

OPTIMIZED ASIP SYNTHESIS FROM ARCHITECTURE DESCRI Document

Optimized ASIP Synthesis from Architecture Description: A Comprehensive Guide

Optimized ASIP synthesis from architecture description is a critical process in the development of application-specific instruction set processors (ASIPs). As the demand for tailored hardware solutions grows, efficient synthesis methods enable designers to create high-performance, low-power, and area-efficient processors that meet specific application requirements. This article delves into the fundamentals of ASIP synthesis, emphasizing optimization techniques derived from architecture descriptions, and provides insights into best practices for achieving optimal results.

Understanding ASIP and Its Significance

What is an ASIP?

An Application-Specific Instruction Set Processor (ASIP) is a customizable processor designed to execute a specific set of applications efficiently. Unlike general-purpose processors, ASIPs are tailored to optimize performance, power consumption, and area for particular tasks such as digital signal processing (DSP), network processing, or multimedia applications.

Importance of Optimized ASIP Synthesis

- Performance Enhancement: Customized instruction sets allow faster execution of target applications.
- Power Efficiency: Reduced instruction complexity leads to lower power consumption.
- Area Reduction: Optimized hardware minimizes silicon footprint.
- Cost Savings: Tailored designs can streamline manufacturing and deployment costs.

Architecture Description: The Foundation of Optimization

What is Architecture Description?

Architecture description involves defining the processor's structural and behavioral aspects, including:

- Instruction set architecture (ISA)
- Data paths and control units
- Memory hierarchy
- Peripheral interfaces
- Performance constraints

The Role in Synthesis

A comprehensive architecture description serves as the blueprint for synthesis tools, guiding the generation of hardware implementations aligned with design goals.

Stages of ASIP Synthesis from Architecture Description

1. High-Level Architecture Modeling

- Use of hardware description languages (HDLs) such as VHDL or Verilog.
- Behavioral modeling using high-level languages like C or SystemC for simulation.
- Specification of instruction set, data paths, and control flow.

2. Instruction Set Customization

- Identifying essential instructions for target applications.
- Removing unnecessary instructions to reduce complexity.
- Adding specialized instructions for performance-critical operations.

3. Optimization Techniques

- Resource sharing and functional unit reuse.
- Pipelining and parallelism for throughput enhancement.
- Power-aware design considerations.
- Area minimization strategies.

4. Synthesis and Implementation

- Logic synthesis translating HDL to gate-level netlists.
- Physical design optimization for placement and routing.
- Verification and validation against architecture specifications.

Key Optimization Strategies in ASIP Synthesis

Instruction Set Optimization

- Minimal Instruction Set: Focus on essential instructions to reduce complexity.
- Instruction Compression: Encode instructions efficiently to save space.
- Custom Instructions: Incorporate domain-specific instructions for performance boosts.

Data Path and Control Optimization

- Streamlining data paths to minimize latency.
- Employing multi-port memories to reduce bottlenecks.
- Control unit simplification to decrease area and power.

Resource Sharing and Scheduling

- Reusing functional units across different instructions.
- Scheduling instructions to maximize hardware utilization.
- Balancing pipeline depth and throughput.

Power and Area Optimization

- Applying clock gating techniques.
- Using low-power standard cells.
- Employing hierarchical design approaches.

Automation Tools and Frameworks

- High-Level Synthesis (HLS) tools to convert behavioral descriptions into hardware.
- Architecture description languages (ADLs) for precise specification.
- Optimization algorithms integrated into synthesis flows.

Challenges in Optimized ASIP Synthesis

- Complexity of Architecture Description: Detailed specifications can complicate synthesis.

- Trade-offs Between Performance and Power: Achieving a balance requires careful planning.
- Design Space Exploration: Navigating vast possibilities to find optimal solutions.
- Verification: Ensuring correctness while optimizing for multiple metrics.

Best Practices for Effective ASIP Synthesis from Architecture Descriptions

- Start with a clear and detailed architecture description aligned with application goals.
- Use high-level modeling to explore various design options early in the process.
- Leverage automation tools for instruction set customization and optimization.
- Incorporate power and area constraints into the early synthesis stages.
- Perform iterative design space exploration to balance trade-offs effectively.
- Validate each design iteration thoroughly through simulation and hardware prototyping.
- Document the architecture description comprehensively for future reference and scalability.

