VIRTUAL INSTRUMENT FOR MICROELECTRONIC DEVICE CHARACTERIZATION

Khyale S. N. - khyale@ee.ufpe.br
Edval J. P. Santos - edval@ee.ufpe.br

Laboratório de Dispositivos e Nanoestruturas - LDN
Departamento de Eletrônica e Sistemas, Universidade Federal de Pernambuco
CEP: 50670-000, Caixa Postal 7800, Recife - PE, Brasil.

Abstract : *We describe a PC-based system to generate arbitrary waveforms, designed and built in our lab, and how to use it for device characterization. This system, also called virtual instrument, is composed by a computer, a PLD-based board and graphical interface. One can create and edit waveforms, such as: exponentials, sinusoidal, ramp, staircase and others periodic signals. As an example of application, we use it for plotting I x V curves of a power MOSFET.*

Key-words*: arbitrary waveform generator, virtual instrument and device characterization.*

INTRODUCTION

In many situations, one needs to generate signals with specific frequency, amplitude and format. Such signals can be used to probe the behavior of entire circuits or single devices to answering questions on signal transfer characteristics, linearity, harmonic distortion, delays, I x V characteristics, frequency response and so on. Basically, there are two ways to generate periodic signals. The first one utilizes analog oscillators to generate square, sinusoidal and triangular waves. The other utilizes digital signal processing, where one stores discrete samples of the signal and reconstruct it using a digital-to-analog converter. This paper describes a digital waveform generator designed and built in our lab (1) and its application in device characterization. This board was used to generate waveforms with third harmonic content (2).

The traditional waveform generator equipment has few pre-defined waveforms and the user has no control over their formats. With the digital approach, an arbitrary waveform generator can be built. Such generator allows the user to create his waveforms, such as: triangular, ramp, exponentials, staircase, and others. For example, to obtain I x V curves, one needs a ramp and a staircase waveform. To create a new waveform, the user utilizes the graphical interface to define the amplitude, frequency and format. All these parameters are downloaded to the waveform generator board and stored in the RAM chip. The DA converter is used to reconstruct the desired signal, under control of a programmable logic device (PLD). In Figure 1, a staircase waveform created by the board is presented; the waveform has been captured with an HP54602B scope.

This paper is divided in four parts. The first part describes the waveform generator board. In the second part, we shall see some aspects of the software or graphical interface that controls the board. The third part shows how this system can used to get I x V curves of a power MOSFET. In the end, we have the conclusions.

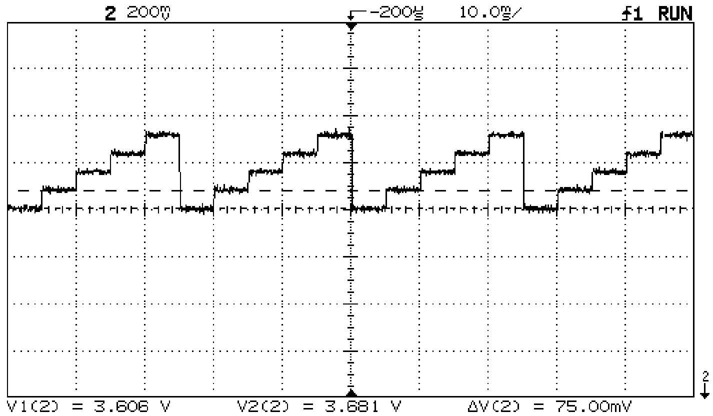

Figure 1. Staircase waveform

WAVEFORM GENERATOR BOARD

The arbitrary generator board was layed out and soldered at the Laboratory for Devices and Nanostructures (LDN/UFPE), it has a high speed 12-bit D/A converter, a 32k bytes of SRAM and a PLD chip. These features allow creating waveforms with maximum amplitude of 10V p-p and frequencies up to 100 kHz. The output impedance is 50 ohm and the maximum output current is 100mA. The PLD chip is programmed using the AHDL language. In Figure 2, the block diagram of the circuit is presented. The board interface is ISA.

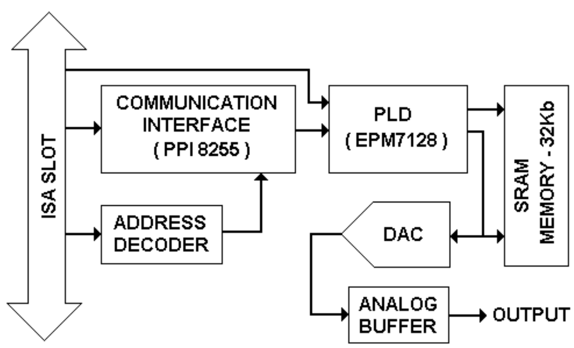

Figure 2. Waveform generator board

The generator board accepts two sources of clock that can be configured by software. The default source is the ISA bus clock signal (14.318 MHz). If more than one generator boards are used, and is necessary to synchronize them. One can make use of an external clock.

