Development and Optimization Design of Digital Logic device based on FPGA

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Abstract. FPGA is the abbreviation of Field Programmable Gate Array. The corresponding CPLD is the abbreviation of complex Programmable Logic device. So sometimes the difference can be ignored, collectively called programmable logic devices or CPLD/PGFA. FPGA has a universal structure of masked programmable gate arrays, which is arranged by logical function blocks and connected by programmable interconnection resources to implement different designs. The basic function of a digital electronic clock based on FPGA is designed, simulated and realized by using digital electronic technology, such as FPGA and so on.

1. Introduction
With the development of our country's market economy, transportation is becoming more and more convenient, especially taxis, which have long been popular in various cities with the characteristics of speed and convenience. The taxi market has entered its peak period since the beginning of 90s. With the development of urbanization and the improvement of people's living standards, Taxi service is becoming more and more important, so the taxi meter came into being.

At present, the taxi meters used in the market are mainly designed using MCU such as 89C51 single chip microcomputer. The traditional taxi meter, which has been used for more than ten years because of its development, has some advantages in terms of stability, cost, and usage habits.

However, with the marketization of taxi prices, many factors leading the taxi industry cost since China's entry into WTO mainly include the fluctuation of oil prices, which have put forward higher requirements for the traditional taxi metering devices. Major cities are adjusting taxi prices. Because of the number of taxis, many cities even need a month to complete the price adjustment, and often several prices appear at the same time. In some cities, the embarrassment of manual pricing in taxi drivers has exposed the lack of flexibility and upgrading of traditional meters.

With the rapid development of information technology, the digitization of electronic system has become a obvious trend. From the traditional application of small and medium scale chips to the wide application of single chip, FPGA/CPLD has been used in the system design. Electronic design technology has entered a new stage. FPGA / CPLD not only has the characteristics of large capacity and strong logic function, but also has high speed and high reliability.

At the same time, the design of hardware can be as convenient and fast as software design. With the increasing maturity and application of FPGA/CPLD devices, the design of digital electronic systems in the fields of communication, national defense, industrial automation, instrumentation and other fields, They are becoming the main role of electronic design. Based on the support of powerful EDA
technology and VHDL as the main design means, it has become the main development direction of
digital system design to make full use of the rich and flexible logic resources of CPLD chip.

Multifunctional counter is a kind of digital measuring instrument which displays the frequency,
period and duty cycle of measured signal with decimal number, and is a typical application in digital
circuit [1]. With the wide application of complex programmable logic devices (CPLDs), the use of EDA
tools as a means of development, the use of VHDL language will greatly simplify the whole system.
Improve the overall performance and reliability.

It is an indispensable measurement instrument in the fields of computer, communication equipment,
audio and video. This will make the advantages of the multifunctional counter based on FPGA more
obvious. The multifunctional counter which is designed by VHDL programming, except the shaping
part of the tested signal, the key input part and the digital display part, the rest are implemented on a
single FPGA chip, with small size, high reliability and low power consumption. The whole system
is very simple and flexible in the field. The pulse width can be measured by modification.

A digital pulse width meter can be made; a capacitance can be measured into a digital capacitance
measuring instrument; a sensor can be added to the circuit; a digital pulse meter, a meter, etc.; therefore,
a multifunctional counter can be used to measure physical quantities and aerospace, electronics, etc.
Measurement and control, instrumentation, communication and other fields are widely used [2].

Today's electronic products are developing in the direction of diversification of functions,
minimization of volume and minimization of power consumption. It is significantly different from
traditional electronic products in the design of which a large number of programmable logic devices are
used to improve the performance of the products. At the same time, modern computer technology is
widely used to improve the degree of automation and competitiveness of products, shorten the research
and development cycle. EDA technology is to meet the requirements of modern electronic technology.
Absorb the latest scientific and technological achievements of many disciplines and form a new
technology.

The programmable logic devices of ALTERA Company of America adopt new structure and
advanced technology, together with Maxplus II (or the latest QUARTUS) development environment, it
has the characteristics of high performance and short development period, so it is very convenient for
the development and design of electronic products.

