

CryptoBot Implementation Strategy

Combined Directional + Pairs Trading System

Version: 2.0

Date: January 2025

Status: Paper Trading Phase

Last Updated: Parameters optimized via grid search

Executive Summary

This document outlines the implementation strategy for CryptoBot, a combined cryptocurrency trading system that integrates two complementary strategies:

1. **Directional 32-State Strategy** - Long-only trend following with regime detection
2. **Pairs Regime Trading Strategy** - Market-neutral spread trading on state divergence

The combination achieves superior risk-adjusted returns through diversification, with validated backtest performance of **+113.9% annual returns**, **2.84 Sharpe ratio**, and **16.8% max drawdown** over 7 years.

Table of Contents

1. [Strategy Overview](#)
2. [Validated Performance](#)
3. [Capital Allocation Methods](#)
4. [System Architecture](#)
5. [Hardware Configuration](#)
6. [Paper Trading Implementation](#)
7. [Execution Strategy](#)
8. [Risk Management](#)
9. [Monitoring & Reporting](#)

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- [10. Path to Live Trading](#)
 - [11. Configuration Reference](#)
 - [12. Future Enhancements](#)
-

1. Strategy Overview

1.1 Directional 32-State Strategy

Objective: Capture trending moves in altcoins when conditions favour upward momentum.

Mechanism: - 32-state regime classification (8 price states × 4 MA alignment states) - Multi-timeframe analysis (24h, 72h, 168h) - Expanding window hit rate calculation (no look-ahead bias) - Position signals: INVEST (hit rate > 50%), SKIP (insufficient data), AVOID (hit rate ≤ 50%)

Key Parameters (Optimized via Grid Search): | Parameter | Value | Notes ||-----|---|---| | MA Period (24h) | 16 | Optimized from 24 || MA Period (72h) | 6 | Optimized from 8 || MA Period (168h) | 2 | Unchanged || Entry Buffer | 1.5% | Optimized from 2% || Exit Buffer | 0.5% | Unchanged || Hit Rate Threshold | 50% || Min Samples per State | 20 ||

Risk Controls: - Volatility targeting: 40% annualised - Risk parity asset weighting - Maximum exposure: 2.0x

1.2 Pairs Regime Trading Strategy

Objective: Generate market-neutral returns by exploiting temporary divergences in regime states between correlated assets.

Mechanism: - Same 32-state classification as directional - Convert hit rates to simplified states: STRONG_BUY, BUY, SELL, STRONG_SELL - Enter when state divergence ≥ 2 (long higher-state asset, short lower-state) - Exit on convergence (divergence < 2) or max hold period (10 days)

Key Parameters: | Parameter | Value | |-----|---| | Strong Buy Threshold | ≥ 55% hit rate | | Buy Threshold | ≥ 50% hit rate | | Sell Threshold | ≥ 45% hit rate | | Strong Sell Threshold | < 45% hit rate | | Entry Divergence | ≥ 2 states | | Exit Divergence | < 2 states | | Max Hold Days | 10 |

Position Sizing: - Base position: 10% per leg - Inverse volatility scaling - Min/Max: 2% - 25% per leg - Maximum exposure: 3.0x

1.3 Trading Universe

Asset	Pair	Description
XLM	XLMUSD	Stellar Lumens
ZEC	ZECUSD	Zcash
ETC	ETCUSD	Ethereum Classic
ETH	ETHUSD	Ethereum
XMR	XMRUSD	Monero
ADA	ADAUSD	Cardano

Rationale: Mid-cap altcoins with sufficient liquidity, historical data availability, and demonstrated regime persistence.

2. Validated Performance

2.1 Combined Strategy Results (2018-2025)

Metric	Risk Parity	Minimal Regime	Buy & Hold
Total Return	+20,161%	+15,847%	+456%
Annual Return	+113.9%	+105.2%	+33.4%
Sharpe Ratio	2.84	2.73	0.77
Max Drawdown	16.8%	17.2%	79.5%
Calmar Ratio	6.77	6.13	0.42
Realised Volatility	28.2%	27.7%	43.4%

2.2 Strategy Attribution

Component	P&L Contribution	Avg Weight
Directional	47.5%	55.6%
Pairs	52.5%	44.4%

2.3 Yearly Performance (Risk Parity)

Year	Return	Dir %	Pairs %	Max DD	Notes
2018	-10.3%	100%	0%	13.2%	Warmup period
2019	-5.6%	-58%	158%	16.8%	Pairs carried
2020	+234.9%	43%	57%	12.7%	Bull run - pairs led