Future Trends in ASIP Synthesis and Optimization

Artificial Intelligence and Machine Learning Integration

- Using AI-driven algorithms to automate optimization decisions.
- Adaptive synthesis processes that learn from previous designs.

Advanced High-Level Synthesis Techniques

- Improved abstraction levels for faster design iterations.
- Enhanced algorithms for resource sharing and scheduling.

Reconfigurable and Adaptive ASIPs

- Hardware that adapts dynamically to changing application requirements.
- Incorporating partial reconfiguration capabilities.

Design for Heterogeneous Architectures

- Combining different processing elements for optimized performance.
- Integration of CPUs, GPUs, and specialized accelerators.

Conclusion

Optimized ASIP synthesis from architecture description is a vital process that enables the development of highly efficient, application-specific processors. By carefully modeling the architecture, customizing the instruction set, and applying advanced optimization techniques, designers can significantly enhance performance, reduce power consumption, and minimize silicon area. Embracing automation tools, exploring innovative design strategies, and staying abreast of emerging trends will continue to shape the future of ASIP development, making it an exciting and dynamic field for hardware designers and embedded system developers alike.

Keywords: ASIP synthesis, architecture description, instruction set optimization, hardware design, high-level synthesis, resource sharing, power optimization, design trade-offs, reconfigurable processors, embedded systems

Optimized ASIP Synthesis from Architecture Description: Advancing Custom Processor Design

In the rapidly evolving landscape of digital systems, application-specific instruction-set processors (ASIPs) have emerged as a pivotal solution for achieving high performance and energy efficiency tailored to specific applications. One of the core challenges in developing ASIPs lies in translating high-level architectural descriptions into optimized hardware implementations. This process, known as optimized ASIP synthesis from architecture description, has garnered significant attention from researchers and industry practitioners alike. It involves converting abstract architectural models into efficient, deployable hardware designs that meet performance, power, and area constraints, all while maintaining flexibility for future adaptations.

Understanding the Foundations of ASIP Synthesis

Before delving into the optimization techniques, it's essential to understand the basic framework of ASIP synthesis.

What is an Architecture Description?

An architecture description is a high-level formal or semi-formal specification of a processor's components, including its instruction set, datapaths, control logic, memory hierarchy, and peripheral interfaces. Languages such as Architecture Description Languages (ADLs), like Bluespec, Chisel, or even customized XML-based formats, serve as the blueprint for hardware generation.

The Synthesis Pipeline

The typical flow from architecture description to a physical hardware implementation involves several stages:

- Parsing and Analysis: Interpreting the architecture description to understand the components and their interconnections.
- Behavioral Modeling: Creating an intermediate model that captures the functional behavior of the architecture.
- Hardware Generation: Translating behavioral models into hardware descriptions, such as Register-Transfer Level (RTL) code.
- Optimization: Refining the RTL to meet specific goals regarding speed, power, and area.
- Verification & Validation: Ensuring the synthesized hardware faithfully implements the intended architecture.

While each stage is critical, the optimization phase is where significant gains are achieved, ensuring the final design is not just correct but also efficient and cost-effective.

The Significance of Optimization in ASIP Synthesis

Optimized synthesis transforms a straightforward hardware translation into a finely tuned processor architecture tailored to target applications. This process is crucial because:

- Performance Enhancement: Ensuring the processor executes instructions at maximum speed.
- Power Efficiency: Reducing energy consumption, vital for embedded and mobile devices.
- Area Reduction: Minimizing silicon footprint, leading to lower manufacturing costs.
- Flexibility & Scalability: Maintaining adaptability for future updates or different variants.

Achieving these objectives necessitates sophisticated optimization strategies, which are rooted in a deep understanding of both hardware design principles and the specific application domain.

Core Techniques in Optimized ASIP Synthesis

- Instruction Set Customization and Optimization

One of the primary advantages of ASIPs is their tailored instruction sets. During synthesis:

- Instruction Selection: Identify the most frequently used instructions and optimize their implementation.
- Instruction Encoding: Use compact encodings to reduce memory footprint.
- Instruction Scheduling: Arrange instructions to maximize parallelism and minimize pipeline stalls.

This targeted approach reduces unnecessary hardware complexity and increases throughput.

