Let’s do a **deep dive into designing an E-Commerce Platform** like **Amazon**, covering all critical aspects from a system design interview perspective—scalability, availability, microservices, data models, search, order processing, and more.

**🧠 1. Functional Requirements**

**✅ Core Features**

* User registration/login
* Browse products by category/search
* Product detail view (with reviews, images)
* Add to cart / wishlist
* Place orders (with payment)
* Track orders
* Manage inventory and returns
* Seller onboarding (optional)
* Promotions and recommendations

**📏 2. Non-Functional Requirements**

* **High Availability** – Ensure users can access the platform at all times.
* **Scalability** – Handle millions of users, orders, and products.
* **Low Latency** – Fast search, page loads, and checkout process.
* **Reliability** – Especially around inventory, payments, and delivery.
* **Security** – Secure transactions and user data.

**🧱 3. High-Level Architecture**

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+-------------------+

| Web / App |

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|

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| API Gateway |

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| | | |

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| Search | | Product Svc | | Order Service | | User Svc |

| Service | | | +---------------+ +-----------+

+---------+ +-------------+ |

| | |

+--------+ +-------------+ +------------------+

|Elastic | |Product DB | |Order DB / Kafka |

|Search | |(SQL/NoSQL) | +------------------+

+--------+ +-------------+ |

+------------+

| Payment Svc|

+------------+

|

+--------+

| Stripe |

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**🔧 4. Microservices Breakdown**

**4.1 User Service**

* User registration/login (OAuth2, JWT)
* Manage addresses, preferences, wishlist
* Service stores in **PostgreSQL / MongoDB**

sql

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Table: users

- user\_id (PK)

- name

- email

- password\_hash

- address[]

**4.2 Product Service**

* CRUD for products (admin/seller)
* Product details, variants (color/size)
* Indexed for search
* Stored in **NoSQL** (like DynamoDB or MongoDB)

json

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{

"product\_id": "123",

"name": "Nike Shoes",

"category": "Footwear",

"variants": [{"size": 9, "color": "Black"}],

"inventory": 200,

"price": 99.99

}

**4.3 Inventory Service**

* Tracks real-time stock levels
* Locks stock when order is placed
* Reduces on successful payment
* **Event-driven** (Kafka for consistency)

**4.4 Cart Service**

* Stores items users add to their cart
* Redis or NoSQL for fast access
* TTL on carts for cleanup

json

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{

"user\_id": "u123",

"items": [

{"product\_id": "p789", "quantity": 2}

]

}

**4.5 Search Service**

* Powered by **Elasticsearch**
* Syncs with product catalog changes via Kafka
* Handles full-text search, filters, and sorts

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Query: "Nike Black Shoes size 10"

→ Results filtered by category, color, and size

**4.6 Order Service**

* Accepts and places orders
* Generates order ID and status = PENDING
* Coordinates with:
  + Inventory Service to lock items
  + Payment Service to confirm payment
* Saves to SQL or NoSQL (partitioned by user ID)

sql

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Table: orders

- order\_id

- user\_id

- total\_amount

- status [PENDING, PAID, SHIPPED, DELIVERED]

- order\_items[]

**4.7 Payment Service**

* Integrates with third-party (e.g., Stripe, PayPal)
* Secure processing (PCI-DSS compliant)
* On success: updates order status + reduces inventory
* On failure: order canceled, stock restored

**4.8 Notification Service**

* Sends email/SMS for:
  + Order placed
  + Payment confirmation
  + Delivery updates
* Async via Kafka

**4.9 Recommendation Service**

* Collaborative filtering, ML models
* “Users also bought...”, “Frequently bought together”

**4.10 Admin Portal / Seller Service (Optional)**

* Product listing management
* Inventory & order management
* Dashboard for analytics

**📦 5. Order Placement Flow**

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Client → Cart Service → Order Service

→ Inventory check & lock

→ Payment Service

→ Third-party Payment Gateway

→ Payment Success → Inventory Deducted

→ Order Status updated → Notification sent

**🛒 6. Product Search Flow**

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Client → Search Service

→ Elasticsearch

→ Filters by category, price, rating, etc.