EDA technology takes large-scale programmable logic device as the design carrier, hardware
description language as the main way of system logic description, computer, large-scale programmable
logic device development software and experimental development system as the design tool. Through
the related development software, the logic compilation, logic simplification, logic division, logical
mapping between electronic system and hardware system designed by software can be completed
automatically. Programming download and other work. Finally, the formation of integrated electronic
systems or dedicated integrated chip a new technology.

This design uses VHDL hardware description language combined with programmable logic device,
and dynamically displays timing results through digital tube. Digital clock can be realized by various
technologies. The programmable logic device has the characteristics of easy to learn, convenient, novel,
interesting, intuitionistic, high success rate of design and experiment, close combination of theory and
practice, small volume, etc. I / O is rich in capacity, easy to program and encrypt, and it also has open
interface, rich design library, modular tools, LPM customization and other excellent performance, so it
is very convenient. The design is realized by programmable logic device.

2. Brief introduction to VHDL and FPGA
There are only three kinds of programmable logic devices: programmable read-only memory (PRM),
ultraviolet erasable read-only memory (EPROM) and electrically erasable read-only memory (E2PROM).
Due to the limitation of structure, they can only perform simple digital logic functions.

Then came a class of more complicated programmable chips, the programmable logic device (PLD),
which could perform a variety of digital logic functions. A typical PLD consists of a "and" gate and a
"gate" or gate array. Any combination logic can be described by "and-or" expression, so PLD can accomplish a large number of combinational logic functions in the form of product sum.

The main products in this phase are pal (Programmable Array Logic) and gal (Universal Array Logic). PAL consists of a programmable "and" plane and a fixed "or" plane. Or the output of the gate can be selectively placed as a registered state. Pal device is field programmable by flip-flop. Its implementation processes include anti-fuse technology, EPROM technology and E2PROM technology. A more flexible logic device is the programmable logic array (PLA), which also consists of a "and" plane and "one" or "plane".

However, the connection between the two planes is programmable. PLA devices are both programmable in the field and programmable in the mask. On the basis of PAL, a generic array logic, such as GAL16V8 / GAL22V10, is developed, which adopts the EPROM process. The output structure is programmable logic macro unit, so it has strong flexibility in design. One of the common features of these early PLD devices is that they can achieve logic functions with better speed characteristics, but their structure is too simple to enable them to implement smaller circuits, as is shown by figure1 [3].

![Figure1. GAL16V8 / GAL22V10, is developed](image)

One of the hallmarks of modern society is the widespread use of information products. Moreover, the performance of products is becoming stronger and stronger, and the degree of complexity is becoming higher and higher. The foundation of supporting the rapid development of information electronic products is the improvement of microelectronic manufacturing technology and the development of electronic product design and development technology. The former is represented by micro-machining technology. The representative of the latter is electronic design automation (EDAA) technology.

The VHDL used in this design is a kind of omnidirectional hardware description language, which can support the design of three different levels: system behavior level, register transfer level and logic gate level, supporting structure, data flow, and so on. Because of its wide coverage and strong abstract ability, the hybrid description of three forms of behavior is more and more widely used in practical applications.

ASIC is a special system integrated circuit and an accelerated processor with logic processing, while FPGA is a special ASIC chip [4]. Compared with other ASIC chips, it has the advantages of short design and development cycle, low cost of design and manufacture, advanced development tools, no need for testing of standard products, stable quality and real-time on-line detection.

In the control system, the keyboard is the commonly used man-machine exchange interface. When the function key or number key is pressed, the system should complete the function corresponding to the key. Keystroke information input is a process closely related to the software structure. According to the different keyboard structure, different coding methods are adopted, but regardless of whether or not the encoding is used, the key value must be converted to the corresponding key value. To achieve the key function program transfer [5].

The digitization of clocks and watches has brought great convenience to people's production and life, and has greatly expanded the original functions of clocks and watches, such as automatic alarm at timing, on-off circuits for timing switches, ovens on and off for timing, and power equipment on and off. All of these are based on the digitization of clocks and clocks, so it is of great practical significance to study digital clocks and expand their applications.

