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LK8820 Integrated Circuit Parameter Measurement Technology for Environmental Adaptability Testing

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Abstract Integrated circuits are increasingly used in complex environments, and the environmental adaptability of their electrical parameters has become a key factor affecting reliability. Based on the LK8820 test platform, the article develops an environmental adaptability testing model for the electrical parameters of integrated circuits. Through the data acquisition module of LK8820 platform, the key electrical parameters of ICs in extreme environments are obtained. Utilizing the Transformer architecture, the mapping relationship between IC electrical parameters and environmental variables is established. The test circuit is designed to improve the convenience of electrical parameter detection, and the effect of electrical parameter detection is verified by combining with simulation experiments. The accuracy of the electrical parameter detection model based on the LK8820 platform is 92.55%~97.28% under the operation of integrated circuits in high temperature, low temperature, high humidity and dry environment. Under different environments, the detection errors of the model for the four electrical parameters of IC static capacitance, dynamic capacitance, dynamic inductance, and dynamic resistance are between 0.04% and 0.95%, with high accuracy. The voltage and current output values of the model on the coal miner traction inverter are consistent with the values calculated in the study, and the output waveforms are correct. The detection error of voltage RMS of the model is higher than that in normal environment under harsh environment, but the detection error is much lower than the design value of 2%.

Index Terms LK8820 platform, Transformer architecture, electrical parameter detection model, circuit design

I. Introduction

The development and research of integrated circuits is the most important part of the current high-tech industry, and to a certain extent the IC R&D and manufacturing industry also belongs to China's strategic industries [1]. The core industry chain of IC mainly includes three major fields: IC design, IC manufacturing, and IC packaging and testing, among which testing is an important means to guarantee the circuit function and ensure the industrial benefits [2]-[4]. From the point of view of the industry chain, IC testing mainly includes design verification, wafer testing and finished product testing [5]. In order to verify the environmental adaptability of integrated circuits, it is necessary to create different working environments, such as high temperature, low temperature, cold and hot shock, different humidity, etc., and at the same time, combine with the test platform to observe its performance changes under different working environments [6]-[8]. As the performance of electrical parameters of integrated circuits in different environments during operation has a certain degree of variability, only according to different environments to further select a reasonable parameter design, in order to better play out the performance of integrated circuit products and their value [9]-[12].

With the wide application of integrated circuits in communication, aerospace, military weaponry and other industries, their environmental adaptability testing has become more and more demanding, which also puts forward higher requirements for testing means [13], [14]. At present, China's testing of integrated circuits is still in the initial stage of development, and there are still corresponding problems in many aspects of the circuit testing, so to strengthen the research and application of testing methods has also become a necessary path for the development of the current electronic information industry [15]-[17].

In this paper, we constructed an IC electrical parameter environment adaptive detection model with the LK8820 platform as the core, which is equipped with the Transformer architecture and can fully learn the characteristics of the IC electrical parameter data collected by the LK8820 platform under different extreme environments. In addition, it can utilize the cross-attention mechanism to fuse multimodal data and realize the fusion analysis of IC multi-environmental parameters. In addition, the designed hardware circuit provides a physical interface for signal acquisition through voltage signal conditioning and current signal conditioning, which improves the anti-interference ability as well as the environmental adaptability of the IC. Through simulation experiments, the accuracy and error of the model's electrical parameter detection in different environments and other parameters are tested to prove the validity of the model.

II. LK8820 test platform

LK8820 IC development platform consists of control system, interface and communication module, reference voltage and voltage measurement module, four-quadrant power supply module, digital function pin module, analog function module, analog switching and time measurement module, which can realize IC chip testing, board-level circuit testing, electronic technology learning and circuit auxiliary design. The industrial control system of the platform is connected to the communication module (CM board) through the USB3.0 interface, and the CM board is connected to the other five modules through the data bus to realize data transmission. Users can design test circuits and write test programs to achieve the test purpose according to the test requirements.