→ Product metadata + thumbnail returned

**🧠 7. Scalability and Reliability**

| **Component** | **Strategy** |
| --- | --- |
| Product Catalog | NoSQL sharding (by category ID) |
| Orders DB | Partition by user or order\_id |
| Cart Service | Redis Cluster |
| Search | Elasticsearch Cluster |
| Inventory | CQRS + Kafka for events |
| Payment | Idempotent APIs, retries, logs |
| Static Media | S3 + CloudFront (CDN) |
| Web/App Tier | Horizontal scaling (Load Balancer) |

**🔐 8. Security**

* HTTPS for all traffic
* JWT + OAuth2 for user authentication
* API Gateway rate-limiting
* Secure payment via PCI-DSS compliant processors
* Admin controls for fraud detection

**🔁 9. Async / Event-Driven Systems (Kafka)**

* Kafka Topics:
  + order\_placed
  + payment\_success
  + inventory\_locked
  + notification\_triggered
  + product\_indexed (for Elasticsearch)

This ensures loose coupling and eventual consistency across services.

**🧪 10. Optional C++ Component Example: Inventory Locking Engine**

cpp

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class InventoryManager {

public:

bool lockStock(const std::string& productId, int quantity) {

std::unique\_lock<std::mutex> lock(mutex\_);

if (inventory\_[productId] >= quantity) {

inventory\_[productId] -= quantity;

return true;

}

return false;

}

void restock(const std::string& productId, int quantity) {

std::unique\_lock<std::mutex> lock(mutex\_);

inventory\_[productId] += quantity;

}

private:

std::unordered\_map<std::string, int> inventory\_;

std::mutex mutex\_;

};

**📊 11. Data Model Summary**

| **Entity** | **Store** | **Type** |
| --- | --- | --- |
| Users | PostgreSQL | SQL |
| Products | MongoDB | NoSQL |
| Orders | MySQL/Cassandra | SQL/NoSQL |
| Cart | Redis | In-Memory |
| Inventory | DynamoDB | NoSQL |
| Media | S3 | Object |

**🎯 12. Interview Tips**

| **Topic** | **Expect Questions Like:** |
| --- | --- |
| Search & Filtering | How to index billions of products fast? |
| Order Consistency | How do you prevent race conditions on stock? |
| Inventory | How do you handle inventory across regions? |
| Fault Tolerance | What happens if payment fails mid-order? |
| Async Communication | How do services stay in sync? |
| Scaling Search | How do you scale Elasticsearch writes & reads? |
| Media Handling | How do you serve images/videos globally? |

Would you like to expand on **seller systems**, **promotions/discount engines**, **real-time order tracking**, or **eventual consistency with retries** in the next step?

4o

**You said:**

Go in details for components/Questions expected in interviews

**ChatGPT said:**

Absolutely! Let’s go **deeper into the key components of the E-Commerce system**, focusing on **how they work**, **why they’re designed that way**, and **what kind of questions interviewers may ask** — especially in **System Design interviews for Amazon, Google, etc.**

**🧱 COMPONENTS + INTERVIEW QUESTIONS DEEP DIVE**

**✅ 1. API Gateway**

**Purpose:**

* Entry point for all client requests.
* Handles routing, auth, rate limiting, etc.

**Design Decisions:**

* Use **OAuth2 / JWT** for authentication.
* Rate-limit and log requests.
* Forward requests to the appropriate microservices.

**Questions Interviewers Might Ask:**

* How do you **throttle users** or **prevent abuse**?
* How do you handle **API versioning**?
* Can the gateway be a **SPOF** (single point of failure)?

**Tips:**

* Use a scalable API Gateway (e.g., Kong, Envoy).
* Apply caching headers and gzip compression at this level.

**🛍️ 2. Product Catalog Service**

**Purpose:**

* Store product metadata (name, price, variants, tags, etc.)
* Serve detailed views of products.

**Storage:**

* Use **NoSQL (MongoDB/DynamoDB)** to scale reads.
* Denormalize for performance (e.g., store product + variants together).

**Sample Interview Questions:**

* How would you store **product variants** like size/color?
* How would you design catalog updates for **millions of items**?
* How do you handle **global product versions (i.e., localized)?**

**Tips:**

* Support eventual consistency (catalog updates don't block user read).
* Use **soft deletes** to mark removed products.

**🛒 3. Cart Service**

**Purpose:**

* Temporarily store items user is interested in purchasing.

**Storage:**

* Use **Redis** or **Cassandra** with TTL for performance.
* UserID → list of productIDs, quantities.

**Questions to Expect:**

* How do you persist carts across sessions?
* How do you prevent **race conditions** (e.g., 2 sessions editing)?
* How to sync cart across devices?

**Tips:**

* Use **Write-through caching** if Redis crashes.
* Add a job to clean abandoned carts.

**🧾 4. Order Management Service**

**Purpose:**

* Place and track orders.
* Handle state transitions: CREATED → PAID → SHIPPED → DELIVERED.