- Data Path Optimization

The data path forms the backbone of the processor's data processing capabilities. Optimization here involves:

- Resource Sharing: Combining functional units where possible.
- Pipeline Depth Adjustment: Balancing between deep pipelines (high frequency) and shorter pipelines (low latency).
- Operand Routing: Efficiently connecting data sources and sinks to minimize latency.

A carefully optimized data path ensures that the processor handles instructions efficiently under given constraints.

- Control Logic Refinement

Control units orchestrate the execution flow. Techniques include:

- Simplified Control Schemes: Using microprogramming or hardwired control for faster operation.
- Control Signal Optimization: Reducing redundant signals to save area.
- Dynamic Control: Employing adaptive control mechanisms for power savings during idle periods.

Optimized control logic contributes significantly to overall processor efficiency.

- Power and Area Management

Power-aware synthesis techniques aim to:

- Clock Gating: Disable inactive modules.
- Voltage Scaling: Adjust supply voltage dynamically.
- Logic Minimization: Use tools like Boolean algebra or synthesis algorithms to reduce gate count.

Simultaneously, area minimization involves:

- Component Reuse: Sharing registers, multiplexers, and functional units.
- Hierarchical Design: Modularizing components for easier optimization.
- Use of High-Level Synthesis (HLS)

High-Level Synthesis tools convert behavioral descriptions written in languages like C or C++ into RTL code. They enable:

- Automated Optimization: Applying algorithms for resource sharing, scheduling, and pipelining.
- Design Space Exploration: Rapidly evaluating various architectural configurations.
- Productivity Gains: Reducing manual coding errors and development time.

HLS is increasingly integral in modern ASIP synthesis workflows, facilitating rapid iteration and optimization.

Emerging Trends and Challenges in ASIP Synthesis

While significant progress has been made, several challenges persist:

- Automation and Design Space Exploration

Automating the optimization process remains complex:

- Multi-objective Optimization: Balancing performance, power, and area simultaneously.
- Constraint Handling: Meeting specific application or manufacturing constraints.

Advanced algorithms, including genetic algorithms and machine learning, are being employed to navigate the vast design space more effectively.

- Incorporating High-Level Descriptions

The push towards higher abstraction levels demands:

- Better ADLs: That can capture complex architectures and facilitate optimization.
- Integration with Software Toolchains: Ensuring the hardware aligns with compiler optimizations.

- Heterogeneous and Reconfigurable Architectures

Modern applications often require:

- Heterogeneous Processing Elements: Combining CPUs, GPUs, DSPs, and accelerators.
- Reconfigurable Hardware: FPGAs and other adaptable fabrics.

Optimized synthesis must handle these complex architectures efficiently.

Practical Applications of Optimized ASIP Synthesis

The benefits of optimized ASIP synthesis are evident across various domains:

- Embedded Systems: IoT devices, wearable tech, and automotive control units benefit from tailored, low-power processors.
- Digital Signal Processing: Custom accelerators for audio, video, and communication applications.
- Machine Learning: Specialized processors that accelerate neural network computations.
- Industrial Automation: Robust, efficient controllers designed for specific tasks.

In each case, the synthesis process ensures that hardware meets stringent performance and power requirements while maintaining cost-effectiveness.

The Future of ASIP Synthesis: Towards Fully Automated, Intelligent Design

Looking ahead, the trajectory points toward increasingly automated synthesis pipelines augmented by artificial intelligence:

- AI-Driven Optimization: Using machine learning models to predict optimal configurations.
- Design Space Automation: Enabling rapid, near-instantaneous exploration of architectural variants.
- Integration with System-Level Design: Ensuring ASIPs fit seamlessly within larger SoC ecosystems.

As these technologies mature, the process of generating highly optimized, application-specific hardware will become faster, more efficient, and more accessible, ultimately accelerating innovation in digital systems.

Conclusion

Optimized ASIP synthesis from architecture description represents a confluence of advanced design techniques, automation, and domain-specific customization. It empowers hardware designers to craft processors that are not only functionally accurate but also highly efficient in performance, power, and area. As applications continue to demand bespoke solutions, the importance of sophisticated, optimized synthesis processes will only grow. Embracing these methods promises a future where custom processors can be generated swiftly and efficiently, fueling innovation across industries from consumer electronics to mission-critical systems.

