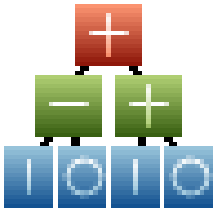

Adaptrade Builder

Version 2

User's Guide

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Chapter 1
Introduction

Overview

Adaptrade Builder is a stand-alone Windows program that automatically generates trading strategies for several popular trading platforms, including TradeStation, MultiCharts, NinjaTrader, MetaTrader 4, and AmiBroker. Builder synthesizes unique combinations of trading indicators, trading rules, price patterns, entry and exit order types, and other user-selectable options and generates the corresponding strategy code. The program can generate an almost unlimited variety of trading strategies, including breakout, trend-following, stop-and-reverse, end-of-day, day trading, and others. Builder can also generate neural network-based strategies in which the elements of the network are chosen automatically. All strategies created by Builder are designed around the user's specified performance requirements and goals and can be as simple or as complex as desired.

In effect, Builder automates the traditional, manual approach to strategy development in which the trader selects elements of a trading strategy based on prior experience combined with knowledge of technical indicators, entry and exit order types, and strategy design. In the traditional method, a strategy is based on a market "hypothesis"; that is, an idea of how the market works. A viable trading strategy is typically developed through a long trial-and-error process involving numerous iterations, revisions, and testing until acceptable results are achieved.

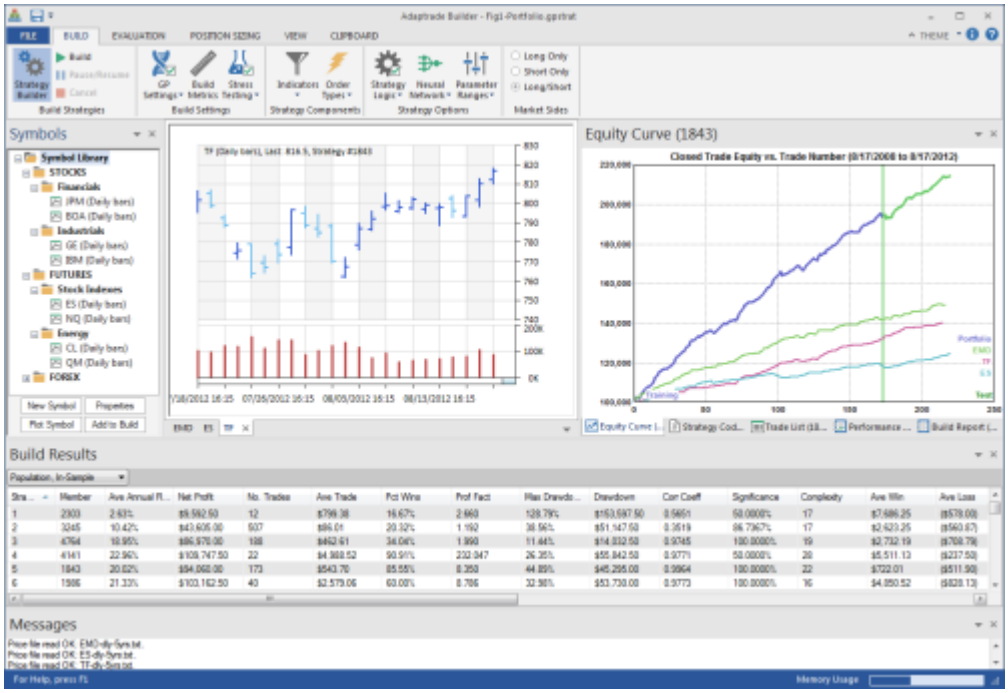

Figure 1.1. Main window of Adaptrade Builder.

Builder performs each step of this process automatically. The program generates an initial population of trading strategies by "seeding" the population based on the user's selected options. The initial population of strategies is then “evolved” over successive generations using a genetic programming algorithm, guided by performance criteria selected by the user. The program builds the strategies over the training or “in-sample” data segment and tests each one over the test or “out-of-sample” data. Each candidate strategy is essentially a hypothesis that is either supported or refuted by the out-of-sample testing. In addition, Builder includes a unique test of statistical significance that takes into account the build process to test whether each member of the population overcomes the so-called data mining bias.

The premise behind Builder is that developing a trading strategy is essentially a problem of *statistical inference*. The price data can be thought of as a combination of “signal” and “noise”. The signal is the tradable part of the data, and the noise is everything else. In this context, the essential challenge is finding strategies that fit the signal while ignoring the noise and avoiding over-fitting. At the same time, market data is often non-stationary: the statistical properties change over time. A successful strategy is therefore one that fits the stationary elements of the market signal with adequate degrees-of-freedom to avoid over-fitting. Out-of-sample testing and the statistical significance test of the build process are used to verify these requirements.

Builder is designed to generate strategies for almost any market and time frame, from tick data to monthly bars, for stocks, futures, forex, ETFs, and other markets. The strategies generated by Builder are complete trading strategies, including rules and trading orders for entering the market, exiting at a profit, and exiting at a loss. The strategy code is provided in open text file format, which can be pasted into the trading platform's editor for compilation and subsequent execution to generate trading signals.

Some of the user options in Builder include the code type (e.g., current versions of TradeStation/MultiCharts, TradeStation 2000i, NinjaTrader 7, MetaTrader 4, AmiBroker); specifying strategies as long-only, short-only, or combined long and short trading; requiring the long and short entry rules to be logical opposites; limiting entries and exits to specified times; limiting the number of entries per day for day trading strategies; including a neural network in the entry conditions; specifying one of several optional position sizing methods to include in the strategy code; building using stress testing/Monte Carlo analysis; excluding specific indicators, entry rules, and exit rules from the build process; and specifying various aspects of the genetic programming process as well as other features to be included or excluded from the generated strategies.

Builder can also be used as a stand-alone trading platform for end-of-day trading. The program includes price charting, which displays the trade entry and exit points on the chart. A Trading Orders window displays the current open position(s) and any pending orders for the next bar. Used in conjunction with the data provider and brokerage of your choice, the generated strategies can be evaluated day-to-day in Builder and the orders sent manually to your broker for execution.

Genetic Programming

Builder uses a computational technique called genetic programming (GP),[1] which belongs to a class of techniques called evolutionary algorithms. Evolutionary algorithms and GP in particular were developed by researchers in artificial intelligence based on the biological concepts of reproduction and evolution. A GP algorithm “evolves” a population of trading strategies from an initial population of randomly generated members. Members of the population compete against each other based on their “fitness.” The fitter members are

selected as "parents" to produce a new member of the population, which replaces a weaker (less fit) member.

Two parents are combined using a technique called crossover, which mimics genetic crossover in biological reproduction. In crossover, part of one parent's genome is combined with part of the other parent's genome to produce the child genome. In Builder, genomes represent the trading rules and order logic of the strategy.

Other members of the population are produced via mutation, is which one member of the population is selected to be modified by randomly changing parts of its genome. Typically, a majority (e.g., 90%) of new members of the population are produced via crossover, with the remaining members produced via mutation.

Over successive generations of reproduction, the overall fitness of the population tends to increase. The process is stopped after some number of generations or when the fitness stops increasing. The solution is generally taken as the fittest member of the resulting population.

The initial GP population might have as few as 50 members or as many as 1000 or more. A typical build process might progress over anywhere from 10 to 100 generations or more. The number of strategies constructed and evaluated during the build process is equal to the size of the population multiplied by the number of generations.

In the context of building trading strategies, GP enables the synthesis of strategies given only a high level set of performance goals. The GP process does the rest. This approach has several significant benefits, including:

- Reduces the need for knowledge of technical indicators and strategy design. The GP algorithm selects the individual trading rules, indicators, and other elements of the strategy for you.
- The rule construction process allows for considerable complexity, including nonlinear trading rules.
- The GP process eliminates the most labor intensive and tedious elements of the traditional strategy development process; namely, coming up with a new trading idea, programming it, verifying the code, testing the strategy, modifying the code, and repeating. This is all done automatically in GP.
- The GP process is unbiased. Whereas most traders have developed biases for or against specific indicators and/or trading logic, GP is guided only by what works.
- By incorporating proper trading rule semantics, the GP process in Builder is designed to produce logically correct trading rules and error-free code.
- The GP process often produces results that are not only unique but non-obvious. In many cases, these *hidden gems* would be nearly impossible to find any other way.
- By automating the build process, the time required to develop a viable strategy can be reduced from weeks or months to a matter of minutes in some cases, depending on the length of the input price data file and other build settings.

Genetic programming has been successfully used in a variety of fields, including signal and image processing, process control, bioinformatics, data modeling, programming code generation, computer games, and economic modeling; see, for example Poli et al.[2] An overview of using GP in finance is provided by Chen.[3] Colin[4] was one of the first to explain how to use GP for optimizing combinations of rules for a trading strategy.

Various academic studies have demonstrated the benefits of GP in trading. For example, Karjalainen[5] found that price pattern trading rules evolved using GP for S&P 500 futures

provided an advantage over buy-and-hold returns in out-of-sample testing. Similarly, Potvin et al.[6] found that rules generated through a GP process for individual stocks outperformed buy-and-hold in out-of-sample testing during falling and sideways markets. Kaucic[7] combined a genetic algorithm with other learning methods to generate simple trading rules for the S&P 500 index and found positive results compared to buy-and-hold on out-of-sample testing.

Until recently, most applications of genetic programming to trading strategy generation have been academic studies based on limited rule sets, overly simple entry and exit logic, and custom-written code, making the results unsuitable for most traders. At the same time, most available software that implements GP for market trading has either been targeted to professional traders and priced accordingly or is very complicated to set up and use. Adaptrade Builder was designed to make GP simple to use for any trader, individual or professional, who has a basic understanding of strategy trading and is familiar with one of the supported trading platforms.

