4/18/2023

Seminar Report

Name: Anmol Sharma
Roll No: 20BPH010
3rd Year
Electrical Engineering

Contents

Acknowledgement

I would like to express my gratitude to the Almighty and the National Institute of Technology for allowing me to work on this seminar report. I would want to express my gratitude to Dr.Himesh Handa and Dr. Rajesh Kumar for guiding and encouraging me to complete this report. I learned a lot about Cryptography and took a deep dive into the realm of FPGA and High Frequency Trading thanks to their guidance. I would want to express my gratitude to I Aldridge, the author of A Practical Guide to Algorithmic Strategies and Trading Systems, as well as everyone who contributed to the sources, I utilized to compile this report. Finally, I would like to extend my deep appreciation to my parents for their support and encouragement.

Introduction

High frequency trading (HFT) is a type of algorithmic trading that relies on high-speed and low-latency systems to execute a large number of trades in a fraction of a second. To achieve the required speed and performance, many HFT firms have turned to Field Programmable Gate Arrays (FPGAs) as a hardware acceleration solution.

FPGAs are integrated circuits that can be reconfigured after manufacturing to perform specific tasks. They offer several advantages for HFT, including lower latency, higher throughput, and better determinism compared to traditional software-based solutions. FPGAs can also be programmed to perform complex computations in parallel, enabling HFT firms to process vast amounts of data and execute trades with minimal delay.

In recent years, the use of FPGAs in HFT has grown significantly, with many firms investing heavily in this technology to gain a competitive edge in the market. However, implementing FPGA-based solutions requires specialized knowledge and expertise, as well as significant upfront investment in hardware and software development.

In this context, it is important to understand the benefits and challenges of using FPGAs in HFT, as well as the key considerations when designing and deploying FPGA-based trading systems. This introduction aims to provide an overview of the use of FPGAs in HFT and highlight some of the key trends and developments in this field.

.

FPGA (Field Programmable Gate array)

Field Programmable Gate Arrays (FPGAs) are integrated circuits that can be programmed and reprogrammed to perform specific tasks. Unlike Application-Specific Integrated Circuits (ASICs), which are designed for a specific purpose and cannot be modified after manufacturing, FPGAs can be reconfigured to suit different applications and tasks.

FPGAs consist of configurable logic blocks, input/output blocks, and programmable interconnects that allow for flexible routing of signals between different components. The logic blocks can be programmed to perform a variety of functions, such as digital signal processing, encryption, or image processing.

One of the key advantages of FPGAs is their high performance and low latency. Because the logic blocks can be configured to perform specific tasks in parallel, FPGAs can process data much faster than traditional software-based solutions. Additionally, FPGAs can be designed to operate

at very high frequencies, making them well-suited for applications that require real-time processing.

FPGAs are used in a wide range of applications, including telecommunications, aerospace, defence, and high-frequency trading. However, designing and programming FPGAs requires specialized knowledge and expertise, as well as significant upfront investment in hardware and software development. FPGAs consist of many configurable logic blocks (CLBs), which can be interconnected in various ways to implement complex digital circuits. Each CLB contains several lookup tables (LUTs) and flip-flops, which can be programmed to implement logic functions and state machines, respectively.

In addition to CLBs, FPGAs may also include other functional blocks such as memory, DSP blocks, and high-speed transceivers.

FPGAs offer several advantages over traditional ASICs and other programmable logic devices such as CPLDs (Complex Programmable Logic Devices). These advantages include:

1. Flexibility: FPGAs can be programmed to perform a wide variety of functions and can be reprogrammed as needed, making them ideal for prototyping and development.
2. Performance: FPGAs can provide high-speed performance and low latency, making them ideal for applications such as digital signal processing, high-speed networking, and video processing.
3. Power efficiency: FPGAs can be designed to minimize power consumption, making them ideal for battery-powered devices and other low-power applications.
4. Time-to-market: FPGAs can help reduce time-to-market for new products by enabling rapid prototyping and design iteration.
5. Scalability: FPGAs can be used to implement designs of varying complexity, from simple logic circuits to complex system-on-chip (SoC) designs.