LK8820 integrated circuit development teaching platform compared with the LK8810 series platform, hardware resources are richer, the tester special function is further optimized, using C language [18] for the design of the program, through the hardware and software tuning to achieve the test for the chip.LK8820 integrated circuit development teaching platform power supply for AC220V/5A, by the industrial control machine, touch screen display, Test host, special power supply, test software, test terminal interface and other components. The four-quadrant power supply module adds two precision four-quadrant constant voltage, constant current, voltage measurement and flow measurement channels. Meanwhile, in order to meet the needs of chip testing below 64pin, the power supply module can be expanded to two four-quadrant power supply modules (8 channels), the digital function pin module can be expanded to four digital function pin modules (64 channels), and the analog switch and time measurement module can be expanded to two analog switch and time measurement modules.

III. Integrated circuit electrical parameters environmental adaptability testing modeling

In this section, the LK8820 platform is combined with the Transformer architecture [19], [20] to construct an integrated circuit electrical parameter environment adaptive detection model incorporating deep learning, which is used to monitor the state of integrated circuit digital chips. The workflow of the electrical parameter environment adaptive detection model is shown in Figure 1.

The digital chip output data of the test motherboard in different extreme environments (-40℃~125℃, humidity 10%~90%RH, etc.) under the working condition is collected as the raw data set. After the host computer receives the data, the dataset is trained and tested and validated by the Transformer algorithm model. Finally, the designed deep learning model is deployed in a long time thermal environmental adaptation test, and the collected output data is imported into the trained model to realize the real-time monitoring of the board's electrical parameter environmental adaptation.

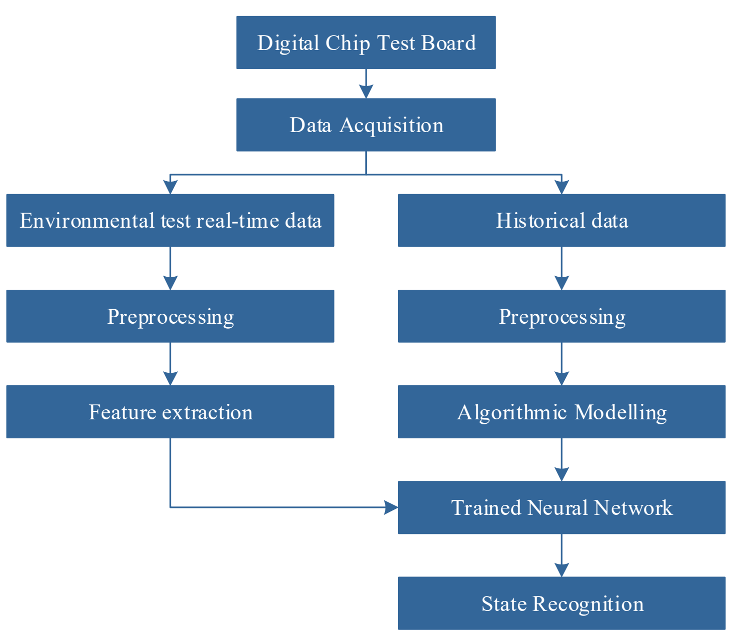

Figure 1: Flowchart of the model

III. A. Chip under test selection

CB54HCT125 model CMOS type four-bus buffer digital chip was selected as the test object, the chip logic diagram shown in Figure 2. The chip has a total of four groups of channels: each channel consists of an output control terminal OE, data input terminal A and data output terminal Y. The chip has a total of four groups of channels. The power supply voltage range of this chip during normal operation is 4.5V~5.5V, and the inputs need to satisfy VIH>2.0V and VIL<0.8V. It is usually used for connecting and transmitting data in a digital system, which can effectively reduce the delay and error of data transmission and improve the overall performance of the system.

