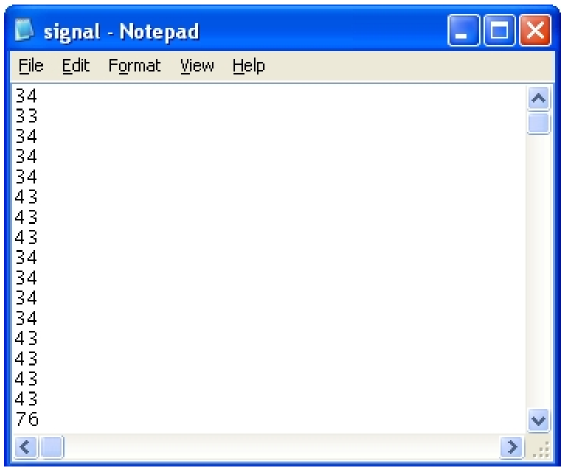
```
function rdwfl_Callback(hObject,
eventdata, handles)
  cmdi=double('STRMODE=');
  i=[16 13];
  fwrite(handles.obj1,[cmdi i]);
  i1=fread(handles.obj1,3);
  cmdj=double('RDWFM1:');
  j=[0 0 0 1 13];
  fwrite(handles.obj1,[cmdj j]);
  j1=fread(handles.obj1,267);
  l=1;
  for k=12:267
    V(l)=j1(k);
    l=l+1;
  end
  plot(V)
```

For writing a signal to the memory is quite similar to reading it. The used SCPI command is *WRREFz:ww*, where *z* is the number of channels, *1* or *2* and the first *w* word is the offset and the second is the length. The signal is written by some numbers in one colon in the signal.txt file.

The function should be the following:

```
function wtwfl_Callback(hObject,
eventdata, handles)
  cmdm=double('STRMODE=');
  m=[88 13];
  fwrite(handles.obj1,[cmdm m]);
  m1=fread(handles.obj1,3);
  load signal.txt -ascii;
  cmdn=double('WRREF1:');
  n=[0 4 0 1 signal' 13];
  fwrite(handles.obj1,[cmdn n]);
  n1=fread(handles.obj1,3);
```

The signal it's transposed with *signal'*, it is more simple to write values in a colon in a *.txt file than in a row. The file must contain exactly 256 values (Fig. 3.).



```
34
33
34
34
34
43
43
43
34
34
34
34
43
43
43
43
76
```

Fig. 3. The signal.txt file with some random numbers forming a random signal.

IV. Conclusion

These days the instruments have simple SCPI commands, where no need for binary calculation is. Some instrument's vendors provide even drivers, where some functions gather the SCPI commands with the binary values and the user just calls the functions and enter decimal values.

As we saw almost any instrument can be programmed as the user wants and in any programming language. The datasheet needs to be analyzed well and with a little binary calculation and some programming trick almost everything can be done.

The goal was achieved. We wanted to program an instrument and we needed some functions that are not possible without a computer, like signal sending to the oscilloscope or saving from it.

Further enhancements would be to make a button for every setting on the oscilloscope, maybe try program it in other programming language, like C, and make an official driver with all function of the oscilloscope, so this way programmers will not have to do so many binary calculations and read all the datasheets.

The whole idea of this oscilloscope programming is that we wanted to see if we are capable of programming an oscilloscope with complicated SCPI commands with binary calculations. With this knowledge now we are capable communicating with almost any equipment. It's an old equipment, but it still needs to be connected to the computer and it still needed to be programmed. As mentioned in the introduction these older equipments are still needed. On the other hand, somebody needs to make drivers for the instruments for simpler programming. This paper's goal is to show how to interpret the SCPI commands and this way to make an instrument driver. This paper is just an example how to program more complicated instruments. With this knowledge we hope that the communication with instruments will not be a problem.

In Fig. 4. we can see the graphical user interface running and acquisitioning a square waveform.

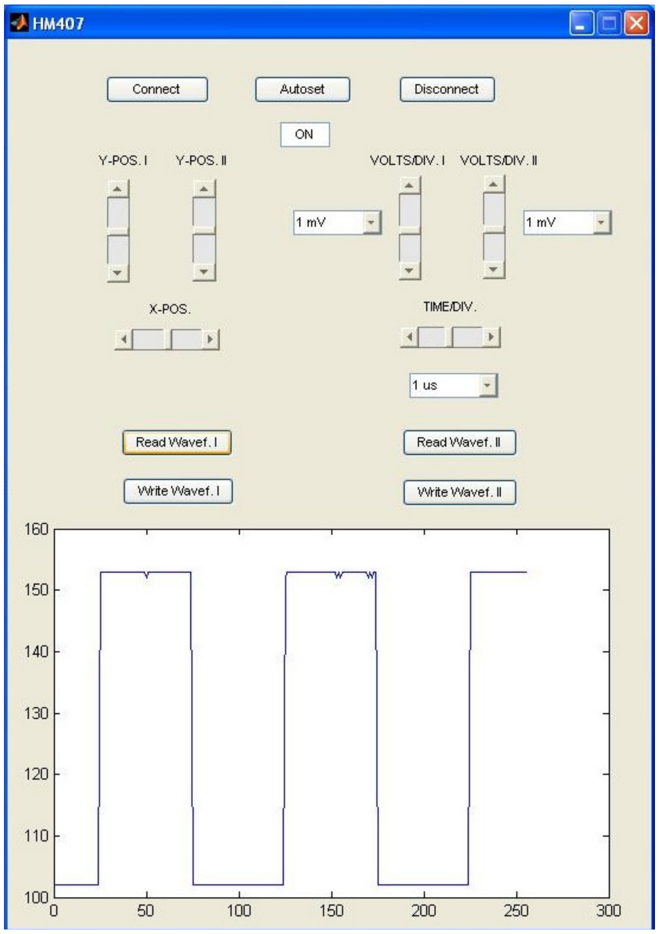


Fig. 4. The graphical user interface for the HAMEG HM 407oscilloscope running when acquisitioning a square signal.

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