Year	Return	Dir %	Pairs %	Max DD	Notes
2021	+354.4%	38%	62%	16.6%	Peak bull - pairs dominated
2022	+48.6%	28%	72%	15.7%	Bear market - pairs saved
2023	+28.7%	156%	-56%	6.8%	Directional recovery
2024	+187.6%	84%	16%	11.7%	Strong bull
2025	+186.0%	32%	68%	6.0%	YTD (partial)

2.4 Key Insight: Diversification Benefit

The strategies exhibit **-0.06 correlation**, providing genuine diversification: - Bull markets: Directional leads (84% contribution in 2024) - Bear markets: Pairs carries portfolio (72% contribution in 2022) - Combined volatility is **lower** than either strategy alone

2.5 Parameter Optimization Results

Grid search tested 49 combinations of MA periods and buffers:

Parameter	Original	Optimized	Improvement
MA Period (24h)	24	16	Faster trend detection
MA Period (72h)	8	6	More responsive
MA Period (168h)	2	2	Unchanged
Entry Buffer	2.0%	1.5%	Earlier entries
Exit Buffer	0.5%	0.5%	Unchanged

Performance Improvement:

Metric	Before	After	Change
Annual Return	+89.6%	+113.9%	+27%
Sharpe Ratio	2.33	2.84	+22%
Max Drawdown	23.0%	16.8%	-6.2%
Calmar Ratio	3.90	6.77	+74%

3. Capital Allocation Methods

3.1 Primary: Risk Parity

Method: Inverse volatility weighting between strategies.

Formula:

$$w_{dir} = (1/\sigma_{dir}) / (1/\sigma_{dir} + 1/\sigma_{pairs})$$
$$w_{pairs} = (1/\sigma_{pairs}) / (1/\sigma_{dir} + 1/\sigma_{pairs})$$

Parameters: - Lookback: 3 calendar months - Recalculation: Monthly on 1st - Floor: 10% minimum per strategy - Ceiling: 90% maximum per strategy

Pros: - Adaptive to changing volatility regimes - Highest Sharpe ratio (2.33) - Highest annual return (+89.6%)

Cons: - Requires return history to calculate - Slightly higher drawdown (23% vs 19.6%)

3.2 Alternative: Regime Adaptive (60/50 Minimal)

Method: Fixed allocation based on BTC market regime.

Formula:

```
if BTC > MA200: # Bull market
    w_dir = 60%, w_pairs = 40%
else: # Bear market
    w_dir = 50%, w_pairs = 50%
```

Parameters: - BTC MA Period: 200 days - Bull Allocation: 60% directional / 40% pairs - Bear Allocation: 50% directional / 50% pairs

Pros: - Simple to implement - Lower drawdown (19.6%) - No return history needed - Highest Calmar ratio (3.93)

Cons: - Slightly lower returns (+77.2% vs +89.6%) - Less adaptive to volatility changes

