IMPLEMENTATIONS FOR A VIRTUAL ELECTRONICS LABORATORY

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1. Introduction

Modern education is more distributed and less time and space restrictive. Engineering seems to be one of the last domains to be reluctant to distance learning, due to a great number of hours that have to be spent in laboratories. The present paper presents a virtual electronic devices laboratory, that can be remotely accessed by Internet. The student can extract a circuit's characteristic or the whole family of a transistor's curves, with the possibility to detail a specific segment or regime. An interactive lesson can be delivered to students in a lecture theatre, accessing a remote laboratory.

2. Laboratory equipment and local operation

The configuration used was one of four automated measuring centres of our Electronics and Computers Department, each of them coordinated by an IBM-PC compatible computer (with HAMEG – HO80 – IEEE488 card) in a local GPIB network. Each configuration includes:

- Digital Multimeter - Hewlett Packard HP34401A (with built-in IEEE488 interface)
- Power Supply – HAMEG - HM8442 (with HO88 - IEEE488 interface)
- Function Generator - HAMEG - HM8131 (with HO88 - IEEE488 interface)
- RF Synthesised Generator - HAMEG - HM8133 (with HO88 - IEEE488 interface)
- Digital Oscilloscope - HAMEG – HM1007 (with HO79 - IEEE488, RS232 and Centronics interface)

To illustrate the operative programming mode, one of the simplest (QBASIC) examples is given for a curve tracer of Zener diodes in the measuring circuit of fig. 1.

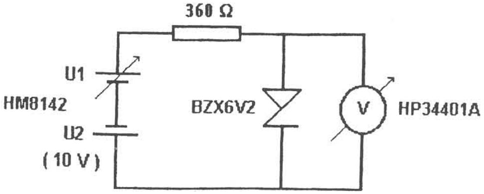


Fig. 1- Simple configuration for automated characterisation of a Zener diode

The short program of the automated measurement is:

```
DEF SEG = &HDE00
CALL ABSOLUTE(21, 0, 0)
VOLTAGE$ = SPACE$(20)
OPEN "VZD.PRN" FOR OUTPUT AS #1
CALL ABSOLUTE(4, "SU2 10", STATE%, 36)
FOR K = 0 TO 100
CALL ABSOLUTE(4, "SU1" + STR$(K * .15), STATE%, 36)
CALL ABSOLUTE(22, "MEASure:VOLTage:DC? 10V, .01mV", STATE%, 36)
CALL ABSOLUTE(VOLTAGE$, LENGTH%, 22, STATE%, 39)
WRITE #1, VAL(VOLTAGE$)
NEXT K
END
```

The subroutines belong to HAMEG – GPIB dedicated USER.LIB library and every call has at its last parameter the number of the subroutine (0 for "initialisation" subroutine, 36 and 39 for "write to- / read from- instrument" subroutine etc.). DE00h is the (configurable) beginning address HO80 memory. "Initialisation" and "write to instrument" subroutines have, as their first parameter, the address of the instrument (0 for the coordinating PC, 4 for the power supply and 22 for the multimeter). The second parameter of the "write to instrument" subroutine is the ASCII string of the dedicated instructions (e.g., for K = 10, the power supply receives a instruction specific to the set of HM8152, "SU1 1.5" that Sets U1 to 1.5 V). The third parameter, found in the same position in "read from instrument" instructions as well, is a numeric variable into which the state of the instrument is read, for operative diagnosis and, eventually, halt with error messages display. "Read from instrument" instruction have slightly different syntax: in the 1st position, the name of the alphanumeric variable into which the measured value is read, than the numeric variable into which is read the length of this value and, in median position, instrument's address.

For the current(voltage) characteristic, the measured VZD (written in an exterior .PRN file, to be introduced in a simple MathSoft MathCAD™ processing) is used to compute also the voltage over the serial resistor [the potential of the input node is known to be ($K \cdot 0.15$ V – 10 V)], than, dividing with resistor's value, the current. The tiny and efficient MathCAD program is presented in fig. 2

$$K := 0 .. 100$$

$$VDZ := READPRN(VDZ)$$

$$ID_K := \frac{-10 + K \cdot .15 - VDZ_K}{360}$$

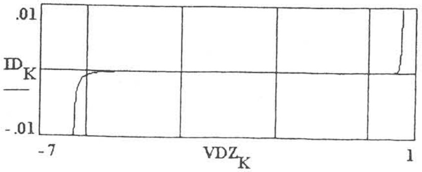
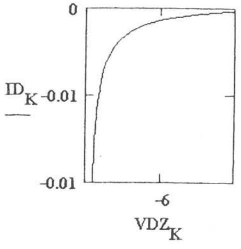


Fig. 2.a – MathCAD "curve-tracer". There are obvious the two zones of simple diode behaviour (aprox. 0.7 V in conduction) and the Zener zone, around 6.2 V.

The automated measurement has, besides the primordial features of speed and precision, the advantages of no subjective (human) errors and of computer-aided mathematical post-processing capabilities. In our simple example, there is, for instance, the possibility of further details – fig. 2.b and 2.c.