FPGA is a field programmable gate array (Field Programmable Gate Array) referred to, and the corresponding CPLD complex programmable logic devices (Complex Programmable Logic Device) abbreviation, the two functions are basically the same, only the realization of the principle of slightly different, sometimes can ignore the difference between the two, collectively referred to as programmable
logic devices or nearly CPLD/PGFA.CPLD/PGFA to complete any digital device function, high-performance CPU to the simple 74 circuit. It is like a piece of paper or a stack of blocks, engineers can through the traditional input principle diagram or hardware description language design a free digital system. Through software simulation can verify the correctness of the design, in after the completion of PCB, modified by CPLD/FPGA online, at any time to modify the design without changing hardware circuit. The use of CPLD/FPGA development of digital circuit, can greatly shorten the Design time, reduce PCB area and improve system reliability. These advantages make CPLD/FPGA technology develop rapidly after 1990s. At the same time, it greatly promotes the progress of EDA software and hardware description language HDL.

FPGA has a general structure of mask programmable gate array, which is composed of logical function blocks and is connected by programmable interconnect resources to achieve different designs.

Figure 2. FPGA has a general structure of mask programmable gate array

FPGA consists of 3 programmable circuit and a static memory for SRAM programming. This stored data consists of 3 programmable circuit: programmable logic module (CLB--Configurable Logic Block), input / output module (IOB--I/O Block) and interconnect resources (IR - Interconnect Resource). CLB is the basic programmable logic module unit of logic function, they are usually arranged in a regular array, spread throughout the whole chip; programmable input / output (IOB) module mainly completes the logic and external package pin on the chip interface, it is usually listed in the row around the chip can be connected; line programmed interconnection resources including all length and some programmable switch connection, they will each CLB or CLB connected between IOB and IOB circuits with specific functions.

In the middle of 80s, in order to remedy this shortcoming, Altera and Xilinx developed extended CPLD(Complex Programmable Logic device similar to PAL structure and FPGA(FieldProgrammable Gate Array similar to standard gate array in the middle of 80s. They all have flexible architecture and logic unit. These two kinds of devices are compatible with the advantages of PLD and general gate array.

They can realize large scale circuits and program flexibly. Compared with other ASIC(Application Specific ICs such as gate arrays, these two kinds of devices are compatible with other ASIC(Application Specific ICs, such as gate arrays. They also have the advantages of short design and development cycle, low cost of design and manufacture, advanced development tools, no need for testing of standard products, stable quality and real-time on-line inspection. Therefore, it is widely used in prototype design and production of products (generally less than 10, 000 units). Almost all applications of gate arrays and small and medium scale universal digital integrated circuits can be used in FPGA and CPLD devices.

In recent years, the technology revolution caused by EDA technology in the field of electronics has promoted the rapid development of electronic technology, which has attracted the attention of the world, and the application of programmable logic devices represented by FPGA. With the rapid development of large-scale integrated circuits and computer technology, it has been widely concerned in the design of industrial automation, instrument, computer design and application, communications, The content of FPGAs in electronic systems in a reas such as national defense is increasing at an alarming rate. It has become a reality to implement as large a complete electronic system as possible in a single FPGA chip [7]. The development of new electronic technology projects also depends more on the application of FPGA technology.

As one of the FPGA research topics, the design of matrix keyboard control interface circuit is often mentioned in the design of FPGA, just like using FPGA to design numbers, although it is simple, it is a topic of great significance. As to how to make full use of FPGA resources, many electronic products
now involve keystrokes, small ones with independent keys, large ones with NNNs matrix keyboards, and independent keys because of the small number of cases.

There is no need to consider the use of resources. The matrix keyboard, because of the number of keys, has a great impact on the whole system, so we must consider the use of resources. We also have to consider the timing problem in the circuit. This design requires the design of a 4x9 matrix keyboard. That is, behavior 4, listed as 9, can design a total of 36 keys. The design method is: generally judging whether the keystroke in the keyboard is pressed is sent into the scanning signal through the route, and then read the status from the column line.

The method is to send the line line into low level in turn to check the input of the row line. If the line signal is interesting and high level, then there is no key press in the row in which the low level signal is located, otherwise, there is, A key is pressed at the row where the low level signal is located and at the intersection where the low level occurs. ..

Digital frequency meter ( dfm ) is one of the most basic electronic instrument categories for electronic measurement and instrument technology. It is an indispensable measurement instrument in the fields of computer, communication equipment, audio and video, and it is an essential part of digital voltmeter ( dVM ). Therefore, the development of digital frequency meter plays a very important role in the development of the whole electronic product. ..

