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The I-V Characteristic Comparison Method In Electronic Component Diagnostics

Tomas Bata University in Zlín
Faculty of Applied Informatics

CZECH REPUBLIC

Neumann Petr, Pospíšilík Martin , Skočík Petr, Adámek Milan

Tomas Bata University in Zlín,
Faculty of Applied Informatics, Department of Electronics and Measurements,
Nad Stráněmi 4511, 760 05 Zlín, Czech Republic
neumann@fai.utb.cz, adamek@fai.utb.cz, skocik@fai.utb.cz

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INTRODUCTION

The electronic component I-V characteristic expresses a relationship between the current flowing via a chosen pair of pins, and the voltage applied on those pins. The applied voltage varies between two limits during the I-V characteristic recording process. The applied voltage variation follows a certain time function – waveform $V_W(t)$, usually sinus, triangle, or ramp. The expression $I = f(V_W)$ represents a general relation between the current I flowing through two pins of a component and an applied voltage waveform V_W swept in set limits. Besides the voltage waveform choice and its voltage range, we can influence the final I-V characteristic course also with the sweep frequency and voltage source resistance settings. Those settings are component type and its production technology specific. We will call those parameters and waveform settings complex a scan profile. I-V characteristic set of an individual component type can naturally differ according to the production technology, according to the particular manufacturer, or according to the measurement conditions itself. Those so called natural differences can be registered by the study of statistically significant model component population with known origin and history, and they could be subsumed in the comparison master pin print.

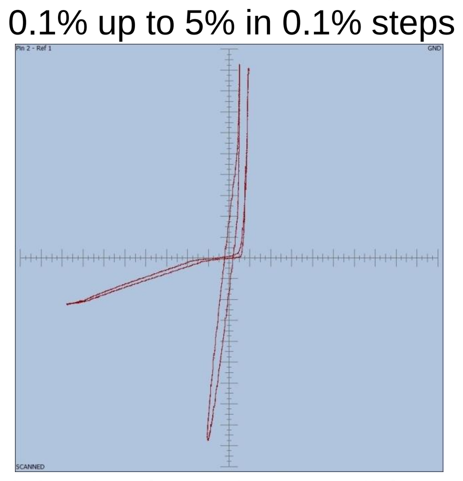
EXPERIMENT EQUIPMENT

Our analytical laboratory is equipped with a 256 channels curve tracer. That equipment has three scanning modes related to the way of pins pairing. The first mode called manual mode uses the reference pin allocated by the operator (the ground pin is recommended as a default reference) for creating pairs with all other pins. The second mode uses all possible pin pairing (matrix mode) among the component pins. The third mode is automatic. Automatic mode checks first all pin combinations for the current flow level, and it excludes combinations with zero or very small current then. The third mode is similar to the first one, only the reference pins are selected automatically.

Fig.1. Diagnostic Equipment Detail

The voltage range is adjustable anywhere between the limits ±10 Volts. The voltage waveform can be selected among sinus, triangle and ramp. The source resistance values of 1 kOhm, 10 kOhm and 100 kOhm are available. The frequency of the test signal used for the scan profile can be set from 100 Hz to 5 kHz in a 1-2-5 sequence. The comparison criteria can be set for I-V characteristic tolerance range and for pins and component evaluation. The tolerance range for I-V characteristics comparison can be set individually for horizontal and vertical axis from 0.1% up to 5% in 0.1% steps

Fig.2. Dual PinPrint I-V Characteristic Example just after Learn Process



Just I-V characteristics comparative analysis offers an interesting preventive method for relatively quick, simple and accessible new component source evaluation. Moreover, that methods is still applicable for standard diagnostic studies of technological and mistreatment consequences for a component with model I-V characteristics recorded in advance.

EXPERIMENT RESULTS 1

We have tested electronic component samples in all modes. Nevertheless, we have concentrated on the automatic mode recently because it could be approached as the easiest mode for users with little previous experience in praxis, and they can start to build the component I-V characteristics database almost from zero. Fig. 3 illustrates the case where the analyzed Zener diode was reported not being able to stabilize the nominal voltage for small current like expected according to the data sheet and specifications. The comparison of the model diode tolerance range and equivalent I-V characteristic shows clearly why. The tolerance range was set both horizontally and vertically to 1% in this case.

The preference for the Manual Mode or for the Matrix Mode depends on the particular component type and its production technology. The basic criterion for such choice is the higher sensitivity for V-I characteristic change. Automatic Mode is very convenient for a quicker analysis.

