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Design And Implementation Of An Automatic Measurement System For The Characterization Of Power MOSFETs

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Abstract- In this paper the design and implementation of an automatic measurement system for the characterization of power MOSFETs is described. Such system allows to obtain a complete characterization of the MOSFET regardless of the final application, totally automated and thus a fast and cheap response to the industrial requests.

I. Introduction

The industrial validation activities aims to establish the fulfill by a component to perform a particular function within an equipment through the analysis of the characteristic parameters of the component itself. Frequently the characterization of MOSFET transistors in industrial field consist of a test on the component already included in its final context. This procedure has two fundamental problems: first, it is related to the access to the component by the operator; then, the characterization of the device depends of its application and final use. To this aim an automatic measurement system for the MOSFET characterization is proposed in this work. A management of o measurement and a storage of waveforms on a particular database is also possible. Finally a measurement session with the MOSFETs under test placed in a climatic chamber was carried out in order to monitor their behavior in function of the temperature. In this way it is possible to guarantee an adequate selection of the components in order to avoid malfunctioning in the system installed on the field [1,2].

II. An example of manual Mosfet validation process

The procedures for the validation of power MOSFETs can be summarized in the following steps:

- preparation of the circuit containing the device under test (opening of the case, difficult access to the component due to complexity of the circuits .....);
- set-up of the measurement instrumentation according to the operating conditions of the component;
- application of the probes to the Mosfet's terminals, so as to be able to acquire (during the test) the waveforms of drain-source voltage, drain current and gate – source voltage;
- application of the thermal probes to measure temperature;
- circuit supply;
- acquisition through an oscilloscope of the waveforms and calculation of the required characteristic parameters;
- repetition of the previous steps replacing the device under test with other alternative devices;
- comparison of the data of the various components;
- release of a validation report about the device with the best performances.

After the analysis of the above mentioned phases it is possible two main problems: the first concerns the difficulty for the operator to access where the component is located, and the second one is the impossibility to have a characterization of the Mosfets independently by the final product. The above procedure are closely correlated to the application for which the Mosfet is employed therefore they cannot be characterized as general purpose, without considering its future use.
For example, if we need a "validation" in a product where the Mosfet is used in switching configuration, the present validation procedures will provide a comparison parameter in dynamic conditions. If the same Mosfet must be validated considering a functioning in static conditions inside a different product, the parameters of the

previous tests cannot be used again. The operator therefore must carry out a new test set-up of the component in order to obtain values to compare in static conditions. This paper aims to propose an automatic measurement system of validation able to obtain a characterization of the Mosfet independent of the final product.

III. The automatic measurement system

The MOSFETs examined in this work belong to three different construction technologies (DMOS, Cool Mos, HexFet IR) by three different manufacturers, in order to carry out a detailed study of the process of characterization as complete as possible.
The MOSFET parameters monitored by the proposed automatic measurement system were selected on the basis of a preliminary analysis in order to compare the performance of the different construction technologies [3-5]:

- rise time and fall time of the drain-source voltage in the switching configuration;
- ON and OFF delay time;
- the amount of the charge on the gate;
- the amount of charge between gate-source;
- the amount of charge between gate-drain;
- the waveforms relating to the voltage of the gate-source, drain-source an the current I_d;
- the measurement of R_{ds}(on) in function of the temperature;
- the measurement of the R_{ds}(on) in function of the current I_d.

The block diagram of the measurement system (see Figure 1) is composed by a HP 8116A function generator, a HP34401A multimeter, two scanner boards to control the devices under tests (DUT) and a HP6060 electronic load. The whole system is controlled by a PC with LabView software; a program for the management and analysis of data and a program for controlling the transmission of data between the various blocks, based on IEEE488 and RS -232 protocols is implemented.
The scanner board, consisting of seven relays in order to execute multiple measurements, communicates with the PC via an RS-232/RS-485 converter and interfaced with RS-485 protocol, which allows the connection of multiple devices to a single controller.