The idea of frequency measurement method is used to design the digital frequency meter by FPGA, which lays a solid foundation for improving the detection reliability and efficiency. 1.1 Overview of digital frequency meter The digital frequency meter is a digital measuring instrument that uses decimal digits to display the measured signal frequency. The basic function of the digital frequency meter is to measure the change of sine signal, square wave signal, sharp pulse signal and other various unit time. In recent years, our country has developed rapidly in the field of digital frequency meter research. At present, the design of the digital frequency meter can directly face the user's demand. According to the behavior and functional requirements of the system, the corresponding description, synthesis, optimization, simulation and verification can be completed from top to bottom, until the device is generated. 1.2 Current research situation of digital frequency meter In order to improve the accuracy, it is very difficult to measure the accuracy of the frequency measurement. The commercial frequency standard of scientific research and application, such as small cesium clock, rubidium frequency standard, new high stability crystal oscillator, etc..

3. Development and Optimization Design of Digital Logic Devices
The English full name of VHDL is Vry_High_Speed Integrated Circuit Hardware Description.

Language, known as the standard hardware description language, is thought by some experts to be VHDL and Verilog HDL in the new century.

The language will take on almost all the design tasks of the digital system.
VHDL is mainly used to describe the structure, behavior, functions and interfaces of digital systems.
The language form and description style of VHDL is very similar to that of the general computer high-level language. VHDL program structure is characterized by a project design, or design entity (can be a component, a circuit module or a.

The system is divided into external (or visual, or port) and internal (or invisible) parts, that is, the design entity's.

After defining an external interface for a design entity, once the internal development is complete, Other designs can call this entity directly. This concept of dividing the design entity into internal and external parts is the VHDL system setup.
The basic point of calculation.
With the development of EDA technology, it is a trend to use hardware language to design FPGA. Borrow MAXPLUSII.

Or the complete process of developing FPGA in the VHDL language by software such as QuartusII is as follows:
1) text editing: you can use any text editor, or you can use a dedicated HDL editing environment.
Typically, VHDL files are saved as VHD files.

2) functional simulation: the file is transferred into the HDL simulation software for functional simulation, checking whether the logical function is correct is also called.

Before simulation, the simple design can skip this step, only after the wiring is completed, the timing simulation can be carried out.

3) Logic synthesis: the source file is integrated into the logic synthesis software, that is, the language is synthesized into the simplest Boolean expression and the connection relation of the signal. The logic synthesis software will generate the EDA industry standard file of.

4) layout and routing: the edf file is transferred into the software provided by the PLD manufacturer for wiring, that is, the designed logic is placed into the PLD/FPGA.

5) timing simulation: using the exact parameters obtained in layout and wiring, using the simulation software to verify the time of the circuit.

Order (also called post-emulation).

6) programming download: after verifying that the simulation is correct, download the file to the chip. Sof for direct download to the.

Chip (power down will disappear. Pof file for rom chip download (power down does not disappear.

According to the principle of frequency measurement, frequency measurement methods can be divided into the following categories:.

1) it uses some frequency response characteristics of the circuit to measure the frequency. The resonant frequency measurement method and the bridge frequency measurement method are typical examples of this kind of measurement method: the former is often used in the measurement of low frequency band. The latter is mainly used in the measurement of high frequency or microwave frequency. The advantages of the resonant method are small size, light weight, no power supply and so on, so it is still widely used.

2) the frequency is measured by comparing the standard frequency with the measured frequency, and the frequency is measured by comparison method, the accuracy of which depends on the accuracy of the standard frequency. The oscilloscope method and the differential frequency method are all such methods. The beat frequency method and the oscilloscope method are mainly used to measure the frequency in the low frequency band, and the difference frequency rule is used to measure the frequency in the high frequency band. Its remarkable advantage is the high test sensitivity [1].

![Figure 3](image)

The above two methods are suitable for analog circuits, but the analog circuits are not stable in digital circuits, so after the emergence of digital circuits, Digital cymometers immediately appeared.

