📚 Object-Oriented Programming (OOP) & SOLID Principles Complete Guide

📖 Table of Contents

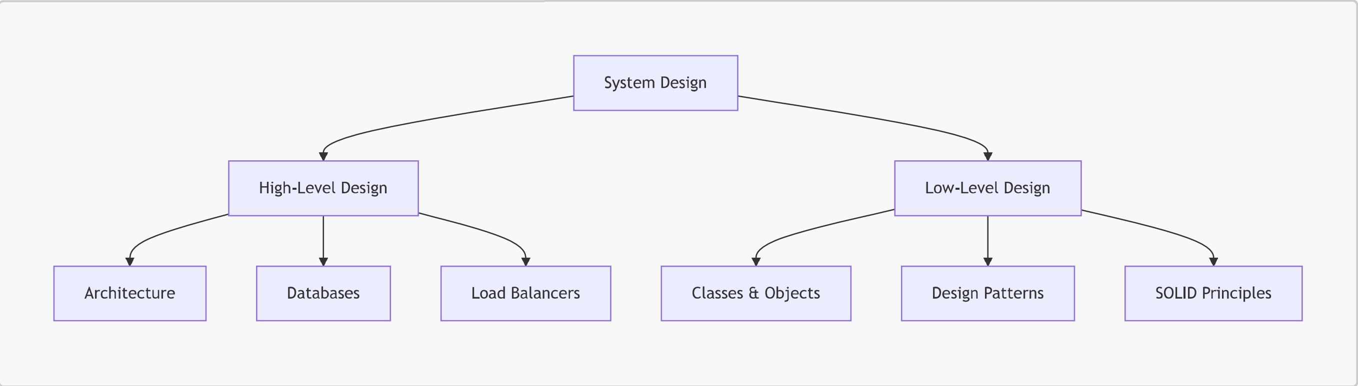
🎯 Introduction

Welcome to the comprehensive guide on **Object-Oriented Programming (OOP)** and **SOLID Principles**! This documentation covers fundamental concepts essential for Low-Level System Design (LLD) and software development best practices.

🎪 What is Low-Level Design (LLD)?

> **LLD focuses on writing clean, maintainable, and extensible code**

- **High-Level Design (HLD)**: System architecture, databases, microservices, load balancers
- **Low-Level Design (LLD)**: Classes, functions, code structure, design patterns



🏗 Object-Oriented Programming Basics

🔧 Classes and Objects

📝 Definition

- **Class**: Blueprint or template that defines structure
- **Object**: Instance of a class with actual values

💡 Real-World Examples

```
// Class - Blueprint
public class Order {
    private String orderId;
    private String status;
    private List<Item> items;

    // Methods
    public void placeOrder() { /* implementation */ }
    public void getOrderDetails() { /* implementation */ }
}

// Objects - Instances
Order order1 = new Order(); // Specific order instance
Order order2 = new Order(); // Another order instance
```

```
// C++ Example
class Car {
private:
    string model;
    int year;
public:
    void start() { /* implementation */ }
    void stop() { /* implementation */ }
};

// Objects
Car hondaCivic;  // Object of Car class
Car toyotaCamry; // Another object
```

🔐 Access Modifiers

Modifier	C++	Java	Description
Private	✅	✅	Accessible only within the class
Public	✅	✅	Accessible from anywhere
Protected	✅	✅	Accessible by subclasses (C++) or within package (Java)

🎭 Four Pillars of OOP

1. 🎒 Encapsulation

> **Bundling data and methods together while controlling access**

🎯 **Benefits:**

- Data integrity

- Clear separation of concerns
- Access control

```
public class BankAccount {
    private double balance; // Private data

    // Controlled access through methods
    public void deposit(double amount) {
        if (amount > 0) {
            balance += amount;
        }
    }

    public double getBalance() {
        return balance;
    }
}
```

2. 🎭 Abstraction

> **Hiding complex implementation details and showing only essential features**

📱 Real-World Example:

When using Google Maps, you don't need to know the complex algorithms behind route calculation.

```
// Interface - Abstract layer
public interface PaymentProcessor {
    void processPayment(double amount);
}

// Concrete implementations
public class UPIPayment implements PaymentProcessor {
    public void processPayment(double amount) {
        // UPI-specific implementation
    }
}

public class CreditCardPayment implements PaymentProcessor {
    public void processPayment(double amount) {
        // Credit card-specific implementation
    }
}
```

3. 🧬 Inheritance

> **Creating new classes based on existing classes to promote code reuse**

```java
// Base class
public class Employee {
    protected String name;
    protected String employeeId;

    public void paySalary() { /* common implementation */ }
    public void promote() { /* common implementation */ }
}

// Derived classes
public class Manager extends Employee {
    private int teamSize;

    public void conductMeeting() { /* manager-specific */ }
}

public class Developer extends Employee {
    private String programmingLanguage;

    public void writeCode() { /* developer-specific */ }
}
```

4. 🔄 Polymorphism

> **One interface, multiple implementations**

Types:

1. **Compile-time**: Function overloading
2. **Runtime**: Function overriding

```java
// Runtime Polymorphism Example
public class OrderProcessor {
    public void processOrder(Order order) {
        // Base implementation
    }
}

public class BuyOrderProcessor extends OrderProcessor {
    @Override
    public void processOrder(Order order) {
        // Buy-specific logic
        checkWalletBalance();
        executeBuyOrder();
    }
}

public class SellOrderProcessor extends OrderProcessor {
    @Override
    public void processOrder(Order order) {
        // Sell-specific logic
```

```
        checkStockAvailability();
        executeSellOrder();
    }
}
```

🏛️ Abstract Classes vs Interfaces

📊 Comparison Table

Feature	Abstract Class	Interface
Implementation	Can have some implemented methods	No implementation (traditionally)
Variables	Can have instance variables	Only constants
Inheritance	Single inheritance	Multiple inheritance
Usage	`extends`	`implements`

💡 When to Use What?

```java
// Abstract Class - When you have common code
abstract class Vehicle {
    protected String model;

    // Common implementation
    public void start() {
        System.out.println("Starting " + model);
    }

    // Must be implemented by subclasses
    public abstract void move();
}

// Interface - When you want to enforce a contract
public interface Flyable {
    void fly();
    void land();
}

public class Airplane extends Vehicle implements Flyable {
    public void move() {
        fly(); // Implementation of abstract method
    }

    public void fly() {
        System.out.println("Flying in the sky");
    }

    public void land() {
        System.out.println("Landing on runway");
```

```
    }
}
```

💎 SOLID Principles

> **Five design principles for writing maintainable, flexible code**

🎯 S - Single Responsibility Principle (SRP)

> **A class should have only one reason to change**

❌ **Violating SRP:**

```java
// BAD: Multiple responsibilities
public class OrderValidator {
    public boolean validateUserInput(Order order) { /* ... */ }
    public boolean checkSecurity(User user) { /* ... */ }
    public boolean validateFunds(User user, double amount) { /* ... */ }
    public void sendErrorEmail(String error) { /* ... */ }
    public void logError(String error) { /* ... */ }
}
```

✅ **Following SRP:**

```java
// GOOD: Separated responsibilities
public class UserInputValidator {
    public boolean validate(Order order) { /* ... */ }
}

public class SecurityChecker {
    public boolean checkPermissions(User user) { /* ... */ }
}

public class FundsValidator {
    public boolean hasSufficientFunds(User user, double amount) { /* ... */ }
}

public class NotificationService {
    public void sendErrorEmail(String error) { /* ... */ }
}
```

🚪 O - Open/Closed Principle (OCP)

> **Open for extension, closed for modification**

❌ **Violating OCP:**

```java
// BAD: Need to modify existing code for new features
public class Logger {
    public void log(String message, String type) {
        if (type.equals("DEBUG")) {
            System.out.println("DEBUG: " + message);
        } else if (type.equals("INFO")) {
            System.out.println("INFO: " + message);
        } else if (type.equals("ERROR")) {  // Adding this requires modification
            System.err.println("ERROR: " + message);
        }
    }
}
```

✅ **Following OCP:**

```java
// GOOD: Extensible without modification
public abstract class Logger {
    public abstract void log(String message);
}

public class DebugLogger extends Logger {
    public void log(String message) {
        System.out.println("DEBUG: " + message);
    }
}

public class InfoLogger extends Logger {
    public void log(String message) {
        System.out.println("INFO: " + message);
    }
}

// New logger can be added without changing existing code
public class ErrorLogger extends Logger {
    public void log(String message) {
        System.err.println("ERROR: " + message);
    }
}
```

🔄 L - Liskov Substitution Principle (LSP)

> **Objects of superclass should be replaceable with objects of subclass**

❌ **Violating LSP:**

```java
// BAD: Square violates Rectangle's behavior
public class Rectangle {
    protected int width, height;
```

```java
    public void setWidth(int width) { this.width = width; }
    public void setHeight(int height) { this.height = height; }
    public int getArea() { return width * height; }
}

public class Square extends Rectangle {
    @Override
    public void setWidth(int width) {
        this.width = width;
        this.height = width; // Violates expectation!
    }
}

// This test will fail for Square
public void testRectangle(Rectangle r) {
    r.setWidth(5);
    r.setHeight(4);
    assert r.getArea() == 20; // Fails for Square!
}
```

✅ **Following LSP:**

```java
// GOOD: Proper inheritance hierarchy
public abstract class Shape {
    public abstract double getArea();
}

public class Rectangle extends Shape {
    private int width, height;

    public Rectangle(int width, int height) {
        this.width = width;
        this.height = height;
    }

    public double getArea() { return width * height; }
}

public class Square extends Shape {
    private int side;

    public Square(int side) {
        this.side = side;
    }

    public double getArea() { return side * side; }
}
```

🧩 I - Interface Segregation Principle (ISP)