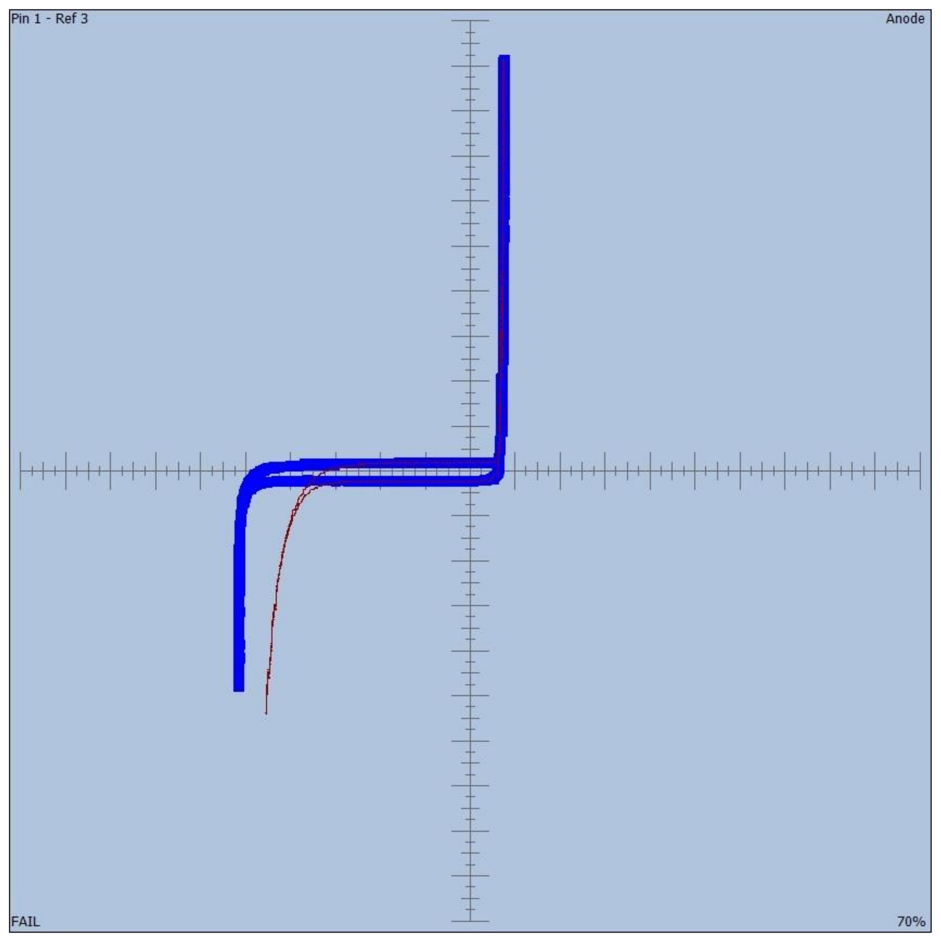


Fig.3. An analysed Zener 5V1 diode I-V characteristic with model diode 1% tolerance range.

EXPERIMENT RESULTS 2

Scan Profile Example	
Voltage Range:	±10V
Waveform:	Sine
Source Resistance:	100 kOhm
Frequency:	100 Hz

Tab. 1. Scan profile example for MOSFET power transistor

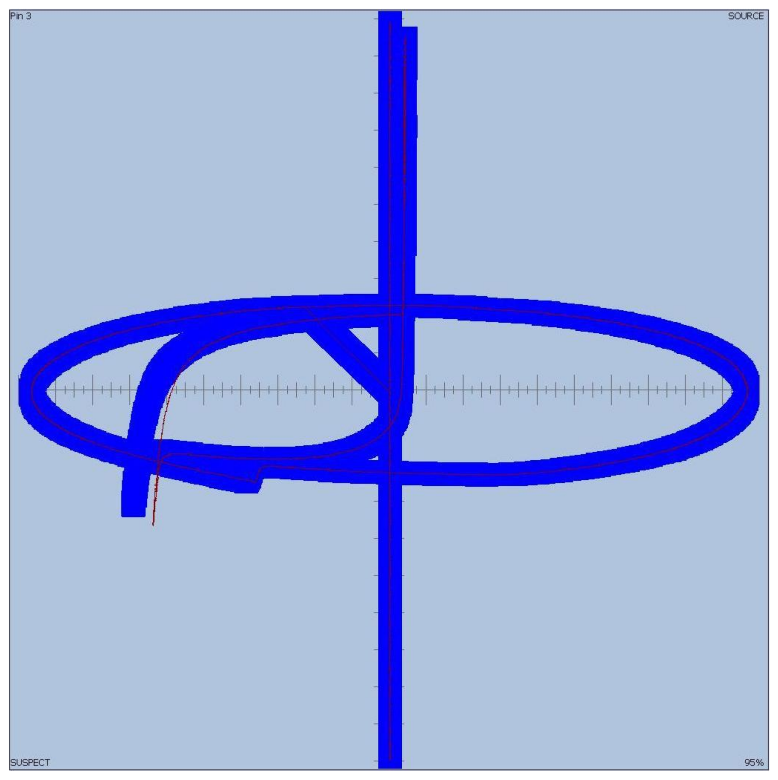


Fig.4. V-I characteristic for Drain pin referred to Source pin in Matrix Mode for a MOSFET

When analysing transistors, we need to choose a suitable reference pin in the manual mode. That choice mostly depends on sensitivity to I-V characteristic changes caused by analysed differences.