Question What is optimized ASIP synthesis from architecture description? **Answer** Optimized ASIP (Application-Specific Instruction-set Processor) synthesis from architecture description involves designing customized processors by translating high-level architectural specifications into efficient hardware implementations tailored for specific applications. Why is architecture description important in ASIP synthesis? Architecture description provides a high-level, formal representation of the processor's components and behavior, enabling automated synthesis tools to generate optimized hardware that meets specific performance, area, and power requirements. What are the key challenges in optimizing ASIP synthesis from architecture descriptions? Key challenges include balancing performance and resource constraints, ensuring correct functionality, managing complex design space exploration, and automating the translation from high-level descriptions to efficient hardware implementations. Which methods are commonly used for optimizing ASIP synthesis from architecture descriptions? Common methods include high-level synthesis, model-driven design, constraint-guided optimization, and using specialized tools like CAD/RTL synthesis frameworks that automate the transformation of architecture specifications into optimized hardware. How does automated optimization improve the ASIP design process? Automated optimization accelerates the design cycle, reduces human error, enables exploration of multiple design trade-offs quickly, and produces hardware that is fine-tuned for specific application requirements, leading to better performance and efficiency. What role do high-level languages play in ASIP synthesis from architecture descriptions? High-level languages like C, C++, or domain-specific languages allow designers to specify architecture and algorithm behavior at a higher abstraction level, which synthesis tools can then translate into optimized hardware implementations, streamlining the design process. What are the future trends in optimized ASIP synthesis from architecture descriptions? Future trends include increased use of machine learning for design space exploration, integration of more accurate modeling techniques, improved automation and tool support, and the development of more flexible, reconfigurable architectures tailored for emerging applications like AI and IoT.

Related keywords: ASIP synthesis, architecture description, hardware design, pipeline optimization, RTL design, custom processor, high-level synthesis, design automation, performance optimization, digital architecture

Architecture A Very Short Introduction Very Short

architecture a very short introduction very short is a concise way to understand the fundamental principles and significance of architecture as an art and science of designing spaces. Architecture shapes our environment, influences our daily lives, and reflects cultural identities across history. In this article, we will explore the key aspects of architecture, its history, types, elements, and its impact on society.

Understanding Architecture: A Brief Overview

What Is Architecture?

Architecture is the art and science of designing and constructing buildings and other physical structures. It combines creativity, technical skill, and practical considerations to create functional, safe, and aesthetically pleasing environments. Architecture is not only about shelter but also about creating spaces that inspire, communicate cultural values, and improve quality of life.

The Importance of Architecture

Architectural designs influence how people interact with their surroundings. Well-designed architecture enhances safety, efficiency, and comfort while also serving as a cultural expression. Iconic structures often become symbols of identity and pride for communities and nations.

The History of Architecture

Ancient Civilizations

Early architecture dates back to ancient civilizations such as Egypt, Mesopotamia, Greece, and Rome. These societies developed foundational structures like pyramids, temples, aqueducts, and amphitheaters, showcasing technological innovation and cultural priorities.

Medieval Architecture

Medieval architecture features castles, cathedrals, and monasteries characterized by Gothic and Romanesque styles. These structures emphasized grandeur, religious symbolism, and defensive features.

Renaissance and Modern Periods

The Renaissance revived classical principles, emphasizing symmetry, proportion, and harmony. The

modern era introduced new materials like steel and concrete, leading to innovative designs such as skyscrapers and contemporary architecture.

Contemporary Architecture

Today's architecture incorporates sustainable practices, smart technology, and minimalist aesthetics. It aims to balance environmental responsibility with functionality and aesthetic appeal.

Types of Architecture

Residential Architecture

Focuses on designing homes, apartments, and housing communities. Priorities include comfort, privacy, and functionality.

Commercial Architecture

Covers office buildings, shopping malls, hotels, and other business-related structures. These designs often emphasize accessibility, branding, and efficiency.

Industrial Architecture

Designs factories, warehouses, and plants. These structures prioritize durability, safety, and operational flow.

Institutional and Public Architecture

Includes schools, hospitals, government buildings, and cultural centers. The focus is on capacity, safety, and community service.

Landscape Architecture

Involves designing outdoor spaces such as parks, gardens, and urban plazas, integrating natural elements with built environments.