> **No client should be forced to depend on methods it doesn't use**

❌ **Violating ISP:**

```java
// BAD: Fat interface forces unnecessary implementation
public interface User {
    void login();
    void logout();
    void doKYC(); // Not needed for all users!
    void processPayment();
}

public class Customer implements User {
    public void login() { /* implementation */ }
    public void logout() { /* implementation */ }
    public void doKYC() {
        // Empty implementation - violation!
        throw new UnsupportedOperationException("Customers don't need KYC");
    }
    public void processPayment() { /* implementation */ }
}
```

✅ **Following ISP:**

```java
// GOOD: Smaller, specific interfaces
public interface Authenticatable {
    void login();
    void logout();
}

public interface PaymentCapable {
    void processPayment();
}

public interface KYCRequired {
    void doKYC();
}

public class Customer implements Authenticatable, PaymentCapable {
    public void login() { /* implementation */ }
    public void logout() { /* implementation */ }
    public void processPayment() { /* implementation */ }
}

public class DeliveryPartner implements Authenticatable, KYCRequired {
    public void login() { /* implementation */ }
    public void logout() { /* implementation */ }
    public void doKYC() { /* implementation */ }
}
```

⬇️ D - Dependency Inversion Principle (DIP)

> **High-level modules should not depend on low-level modules. Both should depend on abstractions.**

❌ **Violating DIP:**

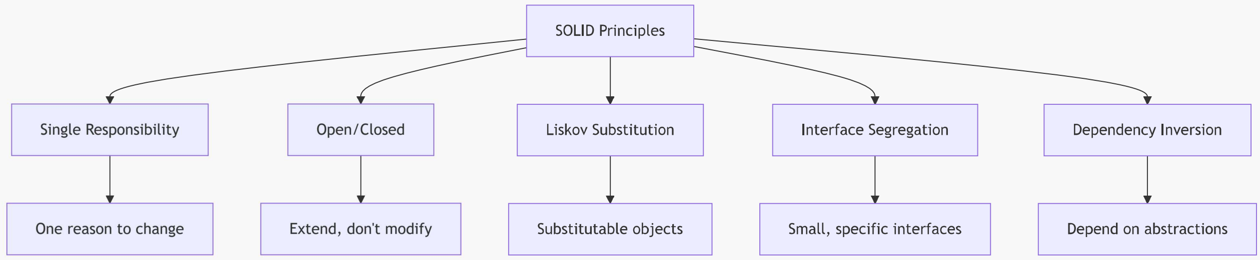
```java
// BAD: Direct dependency on concrete classes
public class NotificationManager {
    private SMSSender smsSender = new SMSSender();
    private EmailSender emailSender = new EmailSender();

    public void sendNotification(String message, String type) {
        if (type.equals("SMS")) {
            smsSender.sendSMS(message);
        } else if (type.equals("EMAIL")) {
            emailSender.sendEmail(message);
        }
        // Adding new type requires code change!
    }
}
```

✅ **Following DIP:**

```java
// GOOD: Depend on abstractions
public interface NotificationSender {
    void send(String message);
}

public class SMSSender implements NotificationSender {
    public void send(String message) {
        // SMS implementation
    }
}

public class EmailSender implements NotificationSender {
    public void send(String message) {
        // Email implementation
    }
}

public class NotificationManager {
    private List<NotificationSender> senders;

    public NotificationManager(List<NotificationSender> senders) {
        this.senders = senders;
    }

    public void sendNotification(String message) {
        for (NotificationSender sender : senders) {
```

```
                sender.send(message);
            }
        }
    }
```

📊 SOLID Principles Summary



🎯 Benefits of Following SOLID

Principle	Benefit	Example
SRP	🎯 **Focused classes**	Easy to understand and maintain
OCP	🔧 **Extensible code**	Add features without breaking existing code
LSP	🔄 **Reliable inheritance**	Predictable behavior in polymorphism
ISP	🧩 **Clean interfaces**	No forced implementations
DIP	⚡ **Loose coupling**	Easy to test and modify

🏆 Best Practices

✅ Do's

- 🎯 Keep classes focused on single responsibility
- 🔧 Use inheritance and composition wisely
- 📝 Write self-documenting code
- 🧪 Make code testable
- 🔄 Favor composition over inheritance when appropriate

❌ Don'ts

- 🚫 Don't create "God classes" that do everything
- 🚫 Don't force inheritance where it doesn't make sense
- 🚫 Don't write comments to explain bad code
- 🚫 Don't violate SOLID principles for short-term gains

📚 Key Takeaways

> **Remember: SOLID principles work together!**

1. **Start with requirements** - Understand what you're building
2. **Design before coding** - Think about structure first
3. **Keep it simple** - Don't over-engineer
4. **Make it extensible** - Code should grow with requirements
5. **Write for humans** - Code should be readable and maintainable

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🎓 Interview Tips

Common Questions:

1. **Explain OOP concepts with real-world examples**
2. **What are SOLID principles and why are they important?**
3. **When would you use abstract classes vs interfaces?**
4. **Give an example of violating and following each SOLID principle**

💡 Pro Tips:

- Always use real-world examples (Swiggy, Uber, Amazon)
- Explain the "why" behind each principle
- Show both violation and correct implementation
- Connect principles to actual work scenarios