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Build Algorithm

The build algorithm used in Adaptrade Builder is illustrated below. The gray-shaded boxes represent the input data, which includes the price data for the markets of interest, the indicators and order types in the so-called *build set*, and the options and performance criteria (build goals) selected by the user.

The algorithm starts with the Strategy Generation step. An initial population of trading strategies is randomly developed from the available technical indicators and rule types in the build set. Any options that the user has selected, such as exiting all positions at end-of-day, are applied at this point. Each strategy is then evaluated over the price data for the selected markets, and a fitness value is assigned based on a weighted average of the build goals specified by the user. For example, you might select net profit and drawdown as the two

performance metrics and weight each one equally. The fitness would then be the average of the net profit and drawdown.

To generate new members of the population, members of the current population are selected at random, and the fitter ones are chosen as parents for crossover and mutation. A less fit member is selected at random to be replaced by the new member. The process is repeated until as many new members have been created as there are members in the current population. This step represents one generation.

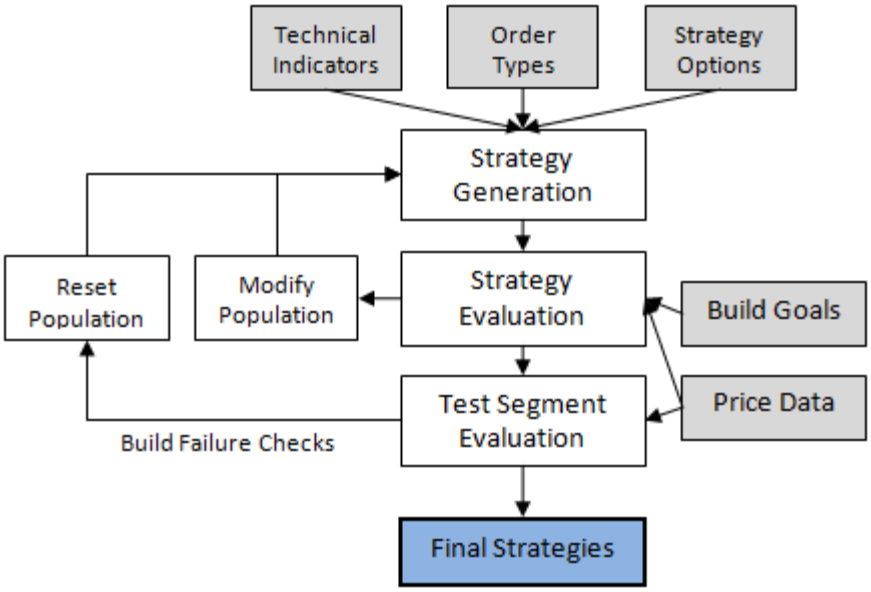


Figure 1.2. Build algorithm in Adaptrade Builder.

If the user has selected one of the build failure rules, the results on the test segment are checked after the specified number of generations. If the results are not above the threshold chosen by the user, the process is reset, which causes the population to be re-initialized and the generation count to be reset to zero. After the specified number of generations has been successfully completed or the build termination conditions have been met, the top strategies are listed in the Build Results table in order of fitness.

Entry and Exit Conditions

The GP process evolves three essential strategy elements simultaneously: entry conditions, exit conditions, and orders for entry and exit. Optionally, a neural network can be evolved as well; see Neural Networks, below. The entry and exit conditions are represented as tree structures, as shown below in Fig. 1.3.

The tree structure enables the generation of entry and exit conditions with considerable complexity. Each node in the tree has between zero and three inputs, each of which leads to further branching. The tree is constructed recursively starting at the top with a logical operator (and, or, >, <, etc.) and proceeding to technical indicator functions, prices, and constants, such as indicator lengths. Each branch is terminated with a node that has no inputs. Available indicators in Builder are listed in Table 1, below. These are described in detail in the appendix.

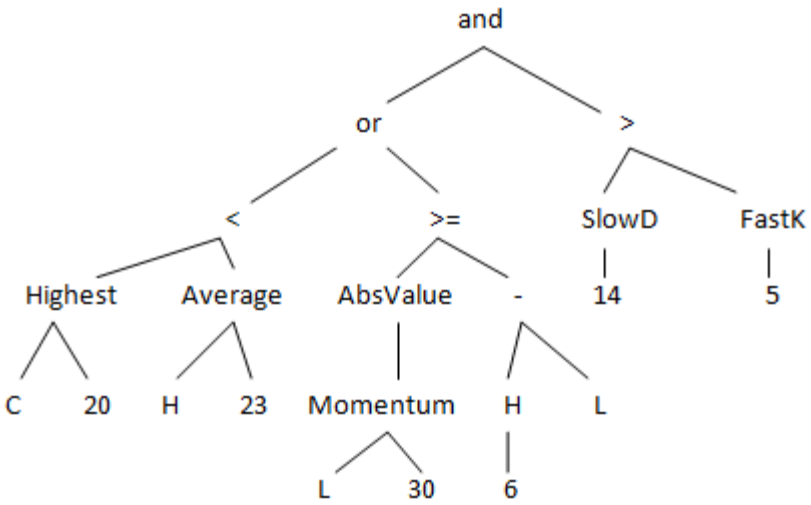


Figure 1.3. Entry condition example showing tree structure.

Note: As shown in Table 1 (see footnotes), not all indicators are available for all code types (scripting languages). For example, if the MetaTrader 4 code type is selected on the Evaluation Options tab prior to building, some indicators will be excluded from the build set and will not be included in the strategies. If a strategy previously built for TradeStation/MultiCharts includes one or more of these indicators and is then re-evaluated when the MetaTrader 4 code type has been selected, the resulting code will be invalid and will not compile in MetaTrader. Also, some indicators generate different values in different platforms, and Builder has been designed to duplicate these differences depending on the selected code type. For this reason, a strategy may produce different results when evaluated under a different code type than was selected for building the strategy.

The EasyLanguage code corresponding to the tree structure shown in Fig. 1.3 is listed below.

```
VarL1 = Highest(C, 20);
VarL2 =  Average(H, 23);
VarL3 = Momentum(L, 30);
VarL4 = AbsValue(VarL3);
VarL5 = H[6];
VarL6 = VarL5 – L;
VarL7 = SlowD(14);
VarL8 = FastK(5);
CondL1 = VarL1 < VarL2;
CondL2 = VarL4 >= VarL6;
CondL3 = CondL1 or CondL2;
CondL4 = VarL7 > VarL8
EntCondL = CondL3 and CondL4;
```

In this example, the long entry condition is given by the last statement, EntCondL.

The crossover operator of the GP process replaces a subtree in one parent with a subtree from the other parent. For example, the subtree on the right of Fig. 1.3, starting with “>” (i.e., SlowD(14) > FastK(5)), might be replaced with a different subtree from another member of the population. Mutation changes individual nodes in the tree. For example, the “Average” node might be replaced with “Lowest” so that the subtree Average(H, 23) becomes Lowest(H, 23).

Table 1. Available Indicators in Builder

Simple moving average	Commodity channel index (CCI)
Exponential moving average	Directional indicator (DI+/DI-)
Weighted moving average	Directional movement index (DMI) [1, 2]
Triangular moving average[1, 2]	Average directional index(ADX)
Adaptive variable moving average	True range (TR)
Zero-lag trend	Average true range (ATR)
Adaptive zero-lag trend	Standard deviation
Moving average convergence divergence (MACD)	Bollinger band
Triple exponential moving average (TRIX) [1]	Keltner channel[1, 2]
Momentum	Lowest
Rate of change (ROC) [1]	Highest
Fast K stochastic[1, 2]	Volume
Fast D stochastic	Accumulation/distribution
Slow D stochastic	Chaiken oscillator[1]
Relative strength indicator (RSI)	Crosses above/below[1]
Inverse Fisher RSI	Price patterns (O, H, L, C, O[N], etc.)
Inverse Fisher cycle	Day of week
Adaptive inverse Fisher RSI	Time of day
Adaptive inverse Fisher cycle	Absolute value

[1]Indicator not available for MetaTrader 4 code. [2]Indicator not available for AmiBroker code.

An entry or exit condition is evolved separately for long and short trades unless the user selects “Long only”, “Short only”, or “Long/Short Symmetry”. Each condition is a logical statement; it evaluates to either true or false. A value of true means the condition is satisfied for that market side (long or short), which is necessary for the order to be placed. Entry conditions are applied to all types of entry orders. In other words, the entry condition must be true for the entry order to be placed. Exit conditions only apply to market exit orders. If the exit condition is true, the trade is exited at market on the next bar, assuming the strategy includes the market exit order type.

In order to generate meaningful entry conditions, Builder applies both *syntactic* and *semantic* rules when building the conditions. Syntactic rules ensure that each node containing a function satisfies the input requirements for the function. For example, the Momentum function requires a price as the first input and a length as the second input. Semantic rules ensure that comparisons between different nodes are meaningful. For example, it makes sense to compare the Highest(C, 20) to a moving average since both functions return a price. However, it would not be meaningful to compare the closing price to the time of day or to compare a stochastic, which has a value between 0 and 100, to a moving average of price. The semantic rules enforce these requirements.

According to the semantic rules, indicators that return a price or volume-based value can be used as input to indicators that take price or volume as an input. Examples of price-based indicators include Average, XAverage, Highest, Lowest, ROC, RSI, Momentum, and MACD. For example, Builder can produce conditions that include statements such as Average(Highest(XAverage(C, N1), N2), N3). This is called indicator nesting. Currently, nested indicators are not available for MetaTrader 4. Where available, nesting can be turned off in order to reduce strategy complexity using an option on the Strategy Logic window.

Order Types

Entry Orders

The following types of entry orders are available in Builder:

- Market Entry
- Stop Entry
- Limit Entry

Entry orders are placed when the entry conditions, as described in the previous section, are true. A market entry means the trade enters at the open of the next bar. Stop and limit entries are placed at a specified price away from the market. Stop orders are intended to be placed above the market for a long entry and below the market for a short entry. Limit orders are intended to be placed below the market for a long entry and above the market for a short entry.