However, FPGAs also have some limitations and challenges that need to be addressed. These include:

1. Cost: FPGAs can be expensive compared to other programmable logic devices and ASICs, especially for low-volume applications.
2. Design complexity: Designing complex FPGA circuits can be challenging and time-consuming, requiring specialized skills and tools.
3. Verification: Verifying the correctness of FPGA designs can be challenging due to the large number of possible configurations and interactions between the various logic blocks.

4. Security: FPGAs can be vulnerable to security threats such as reverse engineering and intellectual property theft, making it important to implement appropriate security measures.

Despite these challenges, FPGAs continue to be widely used in a variety of applications, including aerospace and defense, telecommunications, medical devices, industrial automation, and consumer electronics.

Conventional Trading

Trading refers to the buying and selling of financial instruments such as stocks, bonds, currencies, and commodities with the goal of making a profit. Traders can be individuals, institutions, or companies who participate in the market to generate returns.

There are two primary types of trading: short-term trading and long-term investing. Short-term traders aim to make quick profits by buying and selling financial instruments within a short period, usually within a day or a few weeks. Long-term investors, on the other hand, hold their investments for an extended period, usually for years, with the expectation of generating returns over time.

Trading can be conducted on various platforms, including stock exchanges, foreign exchange markets, and commodity markets. Investors use different trading strategies depending on their investment goals, risk tolerance, and market conditions. Some common trading strategies include:

1. Day Trading: This strategy involves buying and selling securities within the same day, aiming to profit from short-term price movements.
2. Swing Trading: This strategy involves holding positions for a few days to a few weeks, aiming to profit from medium-term price movements.
3. Position Trading: This strategy involves holding positions for several months or even years, aiming to profit from long-term price movements.
4. Algorithmic Trading: This strategy involves using computer programs to execute trades automatically based on pre-defined rules and market data.

Trading involves significant risks, including the possibility of losing your entire investment. Therefore, it's essential to have a well-defined trading plan and a risk management strategy to minimize losses. Successful traders typically have a deep understanding of market dynamics, technical analysis, and fundamental analysis to make informed trading decisions.

In conclusion, trading is a complex and dynamic process that involves buying and selling financial instruments to generate returns. It requires a sound understanding of market dynamics, risk management, and various trading strategies to be successful.

Options, futures, bonds, and shares are different types of financial instruments that investors can use to participate in the financial markets.

1. Options: Options are contracts that give the buyer the right but not the obligation to buy or sell an underlying asset at a specified price (strike price) within a specific time frame. There are two types of options: call options, which give the buyer the right to buy the underlying asset, and put options, which give the buyer the right to sell the underlying asset. Options are commonly used for hedging, speculation, and income generation.
2. Futures: Futures are contracts that require the buyer to purchase an underlying asset at a specific price on a future date. Futures contracts are standardized and traded on exchanges, and they are often used for hedging and speculation. Futures contracts are used to trade commodities, currencies, stock indices, and other financial instruments.

3. Bonds: Bonds are debt securities issued by governments or corporations to raise capital. When you purchase a bond, you are lending money to the issuer, who promises to pay you back the principal amount plus interest at a specified rate and time. Bonds are often considered less risky than stocks and are used by investors seeking a stable source of income.
4. Shares: Shares, also known as stocks, represent ownership in a company. When you buy a share of stock, you are buying a small piece of ownership in the company. Shares are traded on stock exchanges, and their prices are influenced by various factors, including the company's financial performance, industry trends, and macroeconomic conditions. Shares are commonly used for long-term investing and speculation.

In conclusion, options, futures, bonds, and shares are different types of financial instruments that investors can use to participate in the financial markets. Each of these instruments has its unique characteristics and is suitable for different investment goals, risk tolerance, and market conditions. Understanding the features and risks of these instruments is crucial before investing in them.

Algorithmic Trading

Algorithmic trading, also known as algo-trading or automated trading, is a type of trading strategy that uses computer programs or algorithms to execute trades automatically based on pre-defined rules and market data. It is used by traders and institutional investors to execute large orders with high speed and accuracy.

Algorithmic trading works by using complex mathematical models and algorithms to analyze market data, identify trends and patterns, and make trading decisions. The algorithms are designed to make trading decisions based on various parameters, including price, volume, volatility, and other technical indicators.