Table 1 displays an example of scan profile for five analysed MOSFET power transistors.

Table 2 displays the comparison result for that group of five MOSFETs in the Manual Mode with Drain as reference pin in summary.

The dissimilar sub-group consisting from samples 2 and 3 is highlighted red. The dissimilarity is only very small and belongs to the natural variations because there were two different lot codes in the sample group. One lot code is related to the sub-group of samples 1, 4 and 5. The other lot code is related to the sub-group of samples 2 and 3.

MOSFET Power Transistor				
Sample	MANUAL MODE Ref – 2			Result
	Pin1	Pin2	Pin3	
1	100	100	100	Ref.
2	100	100	85	fail
3	100	100	85	fail
4	100	100	100	ok
5	100	100	100	ok

Tab. 2. Comparison results example

EXPERIMENT RESULTS 3

Fig. 5 and Fig. 6 are illustrating an microcontroller type component I-V characteristics comparison analysis results. The comparison analysis was realized in the automatic mode with 5% default tolerance range. We had an approved model component and some equivalent samples for our analysis. The equivalent samples were assembled in an electronic module which was failing repeatedly at the in-circuit test stage in production. The test operator assumption that pin #9 is not connected has been confirmed (see Fig. 6). Even the other pins I-V characteristics were radically different (see indication in Fig. 5).

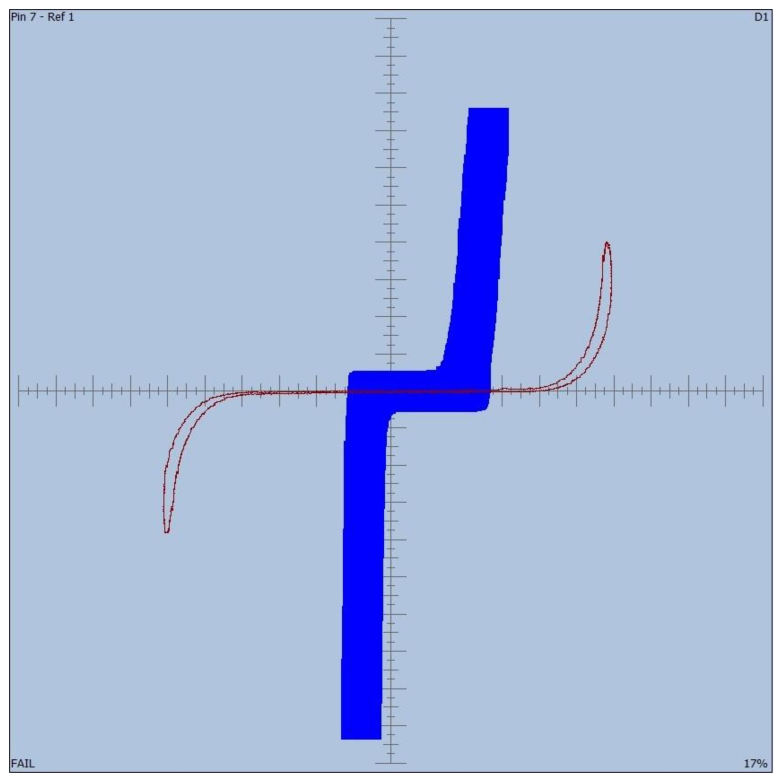


Fig.5. Analysed component pin #7 I-V characteristic with model component pin #7 tolerance range of 5%.