Stop and limit entry prices in Builder are calculated as follows:

```
EntryPrice = PriceValue +/- Fr * PriceDiff
```

where:

`PriceValue` is one of: price, price[N], Highest(price, N), Lowest(price, N), Average(price, N), XAverage(price, N), or DayPrice;
price is one of: O, H, L, or C;
price[N] is the price N bars ago;
DayPrice is one of: OpenD(0), HighD(0), LowD(0), or CloseD(1);
`Fr` is a constant multiplier; and
`PriceDiff` is one of: true range, ATR, $\text{PriceValue}_1 - \text{PriceValue}_2$, or $\text{AbsValue}(\text{PriceValue}_1 - \text{PriceValue}_2)$.

The listed functions, such as OpenD(0) and Highest(price, N), are shown as written in TradeStation's EasyLanguage. PriceValue, Fr, PriceDiff, and the associated function parameters are chosen by Builder during the build process.

The following are examples of long stop entry prices:

```
EntryPrice = Average(C, 10) + 3.5 * AbsValue(C[5] - H[14])

EntryPrice = H + 2.1 * AbsValue (Average(C,20) - Lowest(H,15))
```

These could also be short limit entries since short limit entries are also above the market and therefore use a "+" sign to add the price difference to the price value.

Examples of short stop entry prices are shown below:

```
EntryPrice = OpenD(0) - 1.7 * AvgTrueRange (11)

EntryPrice = C[16] - 4.3*AbsValue(XAverage(L,5)-Xaverage(C,2))
```

These could also be long limit entries since long limit entries are also below the market and therefore use a "-" sign to subtract the price difference from the price value.

The following types of **exit orders** are available in Builder:

- Exit at Target ($)
- Exit at Target (%)
- Exit at Target (Price)
- Trailing Stop ($ Floor)
- Trailing Stop (ATR Floor)
- Protective Stop ($)
- Protective Stop (%)
- Protective Stop (Price)
- Exit After N Bars
- Exit After N Bars Profit
- Exit After N Bars Loss
- Exit After Time
- Exit at Market
- Exit End-of-Day

Target Exits
The three target exits use limit orders to exit the trade at a price that represents a profit for the trade. The first target exit type ($) uses a fixed-size target based on the value of the profit target (e.g., dollars for accounts denominated in dollars) and is applied per share or contract. For example, a target size of $500 means the target price is calculated so that if the target is hit, the profit will be $500 per share or contract before trading costs. For the E-mini S&P futures, for example, this means the stop size would be 10 points above the entry price for a long trade because each point is worth $50 for the E-mini. For a stock trade, regardless of the number of shares, a $2 target would be placed two points above the entry price for a long trade or 2 two points below the entry for a short trade. The size of the target chosen by the program during building is based on the "Fixed Stop Size" parameter range entered on the Parameter Ranges window.

Percentage targets are set at a percentage of the entry price above (below) the entry price for a long (short) trade. For example, if the entry price is 25, a 5% target would be placed 1.25 points above the entry for a long trade. The percentage value is chosen from the "Percentage Stop Size" parameter range on the Parameter Ranges window.

Price-based target exits are constructed the same way as limit entry orders. Specifically, the price for this type of target exit is calculated as follows:

```
ExitPrice = EntryPrice +/- Fr * PriceDiff
```

where `EntryPrice` is the entry price for the trade, and `Fr` and `PriceDiff` are as defined above for entry orders.

For example, the following could be the price for a short target exit:

```
ExitPrice = EntryPrice - 4.3 * AbsValue(C[10]-Xaverage(C,2))
```

Similarly, if the first minus sign were changed to a plus sign, this could be the exit price for a long target exit.

Trailing Stops
Trailing stops in Builder are activated when the open profit on a closed-bar basis is above a threshold called the *floor*. There are two types of trailing stops in Builder: ones with fixed-

size floors ($ Floor), and ones where the floor is calculated as a multiple of the average true range (ATR Floor). For fixed-size floors, the size of the floor is selected by the program from the "Fixed Stop Size" parameter range entered on the Strategy Options tab. For ATR-based floors, the multiple of the ATR is selected from the "ATR Multiple" range on Strategy Options. Once the threshold has been reached, the trailing stop is placed so that a percentage of the open profit is locked in. The stop remains active until the trade exits. The percentage of profit to lock in is chosen by Builder from the range 0 to 100 percent.

Protective Stops

As with target exits, there are three types of protective (also known as money management) stops. The fixed-size protective ($) stops use a fixed value (e.g., in dollars for accounts denominated in dollars), which is applied per share or contract. For example, a stop size of $500 means the stop price is calculated so that if the stop is hit, the loss will be $500 per share or contract. For the E-mini S&P futures, for example, this means the stop size would be 10 points below the entry price for a long trade because each point is worth $50 for the E-mini. For a stock trade, regardless of the number of shares, a $2 stop would be placed two points below the entry price for a long trade. The size of the stop is based on the range entered on the Parameter Ranges window ("Fixed Stop Size").

Percentage (%) protective stops are set at a percentage of the entry price below the entry price. These types of stops are often used for stock trading. For example, if the entry price is 25, a 5% protective stop would be placed 1.25 points below the entry for a long trade. The percentage value is chosen from the "Percentage Stop Size" setting on the Parameter Ranges window.

Price-based protective stops are constructed the same way as price-based target exits. In fact, the only difference is that the sign is reversed preceding the PriceDiff portion of the ExitPrice equation presented above. For example, the equation presented above to illustrate a short target exit alternatively could be a long protective stop.

Exiting After N Bars

The “Exit After N Bars” exit order causes the trade to exit at the open of the next bar when the number of bars since entry is greater than or equal to N, which is a strategy input chosen by Builder during the build process. The "Exit After N Bars Profit" and "Exit After N Bars Loss" exits work similarly. With the "Exit After N Bars Profit" exit, the trade is exited at the open of the next bar if the number of bars since entry is greater than or equal to N *and* the close of the bar is greater (less) than the entry price for a long (short) trade; i.e., if the trade is profitable before costs.

Likewise, with the "Exit After N Bars Loss" exit, the trade is exited at the open of the next bar if the number of bars since entry is greater than or equal to N *and* the close of the bar is less (greater) than the entry price for a long (short) trade; i.e., if the trade is unprofitable before costs. Normally, N is selected from the "Lookback, Indicators" setting on the Parameter Ranges window. However, for intraday strategies for which the end-of-day exit has been selected, N is chosen to be between 1 and the number of bars in the trading session.

Other Types of Market Exits

The “Exit After Time” exit causes the trade to exit at the open of the next bar when the time of the current bar is greater than or equal to an input time chosen by Builder. For example, the exit order might read “If time >= 1030 then sell next bar at market”. Note that this implies the time stamp for the trade exit will be the time of the bar following the bar where the exit is triggered. In the preceding example, if the bars are 30 minute bars, the exit time would be shown as 11:00.

The “Exit at Market” exit causes the trade to exit at the open of the next bar when the exit condition is true on the current bar.

The “Exit End-of-Day” exit causes the trade to exit at the close of the last bar of the current day if intraday or daily bars are used. On weekly or monthly data, this exit causes the trade to exit at the close of the current bar. *For TradeStatio and MultiCharts, this exit type is primarily for back-testing purposes. To achieve end-of-day exits in real-time trading on intraday data in TradeStation and MultiCharts, the optional time-based exit on the Strategy Logic window should be used. This exit type is not available for MetaTrader 4 or AmiBroker. For NinjaTrader, this exit only applies to intraday data.*

Neural Networks

Neural networks are nonlinear models loosely based on the way the brain is structured as a network of interconnected neurons. A neural network is established by fitting it to a given set of input and output data with the goal of accurately predicting the output from input data not used in the fitting process. A successful neural network is one that generalizes well to new input data.

A neural network is often described graphically as a set of nodes connecting an input layer through a "hidden" layer of nodes to one or more outputs. The inputs are summed together using a set of weights that connect the nodes to produce the output. The weights are determined by the fitting or *training* process. A neural network with a single output and one hidden layer is shown below in Fig. 1.4.

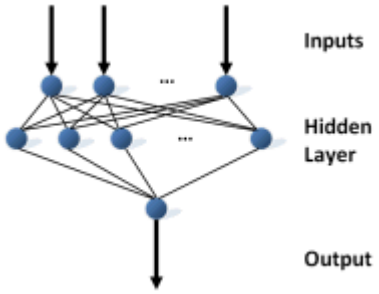


Figure 1.4. A neural network with a single output and one hidden layer.

The output from the network is defined by the following equations:

$$H_1 = \tanh(w_{11} * I_1 + w_{21} * I_2 + \ldots + w_{n1} * I_n)$$

$$H_2 = \tanh(w_{12} * I_1 + w_{22} * I_2 + \ldots + w_{n2} * I_n)$$

$$\ldots$$

$$H_m = \tanh(w_{1m} * I_1 + w_{2m} * I_2 + \ldots + w_{nm} * I_n)$$

$$\text{Output} = \tanh(w_{nm+1} * H_1 + w_{nm+2} * H_2 + \ldots + w_{nm+m} * H_m)$$

The I_i represent the inputs. In the context of trading, these could be anything that might have some predictive value for trading, such as momentum, stochastics, ADX, moving averages, etc. The H_j represent the hidden nodes, the weights are given by the w_{kl}, and the output value by Output. The hyperbolic tangent function, tanh, returns a value in the range -1 to +1, so the

output will lie in this range. The inputs are typically scaled so that they also lie between -1 and +1.

Training the network to determine the weight values involves iterating on the weights using known input-output data. The technique traditionally used to adjust the weights in an iterative manner is called back-propagation, although any similar approach may be used, such as a genetic algorithm.