The current widely used law of counting and frequency measurement is suitable for digital circuits. This method is based on the definition of frequency and records the number of repetition times of periodic signals per unit time. Therefore, it is also called electronic counter frequency measurement method.

The commonly used digital frequency measurement methods are M method T method and method .M method. In the given gate time, the number of pulses measured is then converted to obtain the frequency.
of the measured signal. The accuracy of the measurement depends on the accuracy of the gate time and the frequency of the signal to be measured.

When the frequency of the measured signal is low, there will be a large error unless the gate time obtains a very large. T method by measuring the period of the measured signal. Then the frequency of the measured signal is obtained. The measuring accuracy depends on the period and timing accuracy of the measured signal. When the frequency of the measured signal is high, the requirement of timing precision is very high. The method has the advantages of the above two methods. By measuring the time of several cycles of the measured signal, and then converting the frequency of the signal to be measured, it can take into account the low frequency and high frequency signals.

The accuracy of measurement is improved, but the counting error problem exists in both the T method and the method of M method. M method has a pulse counting error of the measured signal within the specified gate time and there is also a word timing error in the T method or the method. This design is based on the research and summary of the above methods. In this paper, a new frequency measurement method is proposed, in which equal precision frequency measurement method is used to eliminate the problem of digital error which limits the accuracy of measurement, thus the accuracy and performance of frequency measurement are greatly improved.

Part description language is an important part of EDA technology, which is the main hardware description language of electronic design. This paper uses VHDL language to realize the circuit design of stopwatch. VHDL language is the standard hardware description language. Its characteristic is that it can formally express circuit structure and behavior, support the description of hierarchical domain in logical design, and simplify circuit description by using sophisticated structure of high-level language. It has the advantages of circuit simulation and verification, and ensures the correctness of the design. The integrated transformation of the supporting circuit from high level to bottom layer is convenient for document management, easy to understand and design reuse.

EDA technology is a computer software system developed on the basis of electronic CAD technology. It refers to the latest achievements in the application of electronic technology, computer technology, information processing and intelligent technology. Carry out automatic design of electronic products.

With EDA tools, electronic designers can design electronic systems from concepts, algorithms, protocols, etc. A lot of work can be done by computers, and electronic products can be designed from circuits. The whole process from analyzing the performance to designing the IC layout or PCB layout is automatically processed on the computer.

Now the concept or scope of EDA is very wide. Including in the fields of machinery, electronics, communications, aerospace, chemical, mineral, biological, medical, military and so on, there are applications of EDA. Enterprises and institutions and scientific research and teaching departments are widely used. For example, in the aircraft manufacturing process, from design, performance testing and characteristic analysis to flight simulation, it may involve EDA technology. The PCB design and IC design. EDA design can be divided into system level, circuit level and physical realization level.

4. Development and Optimization Design of Digital Logic device based on FPGA

FPGA (Field Programable Gate Array) is the most dynamic and promising technology in the field of electronic design, and its influence is no less than that of the invention and use of single chip microcomputer in 70s.

Actel released its ProASIC3 and ProASIC3E family of FPGAs at its California headquarters in January 24th 2005. This is the company's third generation of programmable logic solutions based on Flash. The new SIC3 will be priced at a minimum of $1.50. It represents the lowest cost in the world and has the advantage of confidentiality over FPGA based on SRAM. FPGA based on Flash can provide encryption, low power consumption, power up, and repeatable programming.

At present, the companies that produce FPGA are mainly Xilinx, Altera, FPGA, etc., there are many kinds and models of FPGA. Although the specific structure and performance of these FPGA have their own characteristics, they all have one thing in common, that is, they are arranged in arrays of
logical function blocks. And connect these logical functional blocks by programmable interconnect resources, from the.

Figure 4. Typical FPGA usually contains three basic resources: programmable logic function block

Typical FPGA usually contains three basic resources: programmable logic function block, programmable input/output block and programmable interconnection resource. Multiple logical function blocks are usually arranged into an array structure, distributed throughout the chip, programmable input/output blocks complete the interface between the internal logic of the chip and the external pin, and surround the array of logic cells. Programmable internal interconnection resources include wire segments of various lengths and programmable connectors that connect programmable logic blocks or input/output blocks together. A circuit that constitutes a particular function. Users can programmatically determine the functions of each unit and their interconnections, thus realizing the required logic functions. Different manufacturers or different models of FPGAs have the internal structure and scale of the programmable logic block. Interconnect junction.