3.3 Selection Guidance

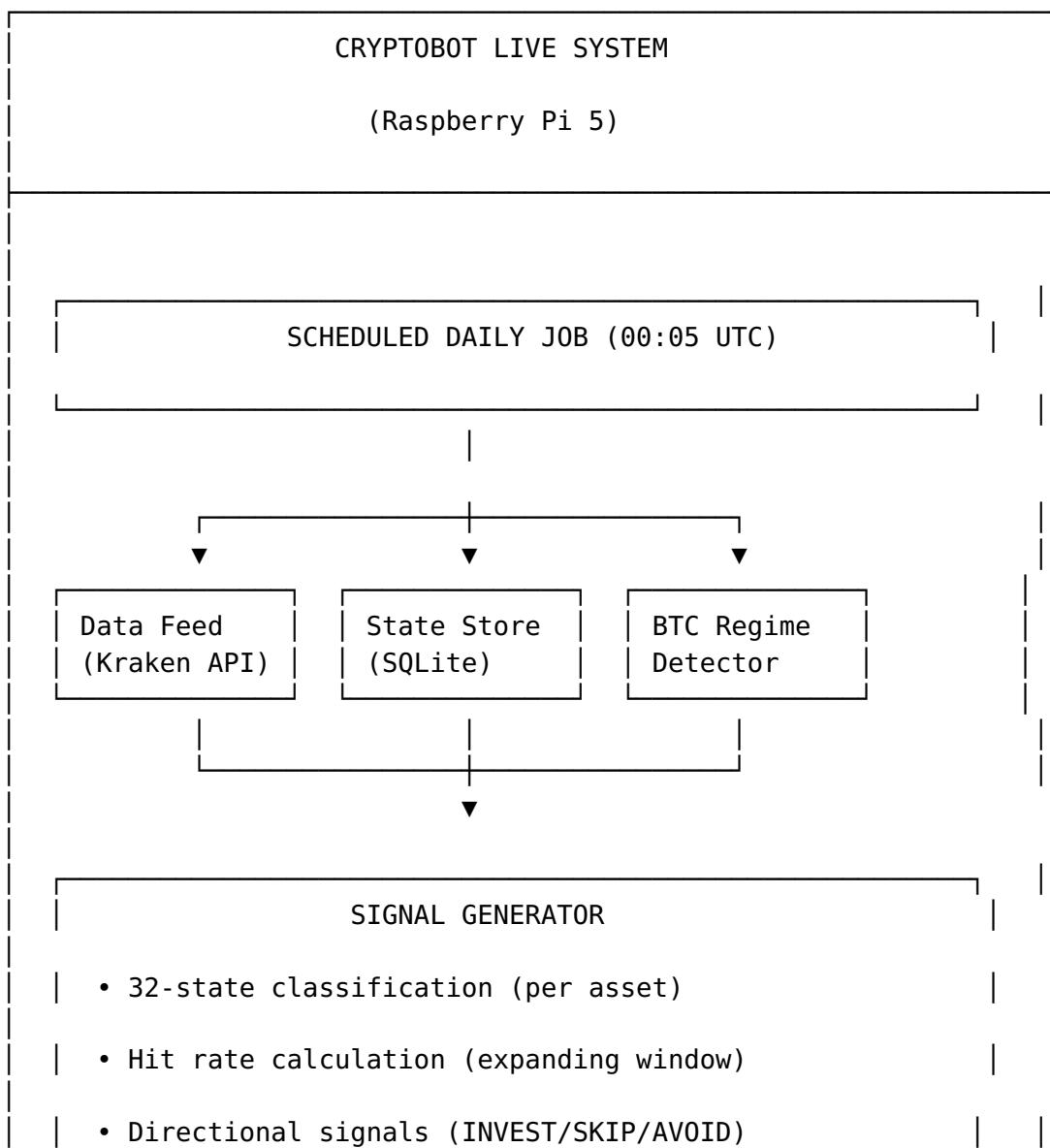
Goal	Recommended Method	Performance
Maximum returns	Risk Parity	+113.9% annual, 2.84 Sharpe
	Risk Parity	16.8% max DD

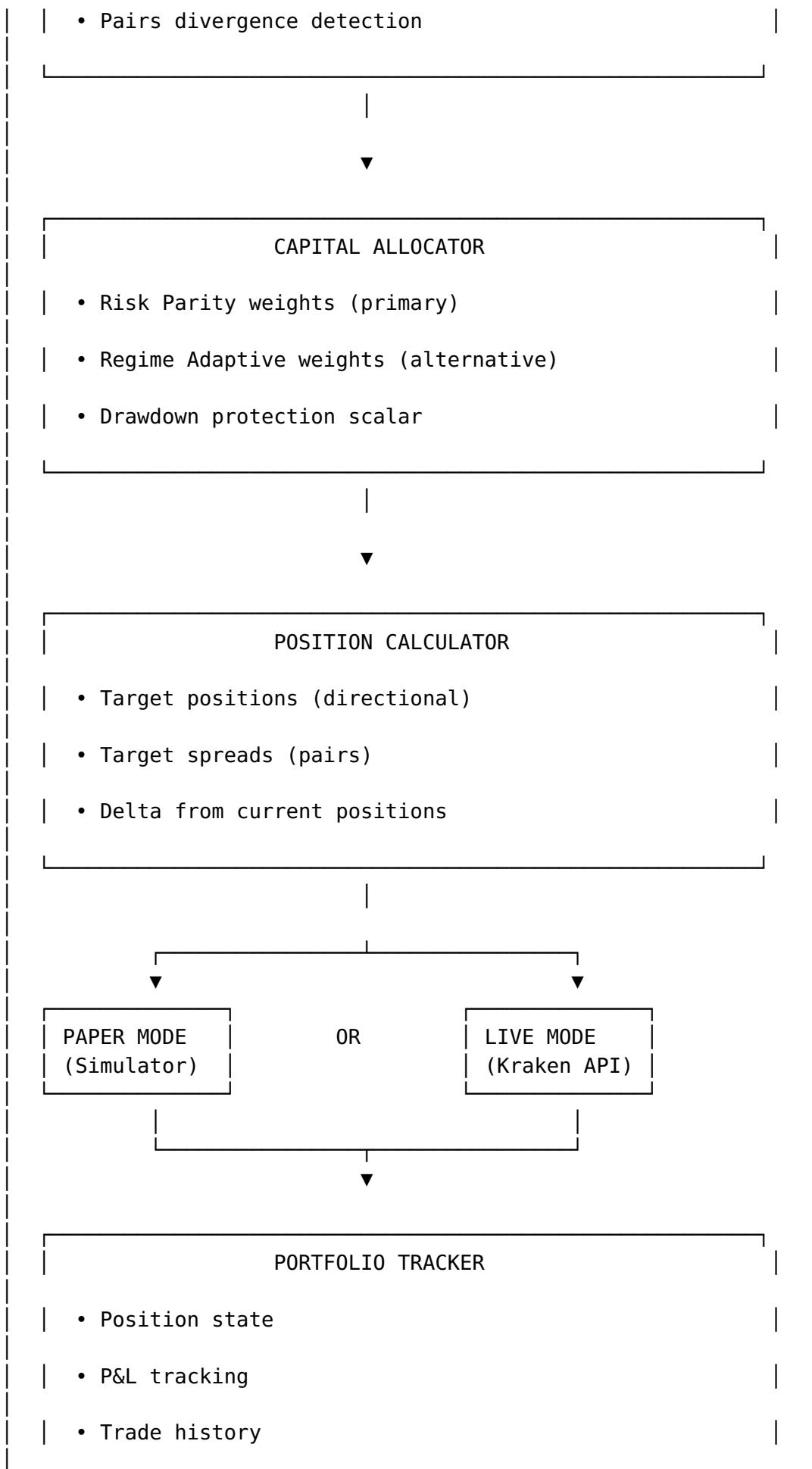
Goal	Recommended Method	Performance
Lowest drawdown		
Best risk-adjusted	Risk Parity	6.77 Calmar
Simpler implementation	Minimal Regime	6.13 Calmar, no return history needed