Key Elements of Architectural Design

Form and Function

The fundamental principle that architecture should be both aesthetically pleasing (form) and serve its intended purpose (function).

Space and Volume

The arrangement of interior and exterior spaces to facilitate movement, interaction, and comfort.

Materials and Construction

Choice of building materials influences durability, appearance, and sustainability.

Lighting and Ventilation

Designing for natural and artificial lighting, along with proper airflow, to enhance comfort and energy efficiency.

Structural Integrity

Ensuring safety and stability through sound engineering principles.

Architectural Styles and Movements

Classical Architecture

Features symmetry, columns, and elaborate ornamentation inspired by Greek and Roman designs.

Gothic Architecture

Known for pointed arches, ribbed vaults, flying buttresses, and stained glass windows.

Modernism

Emphasizes minimalism, functionalism, and the use of modern materials like steel and glass.

Postmodernism

Combines traditional elements with contemporary design, often with playful or ironic touches.

Sustainable Architecture

Focuses on environmentally friendly design practices, energy efficiency, and use of renewable materials.

The Role of Technology in Modern Architecture

Building Information Modeling (BIM)

A digital process that improves accuracy and collaboration during design and construction.

Parametric Design

Uses algorithms to generate complex forms and optimize performance.

Smart Buildings

Incorporate sensors, automation, and IoT technology to improve energy efficiency and user experience.

Green Building Materials

Use of eco-friendly, recycled, or low-impact materials to reduce environmental footprint.

The Impact of Architecture on Society

Economic Impact

Architectural projects generate jobs, attract tourism, and contribute to local economies.

Cultural Significance

Buildings often reflect cultural values, history, and identity, fostering community pride.

Environmental Responsibility

Sustainable architecture helps mitigate climate change through energy efficiency and green practices.

Urban Development and Planning

Good architecture promotes organized, accessible, and vibrant urban environments.

Challenges and Future Trends in Architecture

Climate Change and Sustainability

Architects are increasingly adopting eco-friendly designs to combat global warming.

Technological Integration

Advances in digital fabrication, AI, and robotics are transforming how structures are conceived and built.

Adaptive and Resilient Design

Creating buildings that can withstand natural disasters and adapt to changing conditions.

Inclusive Architecture

Designing spaces that are accessible and welcoming to all individuals, regardless of ability or background.

Conclusion

Architecture, though briefly introduced here, is a vital discipline that combines artistry, science, and social responsibility. It influences our surroundings profoundly, from iconic monuments to everyday homes. As technology advances and societal needs evolve, architecture continues to innovate, striving for sustainability, resilience, and inclusiveness. Understanding its principles and history enriches our appreciation for the built environment and inspires future generations to design thoughtful, impactful spaces.

Architecture: A Very Short Introduction

Architecture is often regarded as both an art and a science—an essential discipline that shapes the spaces where we live, work, and interact. It influences our environment, reflects cultural values, and showcases technological innovation. Despite its significance, many people seek a concise understanding of what architecture truly entails. This guide offers a very short introduction to architecture, exploring its fundamental concepts, history, key elements, and contemporary trends.

What is Architecture?

At its core, architecture is the practice of designing and constructing buildings and other physical structures. It goes beyond mere construction; it embodies creativity, functionality, cultural expression, and technical expertise. Architecture is about solving spatial problems—creating environments that are safe, comfortable, and inspiring.

The Dual Nature of Architecture

- Artistic Aspect: Architecture expresses aesthetic values, cultural identity, and artistic vision. It can evoke emotion, symbolize power, or reflect traditions.
- Technical Aspect: It involves engineering principles, material science, environmental considerations, and sustainability. Architects must ensure their designs are structurally sound and functional.

A Brief History of Architecture

Understanding architecture's evolution helps clarify its significance and the forces shaping it today.

Ancient Beginnings

- Prehistoric Structures: Early humans built shelters from natural materials like caves and simple huts.
- Ancient Civilizations: The Egyptians, Greeks, and Romans developed monumental architecture?pyramids, temples, aqueducts?demonstrating technological innovation and cultural values.

Medieval to Renaissance Era

- Gothic Cathedrals: Characterized by verticality, stained glass, and intricate stonework.
- Renaissance: Revival of classical ideals?symmetry, proportion, harmony?leading to iconic structures like Brunelleschi?s Dome.