In Builder, the inputs to the network are chosen by the genetic programming process and evolved along with the entry and exit conditions using the same processes of crossover and mutation used to evolve the entry and exit conditions. The output of the network allows for a long entry if it's greater than or equal to 0.5 and for a short entry if it's less than or equal to -0.5. This condition is in addition to any existing entry conditions (see Trading Strategy Structure, below). For example, if there is a long entry condition, it must be true and the neural network output must be at least 0.5 for a long entry.

As suggested above, the inputs to the neural network are scaled so that they lie between -1 and +1. The scaling is performed on a moving or trailing basis over the most recent NNLookBack bars. In other words, the minimum and maximum values of each input over the most recent NNLookBack bars are used to scale each input so that it lies between -1 and +1. The value of NNLookBack is a user-selectable option with a default value of 100.

In addition to evolving the inputs to the network, Builder also evolves the number of nodes in the hidden layer and the weight values. The initial number of inputs is a user-selectable option, along with the maximum number of nodes in the hidden layer. The number of inputs may change from strategy to strategy over successive generations as the inputs from different strategies are combined using crossover.

The total number of weights in the network will be given by (n + 1) * m, where n is the number of inputs and m is the number of nodes in the hidden layer, provided m is at least one. If there is no hidden layer (i.e., m is zero), the number of weights is the same as the number of inputs. In the resulting strategy code, each weight is listed as a strategy input. Other strategy inputs may result from the network inputs, such as the look-back length of a moving average.

To include a neural network, simply check the option on the Neural Network window and select the available settings, such as the initial number of inputs and the maximum number of hidden nodes. To develop strategies in which the neural network provides the only entry condition, set the tree depth (GP Settings) to zero, which will ensure that the usual entry conditions are always "true".

Trading Strategy Structure

Trading strategies in Builder have the following general form, shown below in pseudo-code:*

```
Inputs: N1, N2, N3, …

LongEntryCondition = …

ShortEntryCondition = …

LongExitCondition = …
```

```
ShortExitCondition = …

[Neural network inputs]
[Neural network output function]

If [position is flat and] LongEntryCondition is true
   [and neural network output >= 0.5] then
      Long entry order…
      Initialize long exit orders as necessary…

If [position is flat and] ShortEntryCondition is true
   [and neural network output <= -0.5] then
      Short entry order…
      Initialize short exit orders as necessary…

If position is long then
      Long exit order 1…
      Long exit order 2…
      …

If position is short then
      Short exit order 1…
      Short exit order 2…
      …

[End-of-day exit]
```

* Code shown in brackets [] is optional.

Strategies in Builder start with the list of inputs. An input is provided for any indicator parameter, price pattern look-back length, and any parameters required by the entry and exit orders, such as the look-back length for the ATR.

The LongEntryCondition through ShortExitCondition variables are the true/false conditions evolved by the genetic programming process, such as shown in Fig. 1.3. A long entry order is placed if the long entry condition is true, subject to the optional conditions, such as that the position is currently flat (out of the market) and that the neural network output value is above the threshold value. Likewise, a short entry order is placed if the short entry condition is true, subject to the optional conditions. An open long trade is exited at the next open if the long exit condition is true on the current bar. An open short trade is covered (exited) at the next open if the short exit condition is true is on the current bar.

Only one type of entry order is allowed for each side of the market (long/short), although they can be different for each side unless the symmetry option is selected. When an entry order is placed, one or more variables for the exit orders may be initialized within the entry order code block.

The statements for the exit orders follow the entry orders. One or more exit orders may be chosen by the program, with a maximum of one exit order of each type listed above. Unless the necessary orders have been excluded from the build set by the user, the program will ensure that each strategy has an exit-at-a-loss and an exit-at-a-profit. This prevents trades from remaining open indefinitely.

The optional end-of-day exit must be specified by the user on the Order Types tab in order to be included in the strategy.

The meaning of common input variables and order labels used in the strategy code is explained in Appendix: Code Conventions.

Example

As a simple, introductory example, Builder was run on daily bars of a stock index futures market for a small population and a limited number of generations. The performance metrics chosen to guide the process are shown below in Fig. 1.5. These settings imply that the fitness function was a weighted average of the net profit, number of trades, correlation coefficient, statistical significance, and the return/drawdown ratio. Specific targets were set for the number of trades and the return/drawdown ratio. The other selected metrics were maximized.

The build options were set mostly to the defaults, as shown in Fig. 1.6. The population size was set to 100 and the number of generations to five. All members of the population were saved ("Save 100 best strategies"), and the Reset on Build checkbox was unchecked. This means that when the build stops after five generations, the build process will continue where it stopped when the Build button is clicked again. Specifically, the program will initialize the new population with the prior population, rather than starting over. That way, if the build process is progressing well, the population can be evolved beyond the initial five generations.

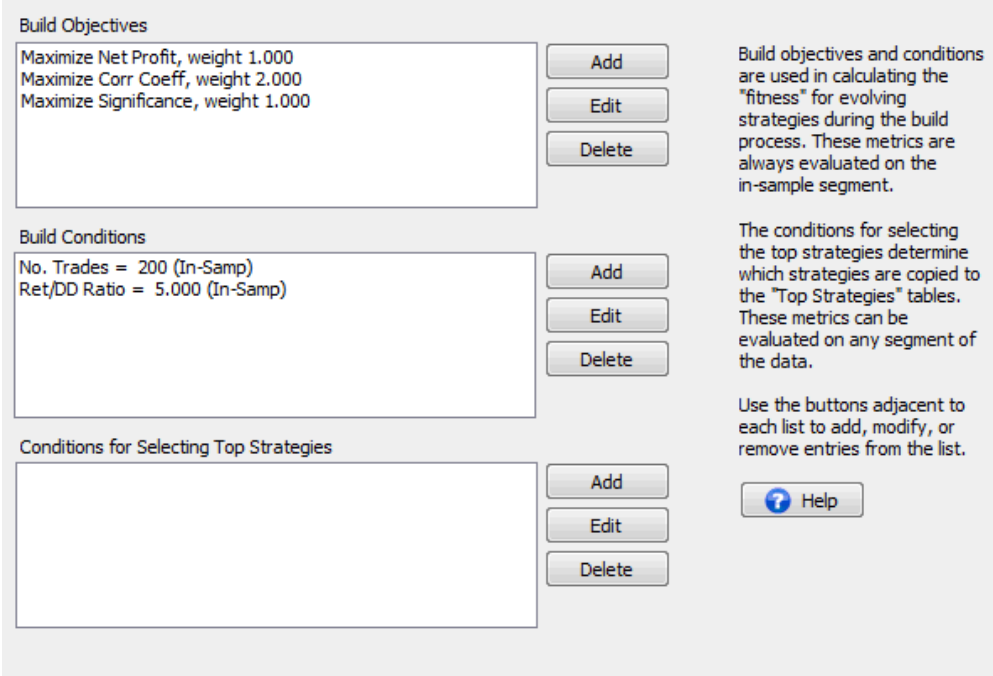


Figure 1.5. Build metrics for example build.

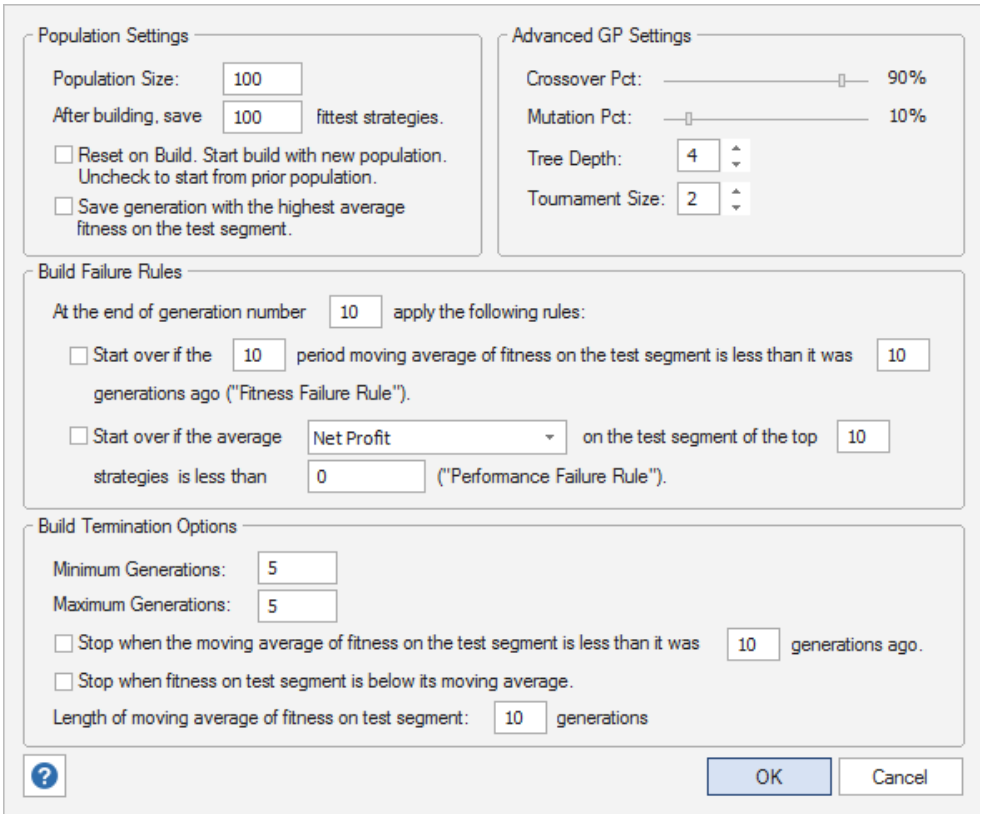


Figure 1.6. Build options for example build.