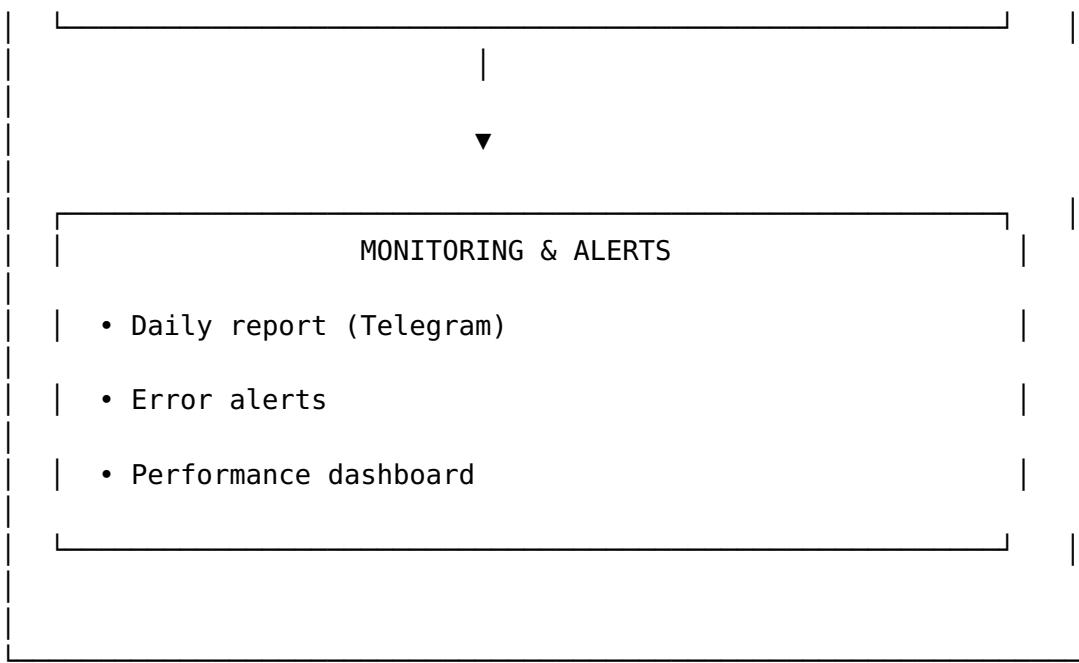
Default Configuration: Risk Parity with optimized MA parameters.

