### Order Book Building Process

Full Order Book building process includes:

I. Processing of Market Data Incremental Refresh (35=X) MDP 3.0 messages for start-of-day book initialization as well as updating real and implied books in normal operation throughout the trading day

II. Merging real and implied books into one consolidated book for instruments that have implied orders

III. Performing recovery using CME Natural Refresh mechanism in the event of packet loss

IV. Reporting the L2 snapshots for consolidated books with the best bid/ask information

### Description

Futures and options exchanges; market makers; hedge funds; and traders require real-time knowledge of the best bid and ask prices for the instruments that they trade. Algo-Logic Systems’ Futures & Options (F&O) Order Book is an FPGA hardware accelerator with the entire feed processing module and Order Book implemented in logic.

Algo-Logic’s single-FPGA platform architecture achieves deterministic, ultra low latency without jitter regardless of the number of tracked instruments at data rates of up to 10 Gbps.

### Applications

- High frequency market makers
- Algorithmic trading systems requiring both complexity and speed
- Highest performance tick-to-trade systems
- Low latency feed distributions needing to minimize bandwidth utilization
- Arbitrage opportunity discovery in the nanosecond timescale

### Algo-Logic’s Futures & Options Order Book supports:

1. Book building for instruments that have actual orders
   - CME multiple depth (i.e. real) book up to 10 levels deep

2. Book building for instruments that have implied orders
   - CME implied book up to 2 levels deep
   - CME consolidated book up to 10 levels deep

3. Processing of CME MDP 3.0 messages
   - Market Data Incremental Refresh (35=X) MDP 3.0 message type, used for:
     - Updating real and implied books in normal operation throughout the trading day
     - Start-of-day book initialization
     - Late joiner book initialization
     - CME Natural Refresh recovery mechanism

4. Reporting L2 snapshots with the best bid/ask information up to 10 levels deep
   - L2 snapshots are generated when each repeating group with a market data update is processed
   - L2 snapshots contain corresponding Security ID field, along with sided Price and Size fields
   - Real book snapshot is generated for instruments that have no implied orders
   - Consolidated book snapshot is generated for instruments that have implied orders

### CME Feed Handler

The CME Futures & Options Order Book integrates with the Algo-Logic Feed Handler to provide additional functions:

- A/B Feed Arbitration
- Multicast Channel Filter
- UDP Parser
- MDP 3.0 Parser
CME Futures & Options Order Book

### Futures & Options Order Book Metrics

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>L2 Snapshot Generation</strong></td>
<td>On processing of each repeating group with an incremental book update</td>
</tr>
<tr>
<td><strong>L2 Price Levels</strong></td>
<td>Provided in snapshot from 1 to 10 levels</td>
</tr>
<tr>
<td><strong>Incremental Book Update Rate</strong></td>
<td>39 million incremental order book update instructions per second</td>
</tr>
<tr>
<td><strong>Number of Instruments for 1 Level</strong></td>
<td>Up to 64 with L2 snapshots containing top of book price</td>
</tr>
<tr>
<td><strong>Number of Instruments for 10 Levels</strong></td>
<td>Up to 20 with L2 snapshots containing 10 price levels</td>
</tr>
<tr>
<td><strong>FPGA Devices Supported</strong></td>
<td>Altera Stratix V A7 and larger Stratix V family devices</td>
</tr>
<tr>
<td><strong>Order Book Processing Time</strong></td>
<td>Under 100 nanoseconds from time parsed repeating group fields are available</td>
</tr>
</tbody>
</table>

### Futures & Options Order Book Application with Example Input and Output

Example Incremental Book Update Instruction From MDP3.0 Feed

<table>
<thead>
<tr>
<th>MDP3.0 Field Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDEntryPx</td>
<td>9536.00</td>
</tr>
<tr>
<td>MDEntrySize</td>
<td>10</td>
</tr>
<tr>
<td>SecurityID</td>
<td>given</td>
</tr>
<tr>
<td>NumberOfOrders</td>
<td>2</td>
</tr>
<tr>
<td>MDPriceLevel</td>
<td>0 (top)</td>
</tr>
<tr>
<td>MDUpdateAction</td>
<td>0 (add)</td>
</tr>
<tr>
<td>MDEntryType</td>
<td>0 (real bid)</td>
</tr>
</tbody>
</table>

Use Cases

- PCIe
- System Memory
- 10GE
- Ticker Plant
- Avalon AXI4
- Trading System IP Core

### Order Book Metrics

- **Real Book**
- **Ask**
  - Price: 9534.00
  - Quantity: 300
- **Bid**
  - Price: 9536.00
  - Quantity: 30

- **Implied Book**
- **Ask**
  - Price: 9537.00
  - Quantity: 150
- **Bid**
  - Price: 9536.50
  - Quantity: 150

- **Consolidated Book**
- **Ask**
  - Price: 9538.00
  - Quantity: 750
- **Bid**
  - Price: 9534.50
  - Quantity: 30

### Ordering Codes

AL-OB – (Market) (# Instruments) (# Price Levels) (L2 Snapshot Interface) → Example:

- Market: CME MDP 3.0
- Number of instruments to monitor: 1-64
- Number of price levels to generate in L2 snapshot: 1-10
- L2 snapshot interface: Avalon, AXI4, PCIe, 10GE