There are several types of algorithmic trading strategies, including:

1. Momentum trading: This strategy involves buying securities that are trending upwards in price and selling securities that are trending downwards.
2. Mean reversion trading: This strategy involves buying securities that are under-priced and selling securities that are overpriced.
3. Statistical arbitrage: This strategy involves identifying pricing discrepancies in related securities and exploiting them to generate profits.

4. High-frequency trading: This strategy involves executing trades at high speeds to take advantage of small price movements in the market.

Algorithmic trading offers several benefits, including:

1. Speed: Algorithms can execute trades much faster than humans, reducing the time it takes to execute large orders and minimizing the risk of price slippage.
2. Accuracy: Algorithms can analyze vast amounts of data and make trading decisions with a high degree of accuracy, minimizing errors caused by human emotions and biases.
3. Efficiency: Algorithmic trading can reduce trading costs by automating the execution of trades and minimizing the need for human intervention.

However, algorithmic trading also has several risks, including:

1. Technical failures: Algorithmic trading relies on technology, which can be vulnerable to technical glitches, network failures, and cyber-attacks.
2. Market risks: Algorithmic trading can be affected by sudden market movements, such as price gaps and flash crashes, which can lead to significant losses.
3. Model risks: Algorithmic trading relies on mathematical models and algorithms, which can be flawed or fail to perform as expected, leading to losses.

In conclusion, algorithmic trading is a type of trading strategy that uses computer programs or algorithms to execute trades automatically based on pre-defined rules and market data. It offers several benefits, including speed, accuracy, and efficiency, but also has several risks that need to be managed carefully. Understanding the features and risks of algorithmic trading is crucial before implementing this strategy.

HFT or Specialized system for arbitrage

Trading arbitrage is a strategy that involves buying and selling the same or similar assets in different markets or exchanges to take advantage of price differences between them. To execute trading arbitrage efficiently, traders often use special systems that are designed to analyze market data, identify arbitrage opportunities, and execute trades automatically.

These special systems are often called arbitrage bots or arbitrage trading software. They use complex algorithms and mathematical models to scan different markets or exchanges simultaneously, analyse price data, and identify potential arbitrage opportunities.

Arbitrage bots typically work in three main steps:

1. Scanning: The bot scans different markets or exchanges for price discrepancies between the same or similar assets.
2. Analysis: The bot analyses the price data and determines whether an arbitrage opportunity exists.
3. Execution: If an arbitrage opportunity exists, the bot automatically executes the trades to buy and sell the assets at the same time, making a profit from the price difference.

Arbitrage bots can be programmed to execute trades automatically and continuously, which allows traders to take advantage of arbitrage opportunities as soon as they arise. This can be especially beneficial for traders who are looking to execute high-frequency trading strategies.

However, there are several risks associated with trading arbitrage using special systems. These risks include technical failures, market risks, and regulatory risks. For example, technical failures can occur if the bot experiences glitches or malfunctions, which can lead to losses.

Market risks can occur if the price discrepancy between markets or exchanges narrows before the bot can execute the trades. Regulatory risks can occur if the bot violates any trading rules or regulations. In conclusion, trading arbitrage using special systems can be a profitable trading strategy for traders who are looking to take advantage of price discrepancies between different markets or exchanges.

However, it is important to understand the risks associated with this strategy and to use proper risk management techniques to mitigate those risks. Additionally, traders should carefully evaluate the performance of their arbitrage bots and adjust their trading strategies as needed to optimize their profitability.

High Frequency Trading

High-frequency trading (HFT) is a type of algorithmic trading that uses powerful computer programs to execute a large number of trades at very high speeds. HFT strategies typically rely on advanced technologies such as high-speed data networks, co-location facilities, and specialized trading hardware to gain an advantage over other traders in the market.

The basic idea behind HFT is to use algorithms to identify trading opportunities and execute trades within microseconds or milliseconds, which allows HFT firms to take advantage of small price discrepancies in the market. HFT firms often use complex mathematical models and machine learning techniques to analyze market data and identify profitable trading opportunities.