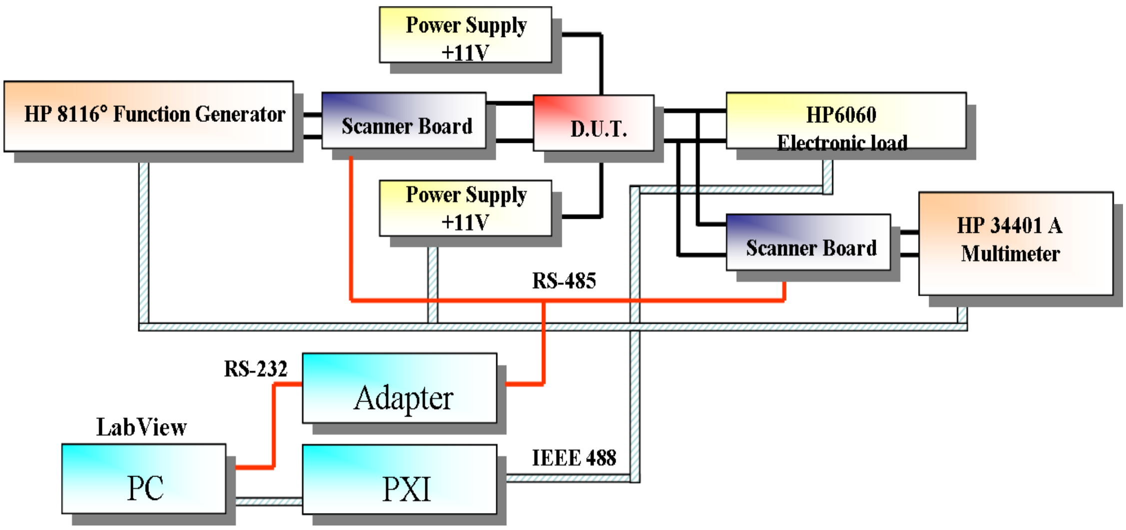

Figure 1 - Block diagram of the automatic measurement system.

The scanner board is composed by 7 relays and it is interfaced with protocol RS-485, which allows the connection of several devices to only one controller and it communicates directly with the PC through an RS-232/RS-485 converter. The control of the transmission is assigned to the microprocessor mounted on the circuit based on an algorithm CRC16. Obviously the receiver must carry out the same operation, in order to detect the presence of transmission errors or faults.
The block PXI (PCI Extensions for Instrumentation) defines a computer platform for measurement and automation systems and it is designed to achieve an increase in performance, functionality and reliability of the automatic instrument for measurement. The PXI modular instrumentation represents the extension of the PCI bus

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(Peripheral Component Interconnect) which is, in fact, the most widely used for hardware and software projects of industrial application for the acquisition of data, tests and measurements.
The driving circuit of the MOSFET has been carried to be able to perform tests on four components simultaneously. Taking into account that the capacitance present between the various electrodes, in particular the C_{gs} between gate and source and the C_{gd} between gate and drain due to Miller effect, leads to an equivalent input capacitance that must be charged and discharged in a short time [6]. Therefore, it is necessary to have a dedicated driver circuits capable to pass, even though for a very short time, high current peak [7], to drive properly the devices under test. Figure 2 shown the electrical scheme of the driver circuit that it is replicated four times one for each device under test.