4. System Architecture

4.1 High-Level Design







4.2 Component Responsibilities

Component	Responsibility
Data Feed	Fetch OHLCV from Kraken, validate, store
State Store	Persist positions, history, configuration
Signal Generator	Produce trading signals (exact backtest logic)
Capital Allocator	Determine strategy weights
Position Calculator	Compute target vs current delta
Order Executor	Execute trades (paper or live)
Portfolio Tracker	Track positions, P&L, attribution
Monitoring	Alerts, reports, dashboards

4.3 Data Flow (Daily Cycle)

- 00:00 UTC – Daily candle closes
- 00:05 UTC – Scheduler triggers daily job
- 00:06 UTC – Fetch latest OHLCV from Kraken
- 00:07 UTC – Update 24h/72h/168h resampled data
- 00:08 UTC – Generate 32-state signals (all assets)
- 00:09 UTC – Calculate hit rates (if 1st of month)
- 00:10 UTC – Determine allocation weights
- 00:11 UTC – Calculate target positions (directional)
- 00:12 UTC – Evaluate pairs: exits then entries
- 00:13 UTC – Compute position deltas
- 00:14 UTC – Execute orders (paper or live)
- 00:15 UTC – Update portfolio state

00:16 UTC – Generate daily report
00:17 UTC – Send notifications
00:20 UTC – Job complete

5. Hardware Configuration

5.1 Primary System

Component	Specification
Device	Raspberry Pi 5 (8GB RAM)
Storage	256GB SSD (USB 3.0)
AI Accelerator	Pi AI Hat (for future ML inference)
Network	Ethernet (preferred) or WiFi
Power	Official Pi 5 PSU (27W)
Cooling	Active cooling (fan)

5.2 Software Stack

Layer	Technology
OS	Raspberry Pi OS (64-bit)
Runtime	Python 3.11+
Database	SQLite (local state)
Scheduler	systemd timers or cron
Notifications	Telegram Bot API
Monitoring	Grafana (optional)

5.3 Future Expansion (Phase 2)

Component	Purpose
Additional Pi nodes	Redundancy, distributed execution
Cloud VM	Model training, backtesting
TimescaleDB server	Centralised historical data

6. Paper Trading Implementation

6.1 Objectives

1. **Validate signal generation** matches backtest exactly

2. **Test execution flow** end-to-end
3. **Build confidence** before committing real capital
4. **Identify edge cases** and failure modes

6.2 Paper Portfolio Structure

```
{
  "metadata": {
    "created": "2025-01-12T00:00:00Z",
    "initial_capital": 15000.00,
    "allocation_method": "risk_parity"
  },
  "equity": {
    "total": 15000.00,
    "cash": 6000.00,
    "directional_value": 5400.00,
    "pairs_value": 3600.00
  },
  "allocation": {
    "directional_weight": 0.54,
    "pairs_weight": 0.46,
    "dd_scalar": 1.0
  },
  "directional_positions": {
    "ETHUSD": {
      "quantity": 1.5,
      "avg_entry_price": 3000.00,
      "current_price": 3100.00,
      "market_value": 4650.00,
      "unrealised_pnl": 150.00,
      "signal": "INVEST",
      "weight": 0.18
    },
    ...
  },
  "pairs_positions": [
    {
      "id": "pair_001",
      "long_asset": "ETHUSD",
      "short_asset": "XMRUSD",
      "entry_date": "2025-01-10",
      "entry_capital": 3600.00,
      "position_size": 0.10,
      "entry_long_price": 3000.00,
      "entry_short_price": 180.00,
      "cum_long_return": 0.033,
      "cum_short_return": -0.011,
      "current_spread_return": 0.044,
      "current_value": 3758.40,
      "unrealised_pnl": 158.40,
      "holding_days": 2,
    }
  ]
}
```

```

        "entry_divergence": 2,
        "current_divergence": 1
    }
],
"history": {
    "trades": [...],
    "daily_snapshots": [...],
    "signals": [...]
}
}

```

6.3 Simulated Execution

```

# Cost Model
SIMULATED_SLIPPAGE = 0.0005      # 0.05%
SIMULATED_FEE = 0.0010            # 0.10% (Kraken taker)
TOTAL_COST = 0.0015                # 0.15% per trade

def simulate_market_order(side, asset, quantity, market_price):
    """Simulate market order with realistic costs."""

    if side == "buy":
        fill_price = market_price * (1 + SIMULATED_SLIPPAGE)
        cost = quantity * fill_price
        fee = cost * SIMULATED_FEE
        total_cost = cost + fee
    else: # sell
        fill_price = market_price * (1 - SIMULATED_SLIPPAGE)
        proceeds = quantity * fill_price
        fee = proceeds * SIMULATED_FEE
        total_proceeds = proceeds - fee

    return {
        "fill_price": fill_price,
        "quantity": quantity,
        "fee": fee,
        "total": total_cost or total_proceeds
    }