One of the key advantages of HFT is its speed. HFT firms typically use high-speed data networks and specialized trading hardware to execute trades at speeds that are orders of magnitude faster than human traders.

This allows HFT firms to take advantage of price discrepancies in the market before other traders can react, which can be especially beneficial in highly volatile markets.

However, HFT is not without its risks. One major risk is that HFT firms can amplify market volatility and contribute to "flash crashes" if their trading algorithms malfunction or if their trades are executed too quickly. Additionally, HFT firms can contribute to market fragmentation and liquidity fragmentation if they preferentially trade in certain venues or instruments.

HFT has become increasingly prevalent in financial markets over the past few decades, and it has been a source of controversy and debate among regulators, traders, and academics. While some argue that HFT provides liquidity and reduces trading costs for investors, others argue that it can distort market prices and unfairly disadvantage other traders. As a result, regulators around the world have implemented various measures to monitor and regulate HFT activities.

FPGA design for High Frequency Trading

The basic idea behind FPGA design for HFT is to create a hardware-based solution that can perform the necessary computations and decision-making processes required for trading without the latency and overhead associated with software-based solutions. FPGA-based solutions can execute trades at speeds that are orders of magnitude faster than traditional software-based solutions, which can be a significant advantage in HFT.

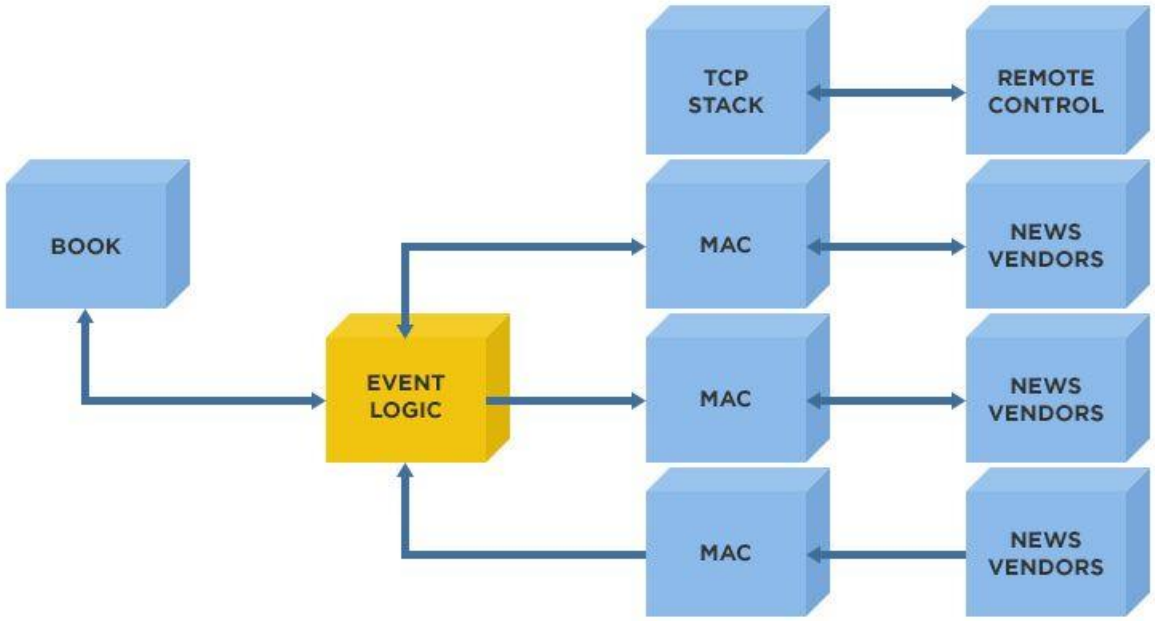
One common application of FPGA design for HFT is to create custom order matching engines. An order matching engine is a system that matches buy and sell orders in a market or exchange. By creating a custom order matching engine using FPGA design, HFT firms can reduce the latency associated with traditional software-based order matching engines, allowing them to execute trades at faster speeds.

Another application of FPGA design for HFT is to create custom network interfaces. HFT firms often use specialized data networks to transmit market data and execute trades. By creating custom network interfaces using FPGA design, HFT firms can reduce the latency associated with traditional software-based network interfaces, allowing them to receive market data and execute trades at faster speeds.