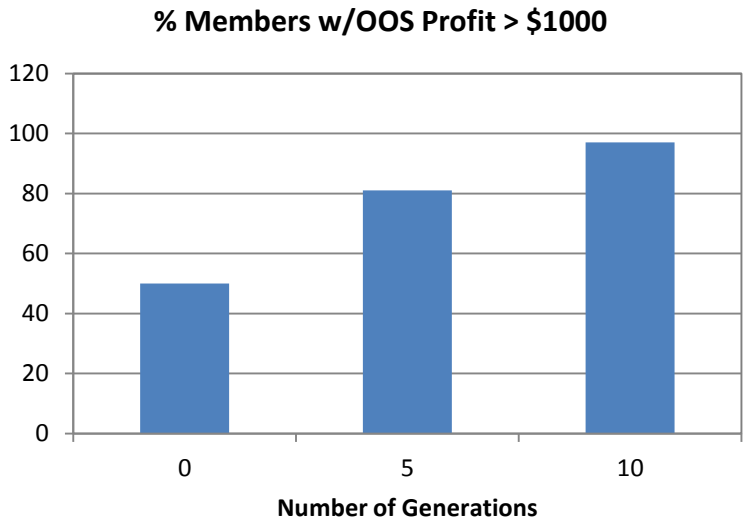


Figure 1.7. Percentage of population members with out-of-sample net profit greater than $1,000.

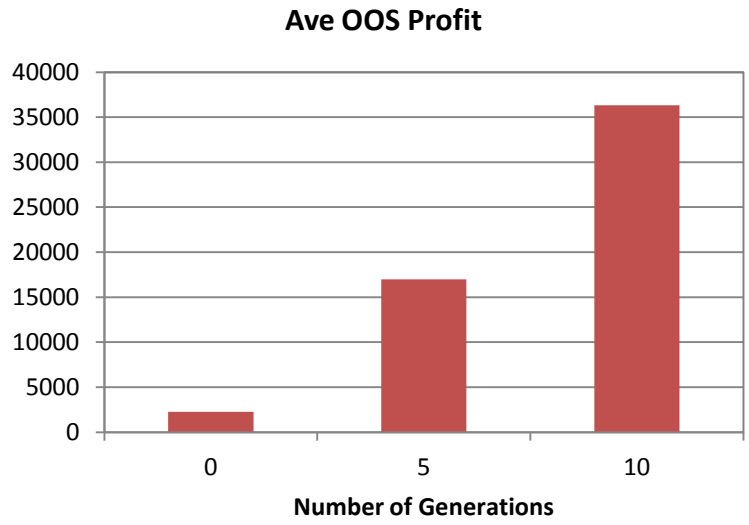


Figure 1.8. Average out-of-sample net profit of population members.

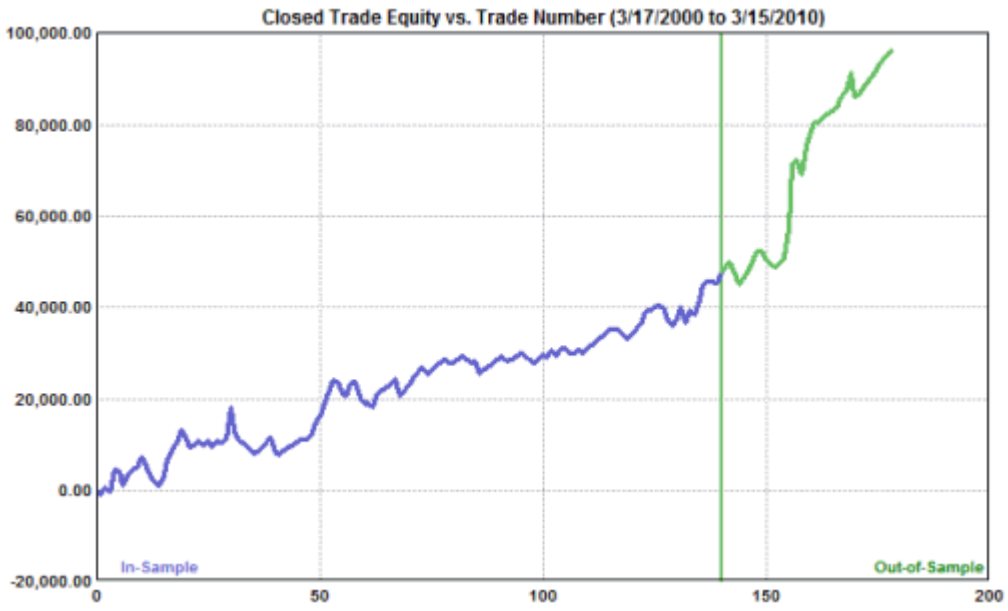


Figure 1.9. Closed trade equity curve after 10 generations.

The in-sample/out-of-sample (i.e., training/test) division of data was set to 80% in-sample (training) and 20% out-of-sample (OOS or test), with the OOS period following the in-sample period. The build process was run over a total of 10 generations. To illustrate how the results evolved during the build, the OOS net profit was recorded after the initial population was generated and after five and 10 generations. Fig. 1.7 demonstrates that the number of members of the population with OOS net profits of at least $1,000 increases after five and 10 generations.

Similarly, the average OOS net profit of the population increases after five and 10 generations, as shown in Fig. 1.8. Note that these results are for the OOS net profit. In this case, the training segment was not used in the build, so the results on that segment are out-of-sample by definition. That means the results on that segment are unbiased; they don't benefit from hindsight. This implies that the GP process not only tends to improve the in-sample results over successive generations, which is a direct effect of the GP algorithm, but the OOS results also tend to improve as the strategies are evolved.

The equity curve for one of the top strategies is shown above in Fig. 1.9 after 10 generations. Finally, the EasyLanguage (TradeStation) code for the corresponding strategy is listed below.

```
{
 EasyLanguage Strategy Code for TradeStation
 Population member: 46

 Created by: Adaptrade Builder version 1.1.0.0
 Created:    10/19/2010 2:19:52 PM

 TradeStation code for TS 6 or newer

 Price File:  C:\TestData.txt
 Build Dates:
}

{ Strategy inputs }
Inputs: NL1 (74),
        NL2 (20),
        NL3 (85),
        NBarEnL1 (59),
        NATREnL (84),
        EntFrL (3.8189),
        NATRTargL (57),
        TargFrL (1.6168),
        NBarExL (100),
        NBarEnS1 (40),
        NBarEnS2 (49),
        NBarEnS3 (7),
        EntFrS (0.6971),
        NBarExS (6),
        NATRTrailS (33),
        ATRFrTrailS (1.4126),
        TrailPctS (50.0000);

{ Variables for average true range for entry and exit orders }
Var:    ATREnL (0),
        ATRTargL (0),
        ATRTrailS (0);

{ Variables for money management and/or trailing stop exit orders }
Var:    SStop (0),
        NewSStop (0),
        STrailOn (false);

{ Variables for entry conditions }
Var:    EntCondL (false),
        EntCondS (false);

{ Average true range }
ATREnL = AvgTrueRange(NATREnL);
ATRTargL = AvgTrueRange(NATRTargL);
ATRTrailS = AvgTrueRange(NATRTrailS);

{ Entry conditions }
EntCondL = (Highest(Volume, NL1) >= Lowest(Volume, NL2)) or (Volume < Average(Volume,
NL3));

EntCondS = true;

{ Entry orders }
If MarketPosition = 0 and EntCondL then begin
```

```
   Buy next bar at XAverage(L, NBarEnL1) + EntFrL * ATREnL stop;
end;

If MarketPosition = 0 and EntCondS then begin
   Sell short next bar at Highest(H, NBarEnS1) - EntFrS * AbsValue(Lowest(L,
NBarEnS2) - Lowest(H, NBarEnS3)) stop;
   STrailOn = false;
   SStop = Power(10, 10);
end;

{ Exit orders, long trades }
If MarketPosition > 0 then begin

   If BarsSinceEntry >= NBarExL then
      Sell next bar at market;

   Sell next bar at EntryPrice + TargFrL * ATRTargL limit;
end;

{ Exit orders, short trades }
If MarketPosition < 0 then begin

   If EntryPrice - C > ATRFrTrailS * ATRTrailS then
      STrailOn = true;

   If STrailOn then begin
      NewSStop = EntryPrice - TrailPctS * (EntryPrice - C)/100.;
      SStop = MinList(SStop, NewSStop);
   end;

   If BarsSinceEntry >= NBarExS then
      Buy to cover next bar at market;

   If STrailOn then
      Buy to cover next bar at SStop stop;
end;
```

This example represents one of the simpler strategies you might create with Builder. Strategies can be created with as much or as little complexity as you want. For other examples, please see the Newsletters section on the Adaptrade.com web site.

Chapter 2
Getting Started

Installation

Recommended System Requirements:

3 GHz or faster processor
4 GB or more RAM
Windows Vista or newer operating system
Monitor: 17 inch or larger

Adaptrade Builder can be downloaded at any time from the download page of the Adaptrade Software web site (www.Adaptrade.com). The program initially installs as a trial, which can be activated (i.e., converted to a licensed copy) following purchase. The trial version is the same as the paid version; i.e., there is no separate installation for the paid version. The download file is a self-extracting installation file. To install Builder, browse to the location of the downloaded file via Windows Explorer (also known as "My Computer") and double-click on the file to open it. Alternatively, select Run from the Accessories menu under the list of programs in the Start menu, browse to the location of the downloaded file, click Open, then click OK in the Run window. The installation should begin.

The installation program will prompt you for the location to install the program files. The default location is the folder Program Files\Adaptrade Software\Adaptrade Builder x.x\, where x.x is the version number (e.g., 2.0). You can install the program in another location if you wish.