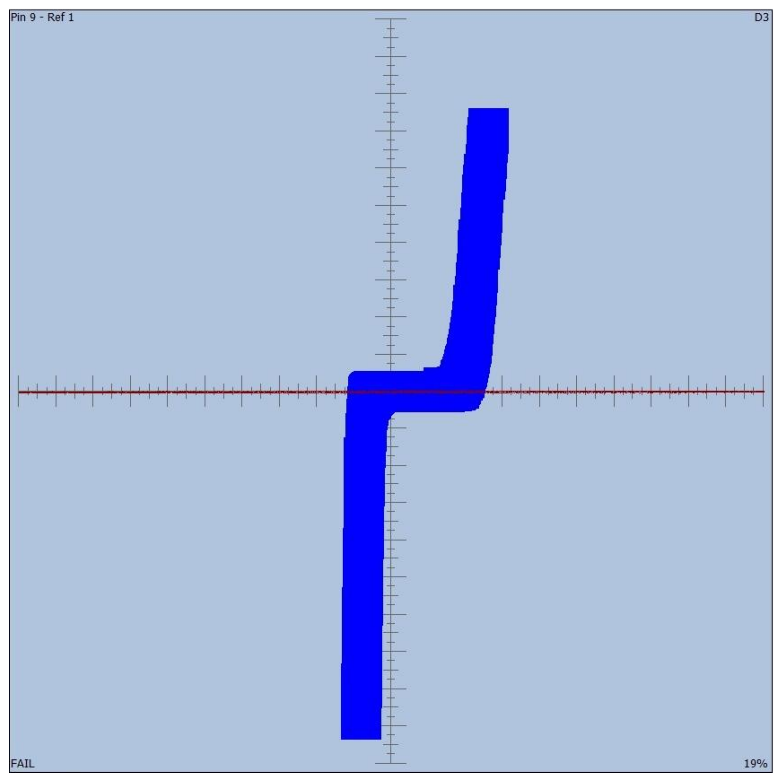


Fig.6. Analysed component pin #9 I-V characteristic with model component pin #9 tolerance range of 5%.

We had also opportunity to compare our pin print results with micro-focus x-ray CT analysis. Fig. 7 illustrates the X-ray analysis result for a model component.

Fig. 8 illustrates the X-ray analysis result for the failing component sample.

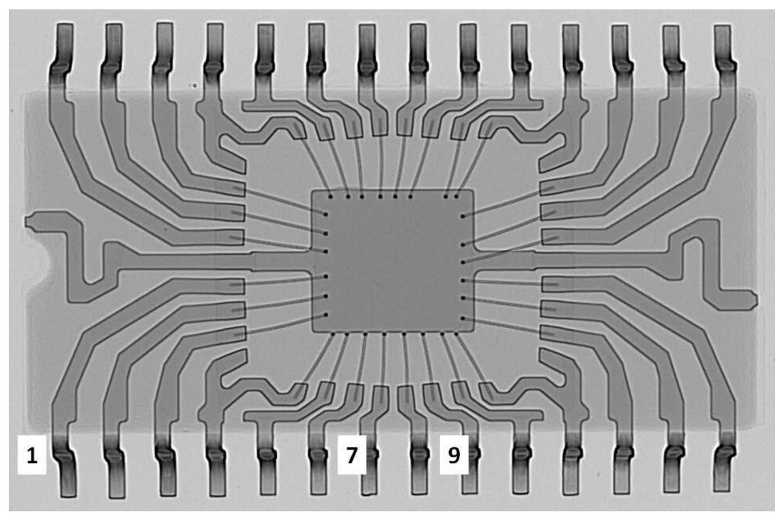


Fig.7. The X-ray image of the model component.

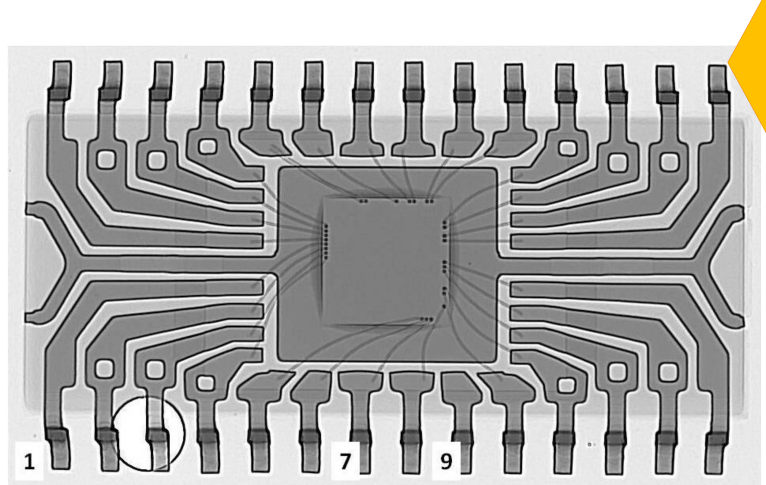


Fig.8. The X-ray image of the analysed component.

We have x-rayed both the model component and the analysed components to see any structural differences if there any would be. The x-ray analysis was accomplished on the CT Phoenix Micromex DXR-HD. The x-ray images are in Fig. 7 and Fig. 8. As you can see in Fig. 8, pin #9 is really not connected in the analysed equivalent components, and there are many other structural differences as mentioned above.

CONCLUSION

Our experiments show the diagnostic potential of the I-V characteristics comparison method. That method is not a replacement for parametric and functional tests, but it can still serve as a quick and cost effective first stage filter for damaged and unauthentic components before letting them to enter the manufacturing process.