However, FPGA design for HFT is a complex and specialized field that requires expertise in both hardware and software engineering. Additionally, FPGA-based solutions can be expensive to develop and

maintain, which can be a significant barrier to entry for smaller HFT firms.

In conclusion, FPGA design can be a powerful tool for creating custom hardware solutions for HFT. However, it is important to carefully evaluate the costs and benefits of FPGA-based solutions and to ensure that they are properly integrated into an HFT firm's overall trading strategy.



Latency analysis for FPGA based system

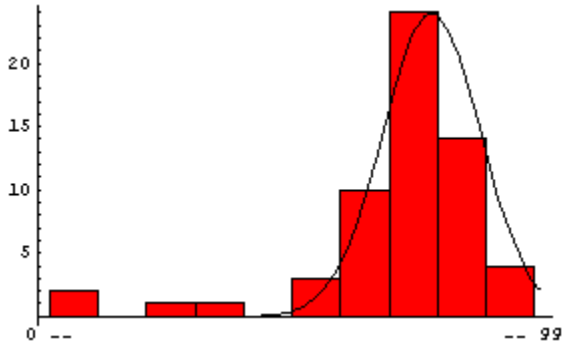
Compare Latency differences between FPGA and Conventional

One of the primary sources of latency in trading systems is the time it takes for data to be transmitted from the source to the destination and processed by the system. With FPGA, data can be processed directly on the hardware, rather than being passed through a series of software-based layers. This can significantly reduce the time it takes to process and execute trades.

Table 8.8 Calculation of χ^2 for comparison between actual distribution and theoretical distribution					
Mice	Observed cases	Theoretical proportions	Expected cases	O - E	$(O - E)^2/E$
Entirely white	380	0.510	400	-20	1.0000
Small brown patch	330	0.408	320	10	0.3125
Large brown patch	74	0.082	64	10	1.5625
Total	**784**	**1.000**	**784**	**0**	**2.8750**

Analyzing Timing Error

Timing errors occur when the FPGA's clock signals are not synchronized properly, causing data to be processed or transmitted at incorrect times. Timing errors can lead to incorrect data processing or missed trading opportunities, which can result in significant financial losses.



Conclusion

In conclusion, FPGA (Field-Programmable Gate Array) based trading offers several advantages over traditional software-based trading systems. By leveraging the hardware-level processing capabilities of FPGA, high-frequency trading (HFT) firms can execute trades at speeds that are orders of magnitude faster than traditional software-based solutions.

FPGA can significantly reduce trading latency by processing data and executing trades directly on the hardware, rather than passing them through a series of software-based layers. Additionally, FPGA can perform multiple tasks simultaneously and prioritize certain tasks to further reduce latency.

While FPGA based trading offers several advantages, it also poses some challenges. FPGA designs can be complex and difficult to program, and errors can have serious consequences in HFT applications. It is important to thoroughly test and verify FPGA designs before deploying them in a production environment, and to have proper monitoring and error reporting systems in place to detect and address errors as they occur.

Overall, FPGA based trading is a powerful tool that can offer significant benefits to HFT firms. By leveraging the hardware-level processing capabilities of FPGA, HFT firms can gain a competitive advantage in the market and execute trades at speeds that were once unimaginable. However, it is important to carefully consider the challenges and risks associated with FPGA based trading, and to implement appropriate measures to mitigate these risks.

References

- Algorithmic Trading Statistics: https://www.mordorintelligence.com/industry-reports/algorithmic-trading-market
- https://straitsresearch.com/report/algorithmic-trading-market
- NASA study on FPGA: https://nepp.nasa.gov/files/22744/nsrec09sc_Berg.pdf
- Article on FPGA based systems: https://www.mavensecurities.com/fpgas-in-trading/
- High Frequency Trading : https://www.youtube.com/watch?v=z4nCTdQlH8w&t=466s
- Textual Reference on HFT: https://www.amazon.in/High-Frequency-Trading-Practical-Algorithmic-Strategies/dp/1118343506
- Optiliver insite on FPGA based trading systems: https://www.youtube.com/watch?v=RCb8PsdipHI