GRAPHICAL INTERFACE

The graphical interface is written in Delphi's *Object Pascal* language and runs under Windows 9x. Others languages (e.g. C, BASIC) and operating systems could be used. One uses some objects, like buttons and virtual knobs to vary amplitude, frequency and format of the desired signal. With this program, the user can "draw" waveforms and configure the waveform generator board. As an example, the following instructions create a sinusoidal waveform with amplitude of 5Vp-p, frequency of 1 kHz and 100 points.

```
VAR
  seno:TSINAL;  // we already created a TSINAL object
  i: integer;
BEGIN
  seno.frequencia:=1e3; // frequency = 1kHz
  seno.num_pontos:=100; // number of points per period =100
  for i:=0 to seno.num_pontos -1 do
        seno.amostra[i]:=5*sin(2*pi*i/100);  // store samples of signal
  seno.grava_amostras; // download samples and other parameters in the board
  ...
END;
```

GETTING I X V CURVES OF A POWER MOSFET

An important application of the arbitrary waveform generator is in device characterization. Although, there are commercial solutions, they are very expensive. In some situations, e.g., an undergraduate lab, one needs to make simple measurements to get parameters and observe the behavior of electronic devices under excitation. For this application, this digital generator, which costs less than US$ 150, can be used. In Figure 2, the experimental arrangement used for plotting ID x VDS curve of a power MOSFET (IRF 840) is presented.

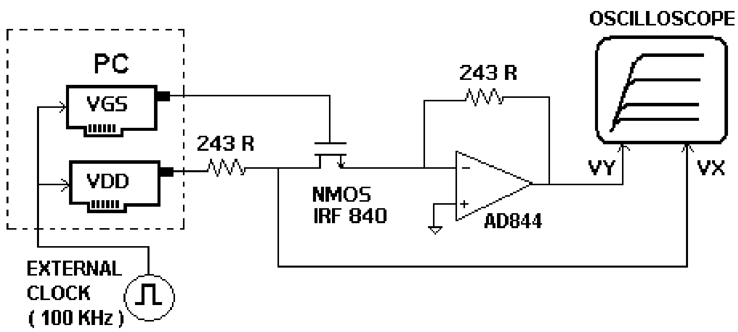

Figure 2. Plotting ID x VD curve

One board generates the 0-10V ramp signal (VDD) and other generates a staircase signal (VGS in Figure 1) which varies from 3.6 to 4 V, with 80mV step. Both signals are synchronized by an external clock. The drain current (IDS) is converted to a voltage and sent to Y channel of the digital scope HP54602B. The scope in XY mode can be used to display the ID x VDS curve, as shown in Figure 3.

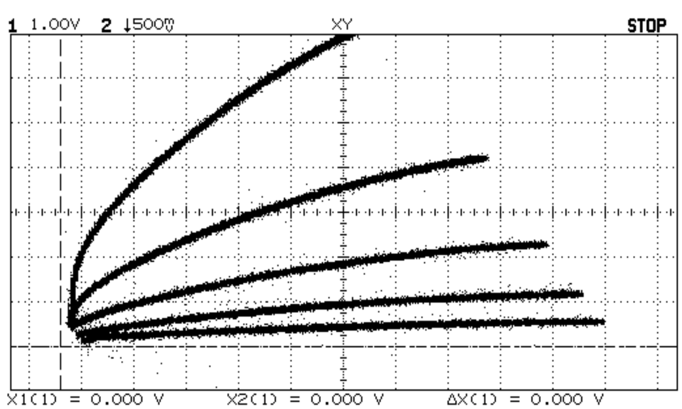

Figure 3. ID x VDS curve

With the same apparatus shown in Figure 2, one can obtain the ID x VGS curve (see Figure 4). In this case, a 3 - 4V ramp signal is applied to the VGS input and VDS = 10V.

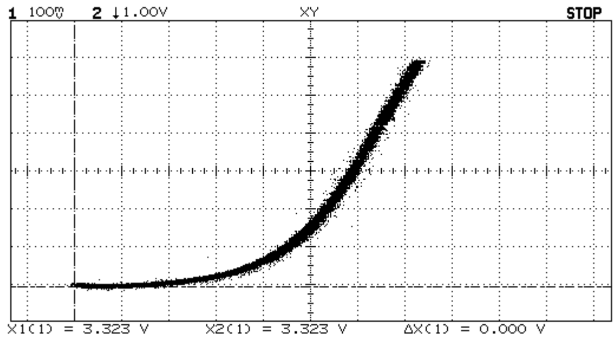

Figure 4. ID x VGS curve

The curves can be used to extract parameters of the device, such as: threshold voltage, transconductance, etc.

CONCLUSIONS

Using the arbitrary waveform generator designed and built in our lab, the required signals to plot ID x VDS and ID x VGS curves are generated. The result is captured with an HP54602B scope. The next step is to redesign the board for the PCI-bus. The board is low cost and can be used in undergraduate labs.

ACKNOWLEDGMENTS

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