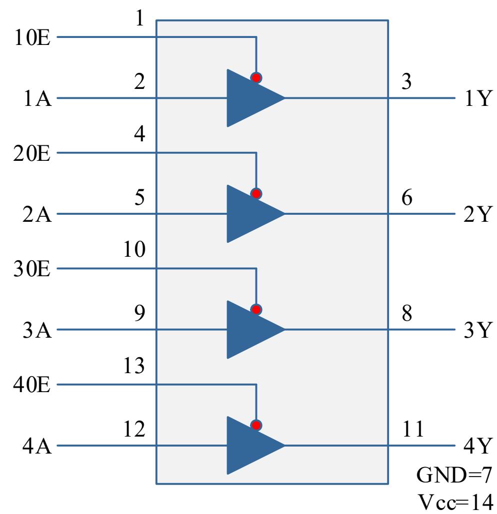

Figure 2: Chip logic diagram

III. B. Data Acquisition and Preprocessing

The raw data is divided into two parts: normal state data and simulated fault data. The normal state data is the CB54HCT125 output data collected during the board-level functional test and electrical environment adaptability test of the motherboard, which are: normal operating state, negative pull bias state of the power supply voltage, low voltage state, high voltage state, which basically covers the output voltage variation range of the chip under test when it functions normally in the environmental test. Fault state data are simulated and output data are collected for the fault states that may occur during the board-level test, and the simulated fault states are: two logic error states and open-circuit faults.

Before the training of the deep learning model, data preprocessing is carried out first, 80,000 points per channel are selected for the data sequence of the four normal operating states, 40,000 points per channel are selected for the data sequence of the logic high fault state, and 10,000 points per channel are selected for the remaining two fault states, and the data set is constructed using the sliding window module, and the data is divided into the training data set and the test data set. Since the original data contains only voltage and frequency features, and the difference in the data distribution range is small, it can be processed directly to provide an accurate basis for identification.

III. C. Test Method Design

This research is mainly carried out by combining hardware circuit design and construction, software programming and debugging, comparative testing and data analysis.

(1) Test circuit design. This test is mainly based on the LK8820 test platform for testing, the specific test is mainly composed of a PC computer, LK8820 test machine, circuit test card and probe card. The core part of the LK8820 test machine mainly consists of power supply, interface, VM board, PV board and PE board to test the electrical parameters of the chip. In this circuit design, according to the test principle can be CB54HCT125 IC chip pins and LK8820 test platform interface directly connected to the CB54HCT125 IC chip input and output pins and LK8820 test platform PE board PIN pins on the test connection, the IC chip under test power supply pins and force The power supply pin of the IC chip under test is connected to the force channel to realize the power supply, and this method can also improve the convenience of the subsequent measurement of electrical parameters, and the portability of the program will also be improved accordingly.

(2) High and low level testing of the CB54HCT125 IC chip under different environmental conditions. Before the whole test, first of all, the functional performance of the CB54HCT125 integrated circuit chip is analyzed in depth,

to understand the standard range of high and low levels of the output of this integrated circuit in the actual working process, and at the same time, the test mode of the LK8820 test platform is studied, to understand the specific test methods and test principles, to set up the workpiece circuit boards on the basis of this, and to establish the test outline, and to write the test functions in the C language environment. C language environment to write test functions. Including input and output state functions, current measurement voltage function, read pin voltage level function, provide program-controlled voltage source function and other related functions. In the specific test process, according to the actual function of the chip needs to be given to the appropriate test vector, and then detect the output pin high and low level of the actual parameters.

(3) CB54HCT125 integrated circuit chip environmentally adaptive high and low level test mode. The CB54HCT125 integrated circuit chip environmental adaptability test, before the test first need to analyze the CB54HCT125 integrated circuit chip environmental adaptability parameter indicators. And then formulate the environmental adaptability test outline, specify the specific test content and test methods, in which the test environment are high temperature environment, low temperature environment, high humidity environment, high temperature to low temperature environment four. After the establishment of the test outline, it is necessary to make the corresponding extreme environment test equipment circuit board according to the actual test requirements of the outline. After the first round of testing on the basis of the test method, according to the changes in the test indicators to write the corresponding test procedures to achieve the optimization of the test process. After the completion of the test program using the LK8820 test platform on the CB54HCT125 integrated circuit chip electrical parameters of the environmental adaptability of the test, and then sort out the relevant test data, compare the results of the first and second test, so as to form a relevant research conclusions.