**Storage:**

* Use **SQL (PostgreSQL/MySQL)** for order integrity.
* Partition by user\_id or region.

**Typical Questions:**

* How do you **ensure orders are processed exactly once**?
* How do you handle **idempotency** in order creation?
* What if payment goes through but order DB write fails?

**Tips:**

* Use **distributed transaction patterns**: SAGA / Outbox.
* Assign **UUIDs** client-side to support idempotency.

**📦 5. Inventory Service**

**Purpose:**

* Maintain stock counts.
* Prevent overselling.

**Storage:**

* NoSQL (DynamoDB) or in-memory with Redis for fast reads.

**Interview Traps & Questions:**

* How do you **handle concurrent orders** trying to buy same stock?
* What if the **stock is locked but order fails**?
* How do you **sync stock across warehouses**?

**Tips:**

* Use **pessimistic locking** or Redis atomic counters.
* Implement **inventory rollback logic** on failure.

**🔍 6. Search & Filter (Elasticsearch)**

**Purpose:**

* Full-text product search, filters (e.g., price, brand, rating).

**Design:**

* Keep search index in **sync with product catalog** via Kafka.
* Store denormalized index docs for performance.

**Sample Questions:**

* How do you keep **Elasticsearch in sync** with product DB?
* How do you scale **autocomplete / keyword search**?
* How do you support **multi-language search**?

**Tips:**

* Use **bulk indexing** with Kafka consumers.
* Denormalize fields for facet filtering.

**🧾 7. Payment Service**

**Purpose:**

* Securely collect payments (Stripe, PayPal).
* Trigger post-payment workflows (shipping, confirmation).

**Design Decisions:**

* Integrate with 3rd-party providers.
* Ensure **idempotent payment handling**.

**Expected Questions:**

* How do you **retry failed payments**?
* How to ensure payment callbacks don’t **double process**?
* How do you deal with **fraud detection or PCI compliance**?

**Tips:**

* Use **Webhooks** from Stripe with **Idempotency-Key**.
* Implement circuit breakers for 3rd party failures.

**🚚 8. Shipping / Fulfillment**

**Purpose:**

* Manage delivery estimates, status, and logistics partner updates.

**Design:**

* External logistics system APIs (FedEx, UPS)
* Track shipments and notify users.

**Common Questions:**

* How do you model **multi-warehouse shipping**?
* How to reduce **delivery times / optimize logistics**?

**Tips:**

* Assign **nearest warehouse** during order placement.
* Use **Kafka** for async shipment status updates.

**🔔 9. Notification Service**

**Purpose:**

* Sends emails, SMS, or in-app alerts for order status, offers.

**Patterns:**

* Triggered via Kafka messages.
* Support templates & localization.

**Sample Questions:**

* How to avoid **duplicate notifications**?
* How to guarantee delivery (at-least-once)?

**Tips:**

* Store notification status in DB for audits.
* Use **email queues** with retries and DLQs.

**💬 10. Reviews & Ratings**

**Purpose:**

* Let users leave product feedback.

**Design:**

* Stored separately (to prevent slowing down product reads).
* Indexed by product\_id.

**Questions:**

* How do you prevent **spam or fake reviews**?
* How do you design for **high-read traffic** on reviews?

**Tips:**

* Cache popular product reviews.
* Add moderation queues.

**🔄 COMMON SYSTEM DESIGN QUESTIONS**

| **Area** | **Questions** |
| --- | --- |
| **High Availability** | How do you avoid SPOF in order placement? |
| **Consistency** | How do you keep stock and order in sync? |
| **Idempotency** | How do you make payment & order operations idempotent? |
| **Search** | How do you scale search to millions of products? |
| **Scalability** | How do you handle seasonal traffic spikes (e.g., Black Friday)? |
| **Ordering** | How do you maintain order of events (stock → order → payment)? |
| **Data Modeling** | How would you store product variants and filters? |
| **Monitoring** | How do you detect failures in the payment pipeline? |
| **Caching** | What should be cached, and where (Redis, CDN, etc.)? |
| **Security** | How do you handle fraudulent users or bots? |

**🧠 Advanced Topics to Bring Up**

* **Circuit Breakers** for Payment and Logistics APIs.
* **SAGA Pattern** for distributed transactions (e.g., Order → Payment → Shipment).
* **Eventual Consistency** vs. **Strong Consistency** tradeoffs.
* **A/B Testing & Experimentation** frameworks for UI and pricing.
* **Multi-region replication** and **geo-routing**.