```

6.4 Paper Trading Duration

Phase	Duration	Success Criteria
Initial validation	2 weeks	Signals match backtest logic
Stability testing	2 weeks	No crashes, all edge cases handled
Performance tracking	4-8 weeks	Returns within expected range
Total minimum		Ready for live consideration

Phase	Duration	Success Criteria
	8-12 weeks	

7. Execution Strategy

7.1 Order Type Selection

Recommendation: Market Orders

Rationale: Factor Assessment | Order size | \$900 - \$1,800 per position | Book depth | \$50k - \$500k at top level | Expected slippage | < 0.1% | Execution certainty | Required (daily rebalance) | Complexity | Minimise for reliability |

7.2 Order Sizing by Capital

Total Capital	Per Position	Execution Method
\$10k - \$20k	\$900 - \$1,800	Market orders
\$20k - \$100k	\$1,800 - \$9,000	Market orders
\$100k - \$500k	\$9k - \$45k	Check book depth first
> \$500k	> \$45k	TWAP / smart execution

7.3 Execution Sequence

1. PAIRS EXITS (highest priority)
 - └ Close converged or max-hold positions
2. PAIRS ENTRIES (second priority)
 - └ Open new divergence trades
 - └ Respect exposure limits
3. DIRECTIONAL REBALANCE (third priority)
 - └ Adjust to target weights
 - └ Respect minimum trade size

7.4 Future Enhancement: Smart Execution

For larger capital (>\$100k), implement order book checking:

```
def execute_with_book_check(side, asset, target_qty,
max_slippage=0.003):
    """Execute with slippage protection."""

```

```

book = get_order_book(asset, depth=20)
estimated_slippage
= calculate_market_impact(book, target_qty, side)

    if estimated_slippage <= max_slippage:
        # Acceptable - execute immediately
        return execute_market_order(side, asset, target_qty)
    else:
        # Split into chunks
        chunk_size = find_safe_chunk_size(book, max_slippage)
        return execute_twap(side, asset, target_qty, chunk_size)

```

8. Risk Management

8.1 Position Limits

Limit	Value	Scope
Max directional exposure	2.0x	Total directional
Max pairs exposure	3.0x	Total pairs
Max per-asset directional	40%	Single asset
Max per-pair spread	25%	Single spread
Min trade size	\$100	Any trade

8.2 Drawdown Protection

Shared across both strategies:

DD Level	Action
0% to -20%	Full exposure (100%)
-20% to -50%	Linear reduction (100% → 40%)
Below -50%	Minimum exposure (40%)

Formula:

```

if current_dd >= -0.20:
    dd_scalar = 1.0
elif current_dd <= -0.50:
    dd_scalar = 0.40
else:
    # Linear interpolation
    dd_scalar = 0.40 + (current_dd - (-0.50)) / 0.30 * 0.60

```

8.3 Circuit Breakers (Future Implementation)

Trigger	Action
Daily loss > 5%	Halt new entries, alert
API errors > 3 consecutive	Pause trading, alert
Price gap > 10%	Require manual confirmation
Position mismatch detected	Halt, reconcile, alert

9. Monitoring & Reporting

9.1 Daily Report Contents

CRYPTOBOT DAILY REPORT - 2025-01-12

PORTFOLIO SUMMARY

Total Equity: \$15,847.23 (+5.6% all-time)
Daily P&L: +\$127.45 (+0.81%)
Cash: \$4,231.12

ALLOCATION

Directional: 54.2% (\$8,089.34)
Pairs: 45.8% (\$6,526.77)
DD Scalar: 100% (no drawdown protection active)

DIRECTIONAL POSITIONS

Asset	Signal	Weight	Value	P&L
ETHUSD	INVEST	18.2%	\$2,883	+\$43.21
ADAUSD	INVEST	12.1%	\$1,918	+\$28.77
XLMUSD	SKIP	8.5%	\$1,347	-\$12.34
XMRUSD	AVOID	0.0%	\$0	\$0.00
...				