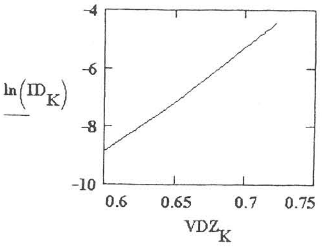


Fig. 2.b – details of non-destructive Zener breakdown regime, with posibilities to compute the slope (g_z), giving r_z , the dynamic resistance of the Zener diode etc.

Fig. 2.c – details of direct conduction area, where $ID \approx I_0 \cdot \exp\left(\frac{\gamma \cdot VZD}{kT/q}\right)$ so the logarithmic representation allows (extending the resulting segment to VZD = 0) experimental determination of γ parameter etc.

3. Virtual test bench integration

One of the most important advantages of modern computer-controlled measurement systems is the possibility of data tele-transmission, processing and recording. The authors completed the above-mentioned configuration with an Internet extension and integrated a virtual test bench driven by National Instruments - LabView™ (via a PCI-GPIB card).

The "distance learning lab" can be opened at scheduled time (the beginning hour of "virtual laboratory session").

The lab-computer runs, in LabView, the virtual instrument called "Remote VI Server.VI", whose panel is presented in fig. 3:

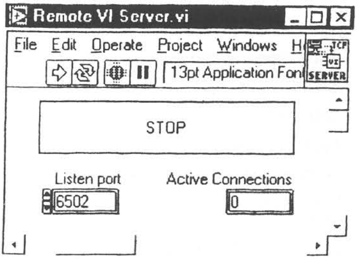


Fig. 3 – Panel of "Remote VI Server.VI", started in the laboratory, in "continous run" mode.

HP34401A is configured a-priori to measure DC voltage or given the specific MEAS:VOLT:DC? command by pre-load of LABOR.VI, the local coordinating VI. The panel of this lab-VI is presented in fig. 4.

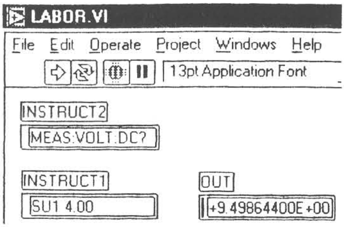


Fig. 4 – Panel of LABOR.VI, enabling also the monitoring of remote commands, sent by the student, (INSTRUCT1) and of the voltmeter's output.

Fig. 5 presents the diagram of LABOR.VI, visually programmed in the "Sequence Mode", to force the order of execution, as appropriate for GPIB configurations.

As obvious, the first two "frames" of the VI's "film" include "GPIB Write" blocks, with two alphanumeric inputs, one for the address and the other one for the instructions to be sent to the instrument (4 and, respectively, INSTRUCT1 for the power supply, 22 and INSTRUCT2 for the multimeter).

The third frame includes a "GPIB Read" block, with the same address input, 22, for the multimeter and an alphanumeric output, OUT, for the measured value. Its length is trimmed to 16 characters, by the corresponding numeric input.

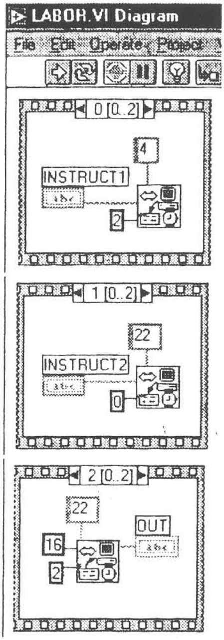


Fig. 5 – diagram of LABOR.VI Diagram – "sequence frames" containing GPIB Write / Read blocks

The user's- (student's-) computer runs (in LabView as well) STUDENT.VI. Its panel (presented in fig. 6) enables the specification of TCPIP parameters, of the name of the lab VI (LABOR.VI in our case) and displays the measured value brought from the remote laboratory.

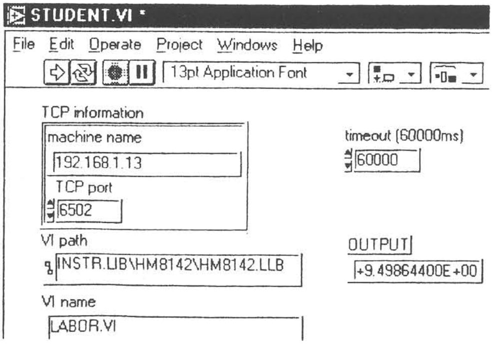


Fig. 6 – panel of STUDENT.VI

As written in the concrete panel in fig. 6, the TCPIP parameters were, in authors' experiment: the address of the lab PC (192.168.1.13), port's number (6502), VI's path in LabVIEW directory of lab PC (INSTR.LIB\HM8142\HM8142.LLB).