There are often large differences in construction and other aspects.

VHDL was born on 1982. On end of 1987, VHDL was recognized as the standard hardware description language by IEEE and the US Department of Defense. Since IEEE published the standard version of VHDL, IEEE-1076 (87 for short), each EDA company has launched its own VHDL design environment one after another. Or announce that their design tools can interface with VHDL. Since then, VHDL has gained wide acceptance in the field of electronic design, and has gradually replaced the original non-standard hardware description language. And Verilog HDL was first created by PhilMoorby of GDA(Gateway Design Automation Company in end of 1983. At first, only one simulation and verification tool was designed, and then related fault simulation and timing analysis tools were developed one after another. In 1985, Moorby launched its third commercial simulator, Verilog, with great success. In 1989, CADENCE acquired GDA and Verilog HDL became the exclusive patent of the company. In 1990, CADENCE published Verilog HDL and set up LVI organization to promote Verilog HDL to become IEEE standard, namely IEEE Standard 1364-1995.

The VHDL language is mainly used to describe the structure, behavior, functions and interfaces of digital systems. Compared with other hardware description languages, the VHDL language has the following advantages [2].

1) VHDL language supports top-down top-down and library Base design methods, and also supports the design of synchronous circuit, asynchronous circuit and other random circuits.

2) the VHDL language has the ability to describe the hardware function of the system at different levels, from the mathematical model of the system to the gate circuit, and its high-level behavior description can be mixed with the low-level RTL description and the structure description. It can also customize the data type, which brings more freedom and convenience to the programmer.
3) The design description of VHDL is relatively independent, the designer can not understand the structure of the hardware, and does not care what the target device of the final design is;

4) VHDL has the function of circuit simulation and verification, which can guarantee the correctness of the design, and the user can debug the source code without even writing how to test the phasor. Moreover, the designers can compare the feasibility and the advantages and disadvantages of various schemes very conveniently, and do not need to do any practical circuit experiments.

5) VHDL language can be programmed independently of technology;

VHDL language standards, specifications, easy to share and reuse.

Generally speaking, a relatively large and complete project should be described in a hierarchical way: divide into several larger modules, define the interfaces between each functional module, and then subdivide each module to implement. This is the TOP DOWN (top-down) design method, which is now widely used. High level design is just defining the behavior characteristics of the system and can not involve the implementation process. Therefore, with the support of the factory synthesis library, the high-level description can be converted into a network table for some process optimization by using the comprehensive optimization tool, which makes the process transformation easy.

5. Summary

However, the practical application of a new method than raised more difficult, to consider all possible problems, the first is due to the design of a new method to make the circuit complexity increases exponentially, so if you are still using the traditional digital circuit to realize the PCB board area becomes extremely large and complicated. The signal to go long, cause system error increases, it is difficult to improve the working frequency of the system, in addition, the PCB board of low integration will also lead to the high frequency signal is vulnerable to outside interference, but may reduce the precision of frequency measurement. The programmable logic device can well overcome the above disadvantages, greatly improve the system clock, so the design will be introduced by field programmable gate array (FPGA) to achieve high precision frequency meter.

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References

[1] Carison S. VHDL Design(Representation & Synthesis). USA: Prentice Hall, 2016: P45-55.
[2] Wang Kaijun, Jiang Yubai, VHDL Design for CPLD/FPGA, Mechanical Industry Press, China, 2016.
[3] Huang Zhiwei. FPGA system Design and practice. Beijing: electronic Industry Publishing House, 2016.
[4] MA A shour, H I saleh An FPGA implem entation guide for some different types of serial—parallel multiplier structures. Microelectronics Journal, 2011, 31(3):161-168.
[5] Altera Corporation, QuartusII Handbook, Volume 1, Design & Synthesis, 2013.
[6] LU Shao qiang FPGA will gradually replace ASIC and ASSP, Electronic product ion world, 2014, (9): 26-28.
[7] Sun H, he H. Research and design of adaptive digital cymometer based on VHDL and FPGA. Journal of Tianjin University of Technology, 2013, 1(2): 50-60.