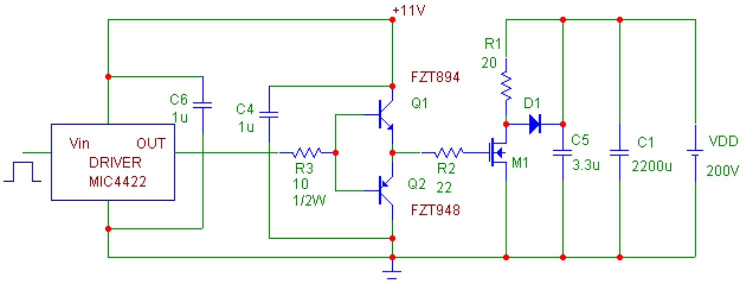

Figure 2 – Electrical scheme of the MOSFET driver circuit

By the introduction of the integrated circuit MIC4422 (non-inverting driver) it was possible to reduce the swicthing times on BJTs Q1 and Q2 which provide the current to the Mosfet using the ability of the driver to charge a test capacitance of 10000 pF at 18V in 50 ns with 3.6A.
In Figure 2, after the driver an “emitter follower ” configuration was necessary in order to have zero output resistance of the driver (driver + emitter follower) making the charge of the equivalent capacitance of the Mosfets independent of initial stage.
Moreover the introduction of two BJTs has the function to adjust, through the value of supply voltage, the level of the gate voltage set to 10V according to the DUTs datasheet.
Besides, this section creates an amplification of current for the following stage and it also has the function to protect against the back currents that the Mosfets produce [6].
Concerning the power section of the circuit, we apply to the drain of the Mosfet a diode STTA1206 with IF current equal to 12A with a recovery time of 28 ns, with an electrolytic capacitor of 3.3 µF connected in series with a power supply to 200V. The diode has the function to clamp possible oscillations on the load caused by disturbances on power supply or to ground returns, defining the measure of the rise time equal to the time voltage employs to go from 10% to 90% of the maximum power supply value and not equal to the maximum value of the peaks that can vary in base of the construction technologies.

In figures 3 and 4 the trends generated automatically by the proposed measurement system of the Rds(on) obtained by three different Mosfets are represented.

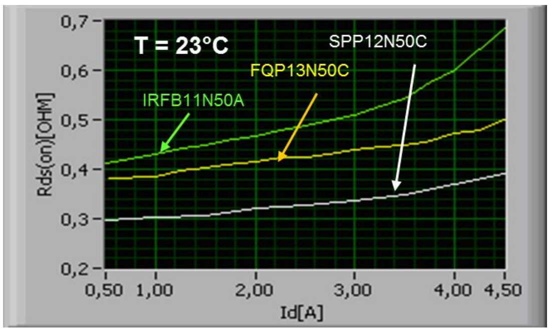

Figure 3 – Rds(on) vs Id

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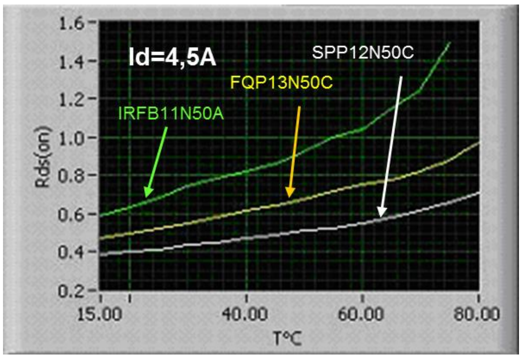

Figure 4 – Rds(on) vs temperature

IV. Conclusions

In this paper an automatic measurement system developed for the characterization of power MOSFET is presented. The system is able to implement a quantitative and qualitative analysis of the characteristic parameters. The results showed the importance of an automatic acquisition of measures to reduce the analysis time. In particular, the numerous tests carried out to obtain the average values of rise time, fall time and delay times corresponding to different values of gate resistance, have emphasized the importance of the automation of this process to facilitate storage and management of data via software. This system is effective for the characterization of power MOSFET in an industrial context. The architecture of the proposed system allows both a total independence between the device under test and the final application thanks to a certain flexibility in the measurement settings, highlighting the potential of the proposed system.
Finally, all the data obtained by means of the proposed automatic measurement system for the characterization of Power MOSFETs allow to select better the device that will be used in power applications [8-10]. Furthermore it is also possible to use such data in the reliability and availability analysis [11-12] and functional safety assessment [13].

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