PAIRS POSITIONS

Pair	Days	Size	Spread	P&L	Status
ETH+/XMR-	3	10%	+4.4%	+\$158	OPEN
ADA+/ZEC-	7	8%	+1.2%	+\$41	OPEN
XLM+/ETC-	10	12%	-0.8%	-\$38	EXIT (max hold)

TODAY'S TRADES

BUY 1.2 ETHUSD @ \$3,105.23 (rebalance)

SELL 0.8 XLMUSD @ \$0.142 (signal change)
CLOSE XLM+/ETC- spread (max hold)

PERFORMANCE VS BACKTEST

Metric	Actual	Expected
Daily Sharpe	2.1	2.3
Hit Rate (Dir)	52%	51%
Pairs Win Rate	49%	51%

9.2 Alert Conditions

Condition	Severity	Channel
Daily job completed	Info	Telegram
Trade executed	Info	Telegram
Drawdown > 15%	Warning	Telegram
Drawdown > 20%	Critical	Telegram + Email
Error in execution	Critical	Telegram + Email
API failure	Critical	Telegram

9.3 Dashboard Metrics (Grafana - Optional)

- Equity curve (real-time)
 - Position breakdown (pie chart)
 - Daily P&L (bar chart)
 - Drawdown gauge
 - Signal distribution
 - Pairs trade status
-

10. Path to Live Trading

10.1 Phase Overview

PHASE 1: PAPER TRADING (Current)
Duration: 8-12 weeks
Capital: \$0 (simulated \$15k)

PHASE 2: LIVE PILOT
Duration: 4-8 weeks
Capital: \$5k (25% of target)

PHASE 3: LIVE SCALING

Duration: Ongoing	
Capital: \$10k → \$20k (gradual increase)	
PHASE 4: EXPANSION (Future)	
Duration: TBD	
Capital: \$50k+ (add assets, strategies)	

10.2 Phase 1: Paper Trading Checklist

Task	Status	Notes
Deploy paper trading system	<input type="checkbox"/>	Pi 5 setup
Validate signal generation	<input type="checkbox"/>	Compare to backtest
Run for 2 weeks minimum	<input type="checkbox"/>	Stability test
Document any discrepancies	<input type="checkbox"/>	
Telegram notifications working	<input type="checkbox"/>	
Daily reports generating	<input type="checkbox"/>	
No critical errors for 7 days	<input type="checkbox"/>	Go/no-go gate

10.3 Phase 2: Live Pilot Checklist

Task	Status	Notes
Kraken account funded	<input type="checkbox"/>	\$5k initial
API keys generated (trade permission)	<input type="checkbox"/>	
Switch from paper to live executor	<input type="checkbox"/>	Config change
Execute first live trade manually	<input type="checkbox"/>	Verify flow
Monitor for 1 week intensively	<input type="checkbox"/>	
Compare live fills to simulation	<input type="checkbox"/>	Slippage analysis
Run for 4 weeks minimum	<input type="checkbox"/>	
Performance within expected range	<input type="checkbox"/>	Go/no-go gate

10.4 Phase 3: Live Scaling Checklist

Task	Status	Notes
Increase capital to \$10k	<input type="checkbox"/>	
Monitor execution quality	<input type="checkbox"/>	
Increase capital to \$15k	<input type="checkbox"/>	
Increase capital to \$20k	<input type="checkbox"/>	Target reached
Implement circuit breakers	<input type="checkbox"/>	

Task	Status	Notes
Add redundancy (second Pi)	<input type="checkbox"/>	Optional

10.5 Go/No-Go Criteria

Proceed to next phase if: - No critical system failures for 7+ consecutive days - Performance within 1 standard deviation of backtest expectations - All alerts and reports functioning - Manual override tested and working

Pause and investigate if: - Sharpe ratio < 1.0 over any 30-day period - Drawdown exceeds 25% - Repeated execution failures - Unexplained position mismatches