IV. Hardware circuit design for electrical parameter detection model

IV. A. Signal Conditioning Circuit Design

In order to realize the acquisition and control of high-intensity signals, voltage signal conditioning circuits and current signal conditioning circuits [21] are needed for in-phase processing of the transformer output signals. Since the electrical parameter monitoring model is mainly used for the measurement of three-phase power grids, the principle of the three-channel voltage conditioning circuit is kept the same, and the current conditioning circuit refers to the principle of the voltage conditioning circuit, which converts the current signal into a voltage signal through a high-precision resistor for processing.

The high-voltage signal is converted into a low-voltage signal that can be processed by the power supply circuit through the voltage sensor, and the signal first passes through the first-stage voltage follower, which plays the role of isolation buffer. Then it enters the in-phase amplifier circuit for corresponding proportional amplification, and then passes through the second stage voltage follower circuit for voltage conversion. In addition, in order to prevent burning the acquisition port, adding clamp diodes to limit the conditioned voltage signal to within +3V. Finally, the resulting low-voltage signal is connected to the acquisition port.

The principle of the current signal conditioning circuit is roughly the same as that of the voltage signal conditioning circuit, but the difference is that the current conditioning circuit converts the weak current signal into a low-voltage signal through a high-precision resistor and feeds it into the current conditioning circuit.

IV. B. AD Acquisition and Peripheral Circuitry

After the electrical parameter acquisition is conditioned by the six-way conditioning circuit, analog-to-digital conversion and synchronous sampling of the six signals are required. The bipolar, low-power successive approximation type converter is utilized, which is responsible for completing the analog-to-digital conversion work. The core processor generates a multiplied sampling pulse according to the frequency of the fundamental wave, and then controls the acquisition signal to realize the sampling of the six input signals.

IV. C. Lower computer control system design

The control system of the lower computer is mainly responsible for receiving the control of the upper computer and realizing data transmission, and sending the data collected by the sampling chip through packing.

When the lower computer control program starts, first of all, the peripheral circuitry, initial variables to complete the initial setup, the initial work is completed, you need to set the processor's interrupt mode, to ensure that the acquisition of data along with the storage and retrieval, used to meet the needs of signal synchronization. After the interrupt trigger mode is set, the wireless module sends a request to establish a connection with the host computer, and if the host computer link sends communication data, the lower computer and the host computer complete the construction of the communication link. If the upper computer is in BUSY state, the lower computer program enters the loop until the communication process is completed. After the communication link is established, the lower computer receives control commands from the upper computer, including switching on and off of the lower computer system, triggering interruptions of AD data acquisition and so on. Finally, it enters the data transmission process, and the lower computer packages the data and sends it to the upper computer for calculation, processing and analysis through the wireless module.

V. Testing and analysis of the environmental suitability of the electrical parameters of integrated circuits

V. A. Performance test for detecting electrical parameters in different environments

In this section, the electrical parameter signal data collected by the LK8820 platform for integrated circuits in extreme environments are divided into five test sets, and the electrical parameter detection in different environments is analyzed for each data set to validate the effectiveness of the electrical parameter environment adaptive detection model constructed in this paper. The simulated environments include normal environment, high temperature environment (>100℃), low temperature environment (<-30℃), high humidity environment (>80%RH) and dry environment (<20%RH). Detected electrical parameter signals include static capacitance (Cs), dynamic capacitance (Cm), dynamic inductance (Lm), and dynamic resistance (Rm).

The detection accuracy of the electrical parameter detection model under different test sets is shown in Table 1. From the data in the table, it can be seen that the model in this paper has achieved high accuracy in the detection of the electrical parameters of the five IC operating environments under the available data. Among them, the electrical parameter detection accuracy of ICs in normal environment is the highest, with an average accuracy of 98.51% under five test sets. The detection accuracies under high-temperature and dry environments are basically the same, 97.28% and 97.07%, respectively. The detection accuracy under high humidity environment cannot reach 95%, which is analyzed as a result of the relatively small amount of actual data in the dataset where the IC operates under high humidity environment. However, the model in this paper is able to meet the prediction requirements in overall detection performance and achieve a high detection accuracy.