Fig. 7 displays the diagram of STUDENT.VI, built in a FOR (i = 1 to N) structure (in the present example, N=105) around a "Call TCP Server" sub-VI with the input of all above mentioned parameters, introduced from the panel. The call transmits via Internet, by a "Read from File" block, instructions for the laboratory equipment, taken from an external file, prepared by the student (D:\INPUT.TXT, in this example) and brings the outputs of the instruments, into a file on the student's computer (D:\OUTPUT.TXT), by a "Write in File" block. Reading from the file is done sequentially, from the line i (with i = 1 to N), a specified number of characters at a time (11 in the example). Data are mainly alphanumeric and their matrix or cluster structure is flattened and un-flattened into strings that are marked with labels that must correspond exactly with those in LABOR.VI ("INSTRUCT1" and "OUT" in our case).

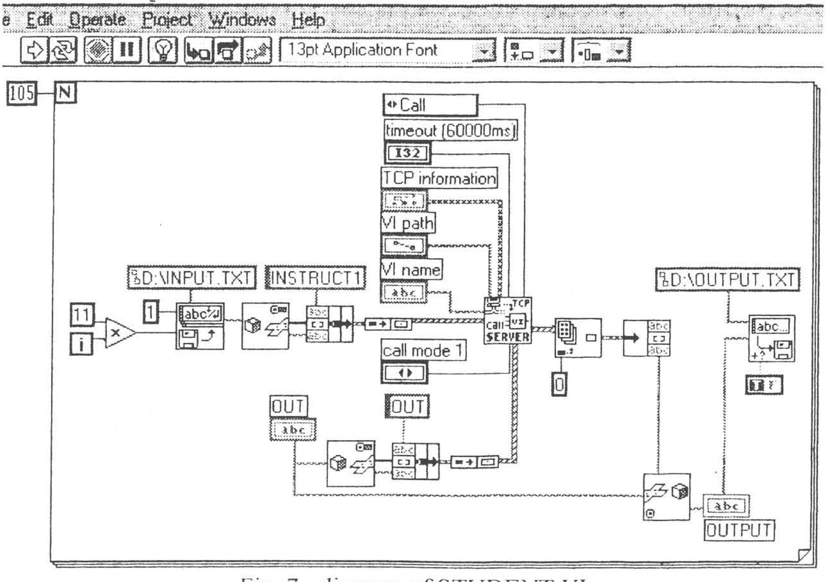


Fig. 7 - diagram of STUDENT.VI

The full operability of authors' experiment is illustrated by the study of a FET-J-n, in the lab configuration of fig. 8:

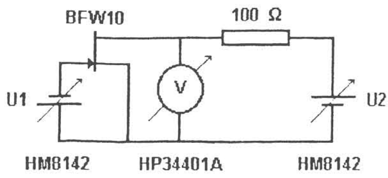


Fig.8 – Circuit for FET characterisation

Fig. 9 presents the structure of D:\INPUT.TXT, containing programming instructions for HM8142, setting U1 (= - U_{GS}) = = 0 ; 1 ; 2 ; 3 ; 4 V. For each value of U1, there are set 20 values of U2 (= 0 ; 0.5 ; 1 ... 9.5 V). The measured values of U_{DS}, arriving from LABOR.VI are gathered in D:\OUTPUT (or directly into UDS.PRN, to be post-processed with MathCAD) by STUDENT.VI.

Fig. 10 presents the mathematical post-processing of the experimental data, with the same principles described in the Zener diode example. The student can detail a zone by re-programming finer measurements (e.g. to emphasise the parabolic zones) or wider curves [e.g. to compute the convergence point (on the horizontal axis, ID = 0) of the saturation obliques (corresponding to the Early point of bipolar transistors) or g_d, their averaged slope]. Interpolation and spline graphic representation, as well as statistical processing is offered also by the math software.

```
SU1 0.00
SU2 0.00
SU2 0.50
SU2 1.00
SU2 1.50
:
SU2 9.50
SU1 1.00
SU2 0.00
SU2 0.50
:
SU1 4.00
SU2 0.00
:
SU2 9.50
```

Fig. 9 - structure of D:\INPUT.TXT

$k := 0..99$

$UDS := READPRN(UDS)$

$ID_k := mod(k,20) \cdot .5 - UDS_k$

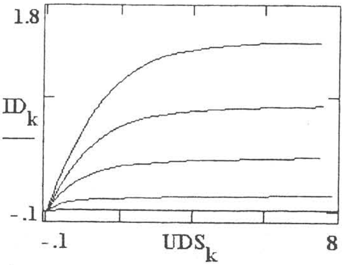


Fig. 10 – MathCAD post-processing for the FET characterisation experiment

LabView enables also queue management (usually considering equal rights for the distance learning students, then simple chronological priorities).

Other alternatives to LabVIEW (that could be considered too expensive for the student's PC) are specific "Component Works" (offered also by National Instruments) - adapted to his preferred programming language [e.g. Pascal, C, (Visual) Basic] or even Unix interfacing (with LabVIEW) at the lab's node (where the student has an own account).

Further development of the mentioned facilities could be tutor's assistance in the lab, completing LABOR.VI with a record of students' commands.

Basic references

1. National Instruments–LabView–User Manual & Reference Manual-1998
2. HAMEG GmbH – HM8142 Power Supply - Manual – 1996
3. Hewlett-Packard – HP34401A Multimeter – Handbook - 1997