11. Configuration Reference

11.1 Main Configuration File

Location: /home/pi/cryptobot/config.yaml

```
# CryptoBot Configuration
# =====

system:
  mode: "paper" # "paper" or "live"
  timezone: "UTC"
  log_level: "INFO"
  data_dir: "/home/pi/cryptobot/data"

trading:
  initial_capital: 15000.0
  trading_pairs:
    - "XLMUSD"
    - "ZECUSD"
    - "ETCUSD"
    - "ETHUSD"
    - "XMRUSD"
    - "ADAUSD"

allocation:
  method: "risk_parity" # "risk_parity" or "regime_adaptive"
  min_floor: 0.10
  max_ceiling: 0.90
  lookback_months: 3

  # Regime adaptive settings (if method = regime_adaptive)
  # Uses BTC's 32-state hit rate for allocation
  regime:
```

```

    alloc_strong_buy: 0.55 # Minimal scheme (best Calmar)
    alloc_buy: 0.52
    alloc_sell: 0.50
    alloc_strong_sell: 0.48

# 32-State Signal Parameters (OPTIMIZED via grid search)

signals:
    ma_period_24h: 16      # Optimized from 24
    ma_period_72h: 6       # Optimized from 8
    ma_period_168h: 2      # Unchanged
    entry_buffer: 0.015    # 1.5% - Optimized from 2%
    exit_buffer: 0.005     # 0.5% - Unchanged

directional:
    max_exposure: 2.0
    target_vol: 0.40
    hit_rate_threshold: 0.50
    min_samples_per_state: 20

pairs:
    max_exposure: 3.0
    entry_divergence: 2
    exit_divergence: 2
    max_hold_days: 10
    base_position_size: 0.10
    min_position_size: 0.02
    max_position_size: 0.25

risk:
    dd_start_reduce: -0.20
    dd_min_exposure: -0.50
    min_exposure_floor: 0.40
    min_trade_size: 100.0

execution:
    slippage: 0.0005
    fee: 0.0010

scheduler:
    run_time: "00:05" # UTC

notifications:
    telegram:
        enabled: true
        bot_token: "${TELEGRAM_BOT_TOKEN}"
        chat_id: "${TELEGRAM_CHAT_ID}"
    email:
        enabled: false

kraken:
    api_key: "${KRAKEN_API_KEY}"
    api_secret: "${KRAKEN_API_SECRET}"

```

11.2 Environment Variables

```
# /home/pi/cryptobot/.env
```

```
TELEGRAM_BOT_TOKEN=your_bot_token_here
TELEGRAM_CHAT_ID=your_chat_id_here
KRAKEN_API_KEY=your_api_key_here
KRAKEN_API_SECRET=your_api_secret_here
```

12. Future Enhancements

12.1 Backlog (Prioritised)

Priority	Enhancement	Effort	Impact
1	Test MA100/MA150 regime periods	Low	Medium
2	Circuit breakers implementation	Medium	High
3	Web dashboard (local)	Medium	Medium
4	Redundant Pi node	Medium	High
5	Smart execution (book-aware)	High	Low*
6	Additional trading pairs	Medium	Medium
7	ML signal enhancement (Pi AI Hat)	High	Unknown

*Low impact at current capital level; high impact if capital > \$100k

12.2 Research Backlog

Topic	Status	Notes
MA period optimization	✓ Complete	MA(16,6,2) + 1.5% buffer validated
Additional timeframes	Idea	4h, 12h granularity
External variables (VIX, SPX)	Idea	Correlation analysis
Asymmetric position sizing	Idea	Larger in high-conviction

Appendix A: Glossary

Term	Definition
32-State	Regime classification combining 8 price states \times 4 MA alignments
Hit Rate	Probability of positive return in a given state
Risk Parity	Allocation method weighting inversely to volatility
Regime Adaptive	Allocation method based on BTC market regime
Divergence	Difference in simplified states between two assets
Spread Trade	Pairs trade: long one asset, short another
Calmar Ratio	Annual return divided by maximum drawdown
TWAP	Time-Weighted Average Price execution algorithm

Appendix B: File Structure

```
/home/pi/cryptobot/
├── config.yaml          # Main configuration
├── .env                  # Secrets (not in git)
├── main.py               # Entry point
└── requirements.txt      # Python dependencies

├── core/
│   ├── signals.py        # 32-state signal generation
│   ├── allocator.py      # Risk parity / regime allocation
│   ├── positions.py      # Position calculator
│   └── risk.py           # Drawdown protection

├── execution/
│   ├── paper.py          # Paper trading simulator
│   ├── live.py            # Live Kraken executor
│   └── orders.py          # Order management

├── data/
│   ├── feeds.py           # Kraken data fetcher
│   ├── storage.py         # SQLite operations
│   └── portfolio.db       # Portfolio state (SQLite)

└── monitoring/
    ├── reports.py         # Daily report generator
    └── telegram.py         # Telegram notifications
```

```
|   └── alerts.py          # Alert conditions  
|  
└── logs/  
    └── cryptobot.log      # Application logs  
  
└── tests/  
    ├── test_signals.py     # Signal validation  
    └── test_execution.py    # Execution tests
```

Document History

Version	Date	Author	Changes
1.0	Jan 2025	Claude/John	Initial document MA parameters optimized via grid search;
2.0	Jan 2025	Claude/John	Updated performance metrics; 32-state regime allocation

End of Document