Table 1: Detection accuracy of the test model under different test sets

Test set	Normal	High temperature	Low temperature	High wet	Drying
1	98.92%	95.37%	97.53%	93.62%	96.45%
2	97.95%	94.08%	97.64%	92.36%	96.66%
3	98.75%	95.96%	97.86%	92.99%	97.21%
4	98.42%	97.86%	97.62%	91.28%	97.48%
5	98.52%	96.34%	95.73%	92.50%	97.54%
Average	98.51%	95.92%	97.28%	92.55%	97.07%

V. B. Simulation Verification of Integrated Circuit Electrical Parameter Detection

The simulation system can simulate the functional behavior of the circuit without establishing the actual circuit, in this paper, LTspice simulation software is selected, and a total of five environments are considered to simulate the detection of the electrical parameters of integrated circuits. The experimental environment is the same as above, the detection of electrical parameter signals include, static capacitance (C_s), dynamic capacitance (C_m), dynamic inductance (L_m) and dynamic resistance (R_m). By measuring the detected values of the IC electrical parameters in different environments and comparing them with the real set values, the accuracy of the electrical parameter detection model based on the LK8820 platform is verified.

Table 2 shows the comparison results of the detected values of the real values of each electrical parameter in the simulation process. As can be seen from the results in the table, the real values of the electrical parameters of the integrated circuits in different environments are very close to the detection values obtained using the model in this paper. Under normal environment, the relative error between the detected value and the true value is between 0.04% and 0.29%. In the extreme environment, the detection error of each electrical parameter is relatively large, between 0.21% and 0.95%, but the overall detection error is within the acceptable range. The above results can prove the accuracy of the environmental adaptation detection model of the electrical parameters in this paper.

In addition, the single-phase power quality analyzer prototype further used in this paper is analyzed for RMS voltage detection. The specific model of the ADC used is the AD9266, which outputs 16-bit parallel data, and the sampling rate can support up to 20MHz, and when the input signal frequency is within 9.7MHz, the SNR can be stabilized at about 77.6dB and the SFDR is above 90dBc when using different sampling rates. Therefore, in this section, the model of this paper will be used to test the impact on the accuracy of the power quality analyzer to measure the voltage RMS, and then further verify that the model of this paper meets the design objectives.

Table 2: Test results and errors of integrated circuit parameters

Frequency	Parameter	True value	Detection value	Relative error (%)
Normal	C_s	13.67	13.63	0.29
	C_m	100.35	100.25	0.10
	L_m	8.44	8.42	0.24
	R_m	15.41	15.40	0.04
High temperature	C_s	15.83	15.92	0.55
	C_m	98.26	98.86	0.61
	L_m	15.19	15.14	0.33
	R_m	23.71	23.66	0.21
Low temperature	C_s	4.15	4.16	0.27
	C_m	56.73	56.29	0.77
	L_m	22.43	22.64	0.95
	R_m	9.46	9.40	0.62
High wet	C_s	21.43	21.29	0.63
	C_m	3.29	3.28	0.38
	L_m	13.17	13.29	0.94
	R_m	12.63	12.55	0.60
Drying	C_s	5.94	5.99	0.89
	C_m	0.79	0.79	0.30
	L_m	7.55	7.59	0.52
	R_m	16.82	16.70	0.70

The test range of RMS voltage is 20V~260V, and the results of this paper's testing model in different environments are shown in Table 3, and Fig. 3 shows the detection error of the RMS voltage of this paper's testing model. Combined with the icon analysis, it can be seen that the model in this paper for electrical parameter sampling, the prototype voltage RMS detection accuracy is better. Among them, the voltage RMS detection error of the model in normal environment is always kept below 1%. When the effective voltage is 20V, the detection error of the model's voltage RMS in different environments is the largest, and with the increase of the standard source voltage, the detection error decreases substantially. After the standard source voltage exceeds 100V, the RMS voltage detection error of the model in different environments is less than 1%. It can be assumed that the RMS voltage detection of this paper's model is in line with the theoretical analysis, and there is a certain margin from the design value of 2% of the detection error in harsh environments.