Note about 32 vs. 64-bit versions: The 32-bit version of Builder will run on both 32 and 64-bit versions of Windows. However, the 64-bit version will be able to take advantage of all available installed memory to process larger data files. If you're not sure which version of Windows you have, you can check the System settings under the Control Panel. Both the 32 and 64-bit versions are compiled from the same code and are functionally identical, including the project (.gpstrat) files they generate. Because they're the same program, only one may be installed on the same computer. If your computer runs 64-bit Windows, it's strongly recommended that you install the 64-bit version.

Once the installation is complete, you should find the Builder icon, as displayed on the title page of the user's guide, on your desktop and the Builder program in the programs menu. You should also find a folder called Examples in the Adaptrade Builder folder. The Examples folder contains sample files that can be opened by Builder.

To activate Builder, enter the license ID and password provided in the purchase receipt in the spaces provided on the activation screen, which will be displayed when the program is first run. Please note that the licensed version of Builder and the trial version are identical. The trial version is converted to a licensed version after purchase by entering the license ID and password. There is no separate download for the licensed executable. The most recent version of Builder can always be found on the trial download page of the Adaptrade Software web site (www.Adaptrade.com).

Bonus files. If your purchase includes set of bonus strategies, they will be provided via a separate download link at the time of purchase. Please check your online order receipt for the download link for these files. Install the bonus files by double-clicking the file after download.

TradeStation/MultiCharts Installation Notes. Several files that work in conjunction with Builder need to be installed separately into TradeStation or MultiCharts. These files can be found in the EasyLanguage folder in the Adaptrade Builder folder under Program Files after Builder is installed. For current versions of TradeStation, the files end with the file extension .eld. For TS 2000i, the file extension is .els, and for MultiCharts, the extension is .pla. The files should be imported into TradeStation using the import command of the File menu. For MultiCharts, the files can be imported via the Import command of the File menu in the PowerLanguage Editor. Please refer to the platform documentation for instructions on importing .eld/.els/.pla files into TradeStation/MultiCharts.

The specific files that need to be imported into TradeStation/MultiCharts include NNCOMPUTE, which contains functions for use with the neural network option in Builder, and BUILDER_ADAPTINDICATORS, which contains the adaptive indicators (Adaptive VMA, Adaptive ZLT, etc.).

NinjaTrader 7 Installation Notes. Strategies created with the NinjaTrader code option require several indicator and strategy files to run. Without these files, the NinjaScript code will not compile or execute. These files are contained in a zip file named NinjaTrader.Adaptrade.zip, which can be found in the NinjaScript folder in the Adaptrade Builder folder under Program Files after Builder is installed. To install the files, open NinjaTrader, select Utilities from the File menu and select Import NinjaScript… Browse to the NinjaScript folder in the Adaptrade Builder installation folder and select the NinjaTrader.Adaptrade.zip file. Follow the prompts to install the files into NinjaTrader.

MetaTrader 4 Installation Notes. MetaTrader 4 strategies created by Builder require files contained in three folders: Include, Indicators, and Libraries. These folders can be found in the MT4 folder in the Adaptrade Builder folder under Program Files after Builder is installed. The files in these folders provide basic functionality that any MetaTrader 4 strategy generated by Builder may require. All the files contained in the three folders should be copied to the corresponding folders within your MetaTrader 4 installation so that MetaTrader 4 can find them when compiling strategies. For MT4 version 600 and newer, the correct folder locations can be found using the "Open Data Folder" command of the File menu in MT4. The general form of the folder path is C:\Users\User_account_name\AppData\Roaming\MetaQuotes\Terminal\Instance_id, in which User_account_name and Instance_id are specific to the user's computer. Within this folder, the Include, Indicators, and Libraries folders are located in the MQL4 folder.

In versions of MT4 prior to version 600, the three folders are located in the installation folder in the experts folder (C:\Program Files (x86)\MetaTrader 4\experts\).

AmiBroker Installation Notes. AmiBroker strategies created by Builder require an associated "include" file: ASBuilderCommon.afl. This file can be found in the AFL folder in the Adaptrade Builder folder after Builder is installed. This file needs to be copied to the Include folder in the AmiBroker Formulas folder under Program Files. The full path under 64-bit Windows is C:\Program Files\AmiBroker\Formulas\Include. This file provides basic functionality that all AmiBroker strategies generated by Builder require.

When installing a new version of Builder on a computer that currently has a prior version installed, please note the following:

- It's usually unnecessary to uninstall a prior version of Builder before installing a newer one. However, if the version number is the same through the second decimal (e.g. 1.2.1 and 1.2.2 are both version 1.2), the newer version will be installed in the same folder as the current version by default and will over-write the older version, making it impossible to use the older version.
- Provided the installation is on the same computer as the prior installation, no new activation code should be required. The new version should install already activated. If not, it may be necessary to enter your license ID and password, as provided on your purchase receipt. If you need an additional activation, please contact Adaptrade Software.
- Uninstalling an older version will not affect any project files (.gpstrat files) you may have created or saved.
- New versions of Builder are designed to read files (.gpstrat files) from prior versions. However, once a file is saved in the new version of Builder, you will not be able to open it in an older version.
- The window layout stored with a currently installed version of Builder is not removed when that version is uninstalled. This means that if a new version, such as 1.1.0, has a different window layout than the prior installed version, the layout may need to be adjusted when the program is first run. All panes in Builder can be moved and resized by clicking and dragging, as explained below. You can reset the layout by deleting the registry entry for Builder using the regedit program of Windows. The registry entry for Builder is located at HKEY_CURRENT_USER\Software\Adaptrade Software\Builder.

Builder can be uninstalled through the Windows Control Panel.

Program Layout and Configuration

The user interface of Adaptrade Builder consists of a number of different windows and panes. The overall layout of the program can be changed by clicking the Strategy Builder button in the Build menu, which can be seen in the upper left-hand corner of Fig. 1.1. This button switches the layout between charting mode and building mode. In building mode, the program includes all the results windows and panes used to display the results of the build process, as shown in Fig. 1.1. In charting mode, shown below in Fig. 2.1, the charting pane becomes more prominent, and the build-related panes are closed. As an alternative to clicking the Strategy Builder button, any of the different windows and panes can be opened or closed at any time by clicking the corresponding boxes on the View menu.

The so-called ribbon menu is located at the top of the main window and consists of the File, Build, Evaluation, Position Sizing, View, and Clipboard menus. In the Build menu, most of the buttons activate drop-down windows for entering build settings, such as the genetic programming (GP) settings, build metrics, strategy logic, and so on. To save space, the ribbon menu can be minimized by clicking the ^ button in the upper right-hand corner of the main window next to the Theme menu.

Aside from the ribbon menu and the chart window, most of the other windows displayed in build mode are referred to as docking windows or panes. Docking panes are floating windows that can be re-positioned by clicking and dragging. The panes shown in Fig. 1.1 consist of the Symbols, Build Results, Messages, and the set of tabbed panes for the Performance Report, Build Report, Equity Curve, Trade List, and Strategy Code windows.

The Symbols pane (i.e., symbol library) displays all the market symbols that can be plotted or used in building strategies. To build a strategy for a new market, the symbol must be added to the symbol library through this pane. Once added to the library, the associated price data is available to any project.

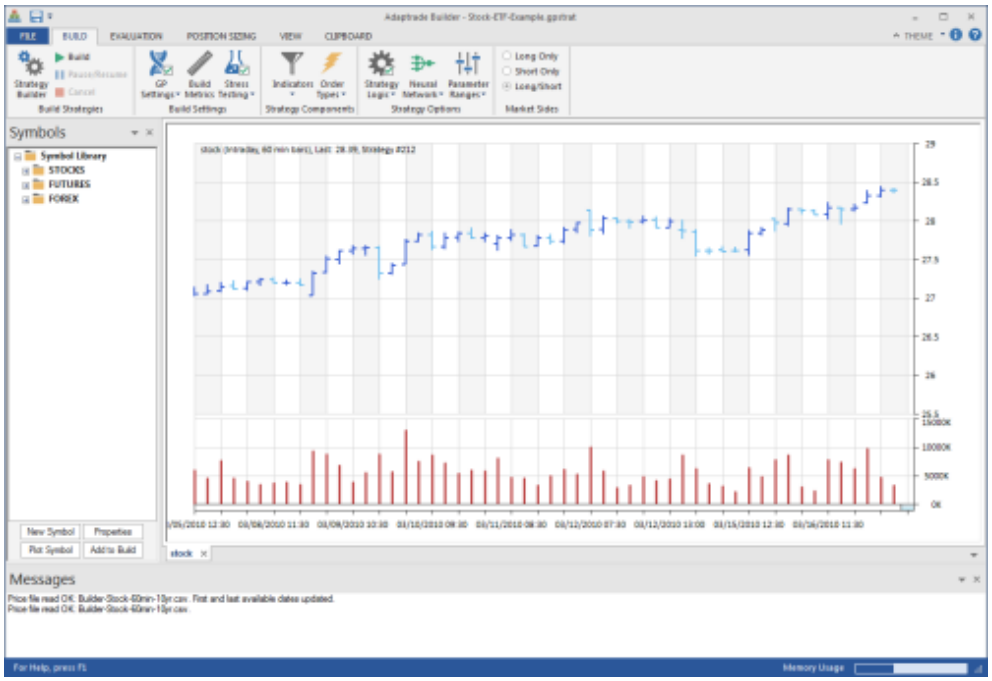


Figure 2.1. Adaptrade Builder in charting mode.

The Build Results pane displays summary statistics for all strategies in the population. This is the main display of results from the build process, where each row in the table represents a strategy in the population. Clicking on a row in the table changes the display of results in the tabbed results windows (Equity Curve, Trade List, Strategy Code, etc.), which display the results for the selected strategy. In addition, if the option to show the strategy trades on the price chart has been selected, the chart(s) will be updated to display the trades for the selected strategy.