Modern Architecture

- Industrial Revolution: New materials (steel, glass) and technologies revolutionized design possibilities.
- 20th Century: Movements like Modernism and Postmodernism challenged traditional aesthetics, emphasizing function, minimalism, and diversity.

Contemporary Trends

- Emphasis on sustainability, smart buildings, and adaptive reuse.
- Integration of digital tools like Building Information Modeling (BIM).

Key Elements of Architecture

Understanding architecture involves recognizing its core components:

Form and Space

- Form: The shape and configuration of a building.
- Space: The interior and exterior environments designed for human activity.

Function

Designs are driven by their purpose?residential, commercial, cultural, or recreational.

Materials

Choices range from traditional (stone, wood) to modern (concrete, steel, glass), affecting aesthetics, durability, and sustainability.

Light and Color

Lighting influences mood, functionality, and perception of space. Color adds emotional and visual impact.

Structural Systems

Frameworks that support buildings include:

- Load-bearing walls
- Framing systems (steel, timber)
- Innovative solutions (tensile structures)

Context and Environment

Designs respond to their surroundings?climate, landscape, urban fabric?blending or contrasting with existing environments.

The Role of an Architect

An architect is a professional responsible for the conception, design, and oversight of building projects. Their role includes:

- Understanding client needs and site conditions
- Developing design concepts
- Creating detailed drawings and models
- Coordinating with engineers, contractors, and stakeholders
- Ensuring compliance with regulations and standards

Modern Architectural Movements and Styles

While architecture is diverse, some notable styles include:

- Modernism: Emphasizes simplicity, functionality, and the absence of ornament.
- Postmodernism: Reacts against modernism, embracing eclecticism and symbolism.
- Brutalism: Features raw concrete and bold, geometric forms.
- Deconstructivism: Disrupts traditional forms to create fragmented and dynamic structures.
- Sustainable Architecture: Focuses on eco-friendly practices, energy efficiency, and materials.

Contemporary Topics in Architecture

Sustainability and Green Building

- Use of renewable energy sources
- Incorporation of green roofs and walls
- Passive design strategies for energy conservation

Smart Buildings and Technology

- Integration of IoT devices for automation
- Building management systems for efficiency
- Use of digital modeling and visualization tools

Urban Design and Public Spaces

- Creating inclusive, accessible urban environments
- Revitalization of neighborhoods and public parks
- Addressing urban challenges like congestion and pollution

The Impact of Architecture on Society

Architecture shapes societal values and behaviors. Well-designed spaces promote health, community, and cultural identity. Conversely, poorly planned structures can lead to social issues and environmental degradation.

Cultural Reflection

Buildings often symbolize cultural identity, history, and aspirations.

Economic Influence

Architectural innovation can boost tourism, property values, and local economies.

Environmental Responsibility

Sustainable design reduces carbon footprint and conserves resources.

Final Thoughts

While this very short introduction touches on the essentials, architecture is a vast field that intertwines creativity, science, and societal values. Every structure tells a story?about its creators, its users, and the times it was built in. Whether ancient or modern, architecture remains a vital part of our human experience, shaping the world around us in profound ways.

Remember: architecture is not just about buildings; it?s about creating environments that inspire, protect, and serve humanity?an ongoing dialogue between form, function, and environment.

QuestionAnswer What is the main focus of 'Architecture: A Very Short Introduction'? It provides a concise overview of architecture's history, principles, and significance in society. Who is the author of 'Architecture: A Very Short Introduction'? The book is authored by Andrew Ballantyne. Why is 'Architecture: A Very Short Introduction' considered a good starting point? Because it offers a brief yet comprehensive overview suitable for beginners and those interested in architecture. What topics are covered in this book? It covers architectural history, design principles, urban planning, and the cultural impact of architecture. Is 'Architecture: A Very Short Introduction' suitable for non-experts? Yes, it is written in an accessible manner, making complex concepts understandable for general readers. How does the book address modern architectural trends? It discusses contemporary styles, innovations, and the evolving role of architecture in society. Can this book help someone pursuing a career in architecture? Yes, it provides foundational knowledge that can enhance understanding and inspire further study in the field.

Related keywords: architecture, introduction, brief, overview, design, structure, building, urban planning, history, fundamentals

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