Table 3: Test results of voltage effective value in different environments

Standard source voltage (V)	Normal	High temperature	Low temperature	High wet	Drying
20	20.15	20.27	20.32	20.30	20.24
40	40.16	40.52	40.41	40.46	40.33
60	60.07	60.51	60.84	60.92	60.85
80	80.02	80.97	80.72	80.52	80.52
100	100.14	100.87	100.63	100.91	100.93
120	120.04	120.94	120.45	120.69	120.33
140	140.19	140.78	140.67	140.69	140.97
160	160.18	160.48	160.4	160.81	160.41
180	180.05	180.42	180.33	180.57	180.86
200	200.1	200.65	200.39	200.8	200.84
220	220.13	220.9	220.39	220.91	220.32
240	240.18	240.76	240.31	240.43	240.8
260	260.19	260.97	260.76	260.45	260.62

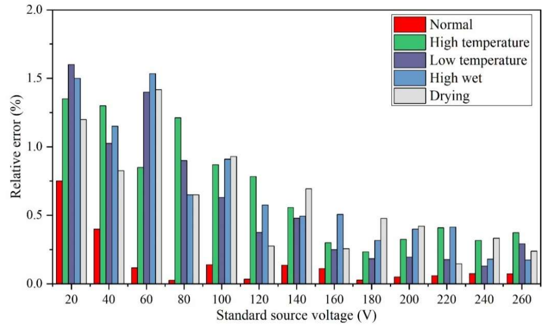

Figure 3: The error of the voltage effective value of the model voltage

Finally, the electrical parameter detection model designed in this paper is tested on a 45kW coal miner traction inverter. The main parameters of the system are: input voltage of coal miner traction inverter AC380V, rated power of traction motor 45kW, rated voltage AC380V, rated current 90A, rated frequency 50Hz.

Figure 4 shows the voltage and current waveforms measured at the test point when the rated voltage is output from the coal miner traction inverter, and the measured voltage RMS value is 2.35V, which is the same as the calculated value in the study. It shows that the model of this paper is simulated in the coal mining machine, and the voltage waveform output from the traction inverter is correct and the harmonics are small.

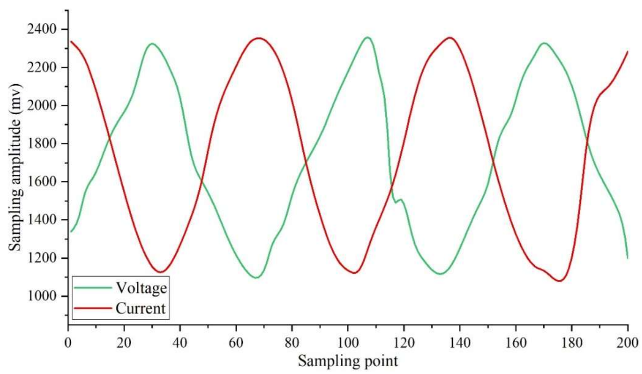

Figure 4: Test points of voltage and current waveform

VI. Conclusion

The research constructs an environment-adaptive detection model of integrated circuit electrical parameters integrating deep learning framework and LK8820 platform. The model is based on the premise that the LK8820 platform collects high-precision electrical parameter signals in different extreme environments, and uses the Transformer framework to extract the timing features therein, such as current and voltage waveforms, to capture the long-distance dependence between the electrical parameter signals and the environment. Meanwhile, hardware circuits are designed in order to measure the electrical parameters of integrated circuits in different environments. Through signal conditioning and other operations, the data are accurately sent to the host computer for calculation and analysis. The accuracy of the model in this paper is 98.51% for the detection of electrical parameters in normal environment, and the detection accuracy in extreme environment is relatively low, such as the detection accuracy in high humidity environment is only 92.55%. And the model in the normal environment of static capacitance, dynamic capacitance high, dynamic inductance and other electrical parameters of the detection value and the real value of the error in the normal environment of 0.04% ~ 0.29%, in the extreme environment of the detection error between 0.21% ~ 0.95%. In addition, the model in this paper can accurately output voltage and current waveforms. In voltage RMS detection, the detection error of this paper's model is always lower than 2%, and the voltage RMS detection accuracy is high. This study provides a data basis for the environmental adaptive design and reliability optimization of integrated circuits.

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