Two other non-pane windows are also part of the program. The Build/Eval Process window is where you select the markets to use in the build process and in evaluating strategies after building when changing markets or other evaluation settings, such as position sizing. This window also displays two graphs that show the progress of the build process while it's ongoing. This window can be left open while working elsewhere in the program or it can be minimized or closed as desired. It can be opened or closed at any time through the View menu.

The other non-pane window is the Trading Orders window. This window is displayed when the option to "Show Trading Orders" is selected on the right-click context menu of the chart window. This window can also be kept open while working elsewhere in the program and can be opened and closed through the View menu.

Changing the Pane Layout

Panes are moved by clicking and dragging them relative to each other and to the outer window frame. To move a pane, click the title bar and start dragging the window. This action will cause a set of docking locations to appear. You can move the mouse cursor over the different docking locations to see a preview of where the window will appear if you release the mouse at that location. You will usually see four docking locations (top, bottom, left, right) for the entire program window (main frame) and four others relative to the current pane location. When two or more panes are moved to the same location, they appear with tabs, as with the Equity Curve and Strategy Code windows. The tabs can be moved relative to each other by clicking and dragging.

To rearrange the pane windows, sometimes it's necessary to move them in multiple steps. For example, to switch the locations of the symbols pane and the set of tabbed results panes, you could move the symbol pane to the right of the tabbed results panes first, then move the tabbed results panes as a group to the left of the charts. Because the chart view window is not a docking window, it can't be moved directly. If you want to move the chart windows to a different location, you can move the other panes relative to them. For example, if you want the chart windows on the right, you could drag the equity curve pane, along with the other panes in that tab group, to the left side. This will force the chart windows to the right. Any pane can be closed using the close button in the upper right-hand corner of the title bar. Use the View menu to restore a closed pane.

When Builder is first installed, it arranges the panes in the default configuration shown in Fig. 1.1. However, if you're installing the program on top of an older version, the stored locations for windows and panes in the older version may take precedence. Uninstalling Builder won't affect the layout because the layout is stored in the registry, which is not deleted during uninstall. If you're comfortable working with the registry, you can delete it yourself. That will cause the entire layout to be reset the next time you run the program. Otherwise, the windows can be rearranged manually as described above. The registry entry for Builder can be deleted using the regedit program of Windows. The registry entry for Builder is located at HKEY_CURRENT_USER\Software\Adaptrade Software\Builder.

Working with Project Files

The settings made in Builder can be saved for later use. Builder project files end with the extension .gpstrat; e.g., MySampleFile.gpstrat. To save your work, select Save Project from the File menu. This will prompt you to select or enter a file name. This file will not include the price data but will save the name and location of the text file containing the price data. To return to the project file later, open it by selecting it from the list of recently used files on the File menu or select it using the Open Project command of the File menu. Project files also store the strategy code for all the saved strategies, as shown in the Build Results tables, along with the performance results for each strategy. Only one project file can be open at a time.

When New is selected from the File menu, the new project is given the default name "BuilderProject". When Save is subsequently selected, you'll be prompted to enter a new file name. If Close is selected from the File menu, you'll be prompted to save the file if it has not been saved since last changed, and the current project file will be closed. When no project file is open, most of the menu commands are unavailable, and you'll be unable to start a new project until selecting New.

If a project file is open at the time the program is exited, that project file will be automatically opened upon start-up the next time Builder is run.

Quick Start Steps

The process of building trading strategies in Adaptrade Builder begins by specifying the price data or market symbols. Next, a series of settings is entered in the ribbon menu. The settings determine the types of strategies that are built and control various aspects of the build process. While the build process is ongoing, progress messages are displayed in the Messages window. Additionally, the results windows (Build Results, Performance Report, Build Report, Equity Curve, Trade List, and Strategy Code) are updated after each generation is completed.

Step 1. Obtain the Price Data

Builder is designed to read files of price data saved in text format, such as price data saved from the TradeStation Data Window. To display the Data Window from a TradeStation price chart, go to the View menu in TradeStation and select Data Window. To save the price data to a text file, click the disk icon on the data window, or, for TS 2000i, right-click and select "Send to File". In the Save-As dialog, select a file, then click the Save button. This will save the price data for the chart window to the text file you've selected. In MultiCharts, select "Export Data" from the File menu to save the chart data to a text file. In MetaTrader 4, go to the Tools menu and select History Center. Select the symbol from the list at left and click the Export button. In NinjaTrader, use the Export tab on the Historical Data Manager window. For AmiBroker, the price data should be exported to a text file using the software provided by your data vendor.

Step 2. Add the Price Data File Obtained in Step 1

Open Builder and, in the Symbols pane, select a folder, right-click, and select the New Symbol command or click the New Symbol button at the bottom of the Symbols pane. This will open the Symbol Properties window, shown below in Fig. 2.2. To select the price file obtained in step 1, click the "..." button in the Price File Name field.

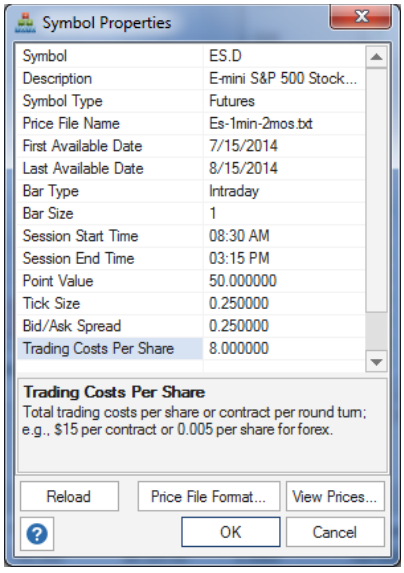


Figure 2.2. Symbol Properties window.

When you add a file of price data, Builder opens the Price File Format window, as shown in Fig. 2.3. The top table displays the contents of the price file and enables you to set the formatting that tells the program how to read and interpret the data in the file. Select the field delimiter (comma, semi-colon, tab, or space) used in your file to separate the data fields. The default column headings for the data fields are date, time, open, high, low, close, and volume. Click any column heading in the table to change, add, or remove its label. Each column of data you want the program to read should have a label. Change the heading for the volume column(s) as necessary, depending on whether the price file contains one column of volume data or separate columns for up-tick and down-tick volume. Click the Clear Column Headings button to remove all column labels in order to start fresh.

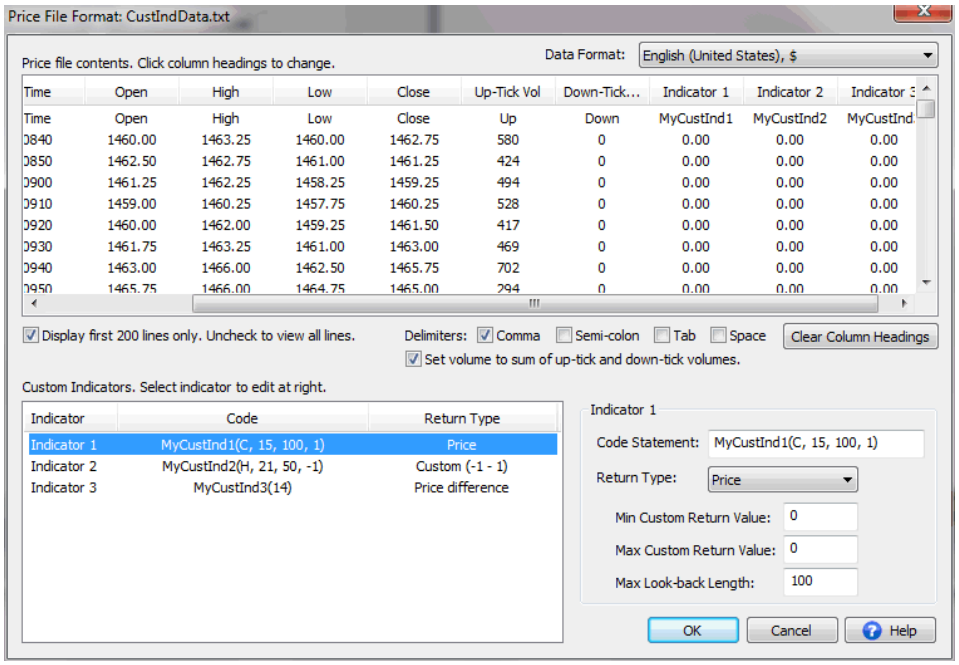


Figure 2.3. The format of the price file is selected on the Price File Format window.

If necessary, use the Data Format pull-down menu to select a locale for reading the price data. For example, price data saved from MetaTrader 4 have an unusual combination of date/time and number formats that can be read using the "French (Switzerland)" locale.

Once you've selected the format for the file of price data, clicking OK will return you to the Symbol Properties window. Enter values for each entry in the list of properties, including symbol, bar type, point value, and so on. Builder will try to properly infer the bar type, bar size, and session times from the data file. If any of these are incorrect, they should be manually corrected here. Click OK to return to the Symbols pane.

To add the newly entered symbol to the build process, where it will be used to build your strategy, right-click on the symbol and select Add to Build or click the Add to Build button at the bottom of the Symbols pane. Any symbols added to the build in this manner will be displayed in the Market Symbols table in the Build/Eval Process window, shown below in Fig. 2.4.

Click the Add button to add a price file from the symbol library or click Remove to delete one from the table. Select the files to include in the build by checking the boxes in the Include column. The strategies will be built over the data from all selected symbols.

The settings in the Market Symbols table for Bar Type, Bar Size, and Costs Per Share are the settings you want to use when building and/or evaluating a strategy. These can be different from the values for the symbol in the library. For example, if the price file consists of 1 minute bars, the settings in the Symbol Properties window should always specify 1 minute bars, but once added to the Build/Eval Process window, you can change the bar type to any multiple of 1 minute or to daily, weekly, monthly, or range bars.

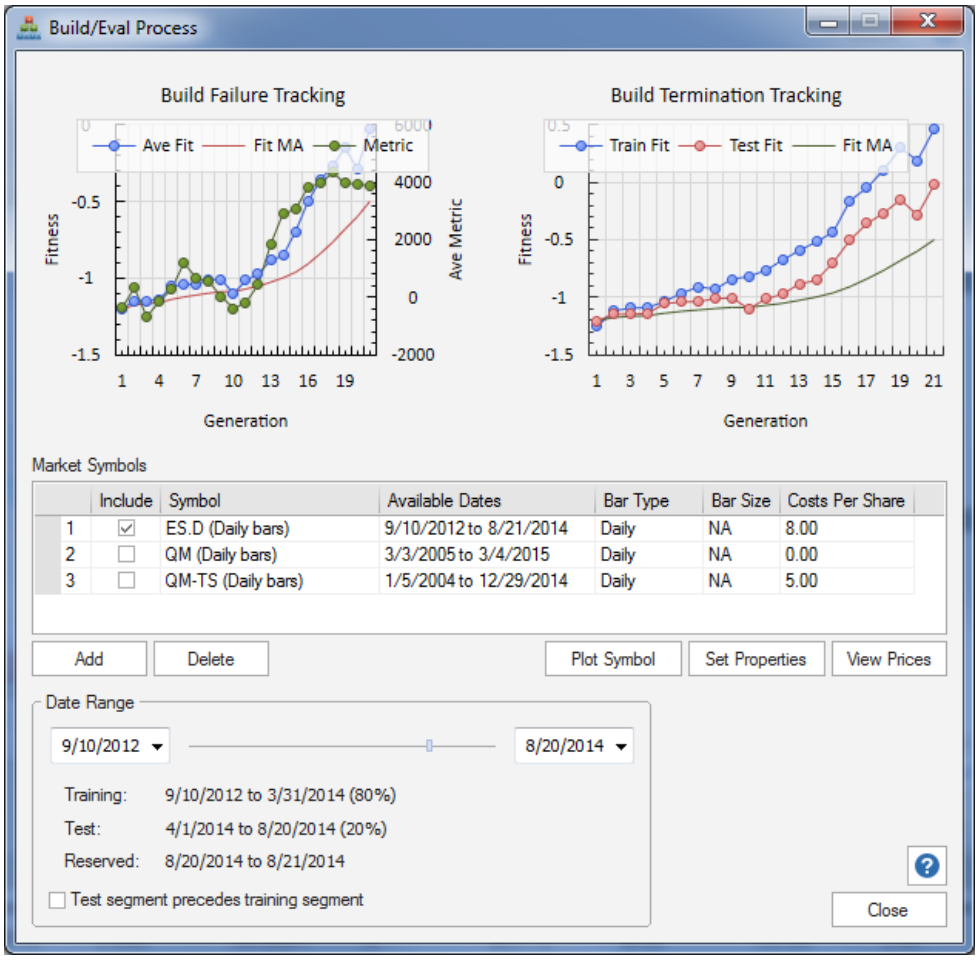


Figure 2.4. Settings for the markets used in the build are made in the Build/Eval Process window.

Step 3. Select the Date Ranges

The Build/Eval Process window also includes controls for changing the start and end dates for analysis as well as the training/test dates. You can change the start and end dates for building or evaluating a strategy by clicking on the calendar controls at either end of the Date Range slider. Move the slider to change the dates for training and test analysis. The training data are used in building the strategy. Test data are used in evaluating the results on the training segment, which helps to guide the build process. Any data outside of both the training and test segments is shown under "Reserved". This data can be used to validate the final results. Because the validation data are not used during the build process, the results achieved on validation data are unbiased. Generally speaking, a ratio of between three and five to one for training to test data is recommended.

Step 4. Choose the Genetic Programming (GP) Settings

The GP Settings button in the Build Settings panel of the Build menu opens the GP Settings drop-down window, as shown in Fig. 2.5. Different options that influence the build process are selected on this window. For example, this is where you enter the population size and the number of generations. You can also select from two different Build Failure Rules, which will restart the build process after a specified number of generations if the results on the test segment are not satisfactory. The build process can be terminated (Build Termination Options) when a maximum number of generations has been completed or when the fitness on the test segment starts to decline.

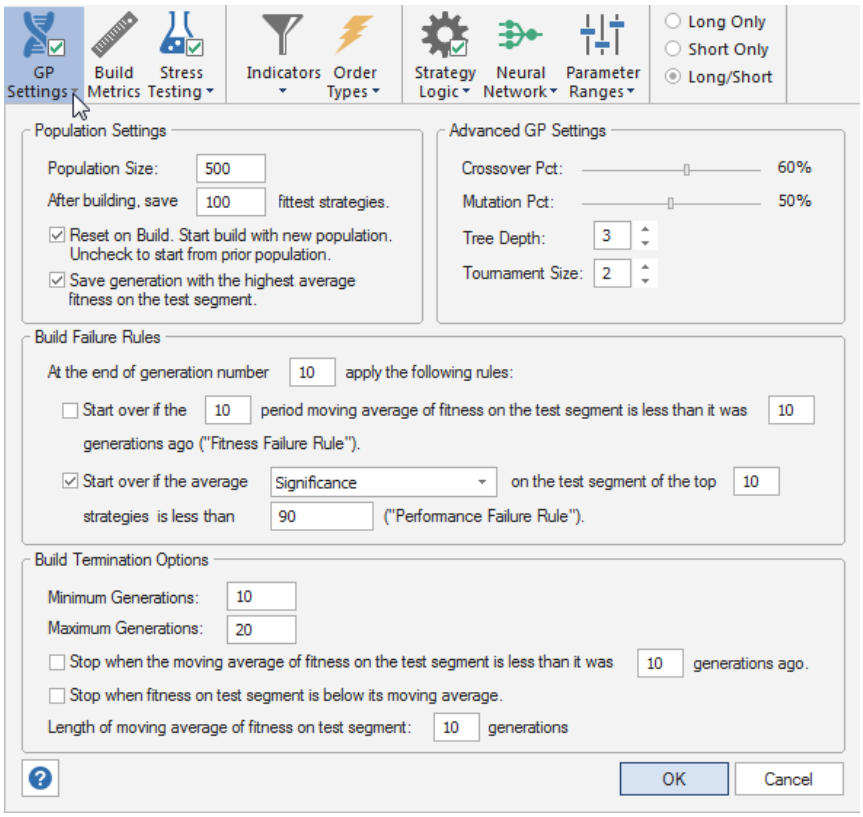


Figure 2.5. Options that affect the build process are specified on the GP Settings drop-down window.

You can also modify the crossover and mutation percentages, tree depth, and tournament size on this window. These options are discussed further in the next chapter. To incorporate the best strategies from the prior build into the next build, uncheck the Reset on Build box before building. This will cause Builder to initialize the population with the saved strategies from the prior build. The number of saved strategies is specified using the "After building, save [] fittest strategies" option. If the Reset on Build box is checked, the population will be initialized randomly.

Step 5. Select the Build Metrics

The Build Metrics window is shown in Fig. 2.6. This is where you select the build objectives and conditions that will guide the build process. Strategies are ranked during the genetic programming process according to the *fitness*, which is a combination of the build objectives and conditions selected on this tab. The objectives are metrics that you want to minimize (e.g., drawdown) or maximize (e.g., net profit). The conditions are expressed as inequality or equality statements, such as a correlation coefficient greater than or equal to 0.95 or the number of trades between 100 and 300. The third list box is for selecting conditions for filtering the strategies for the Top Strategies results. Use the buttons adjacent to each list to add, modify, or remove entries from the list.

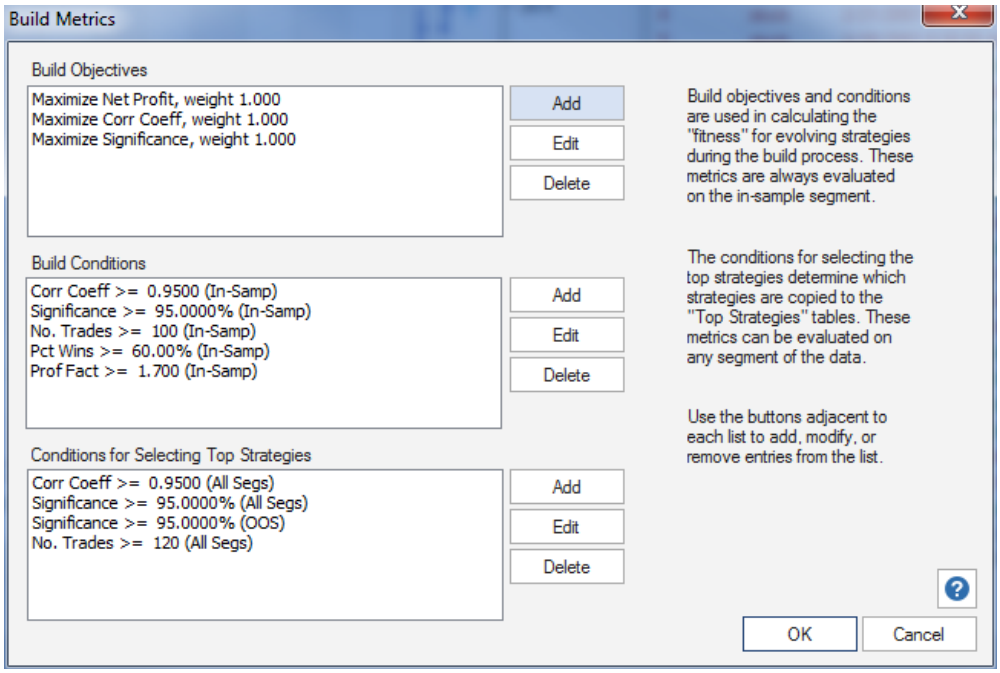


Figure 2.6. Build metrics are specified in the Build Metrics window by selecting objectives and conditions for key performance metrics.

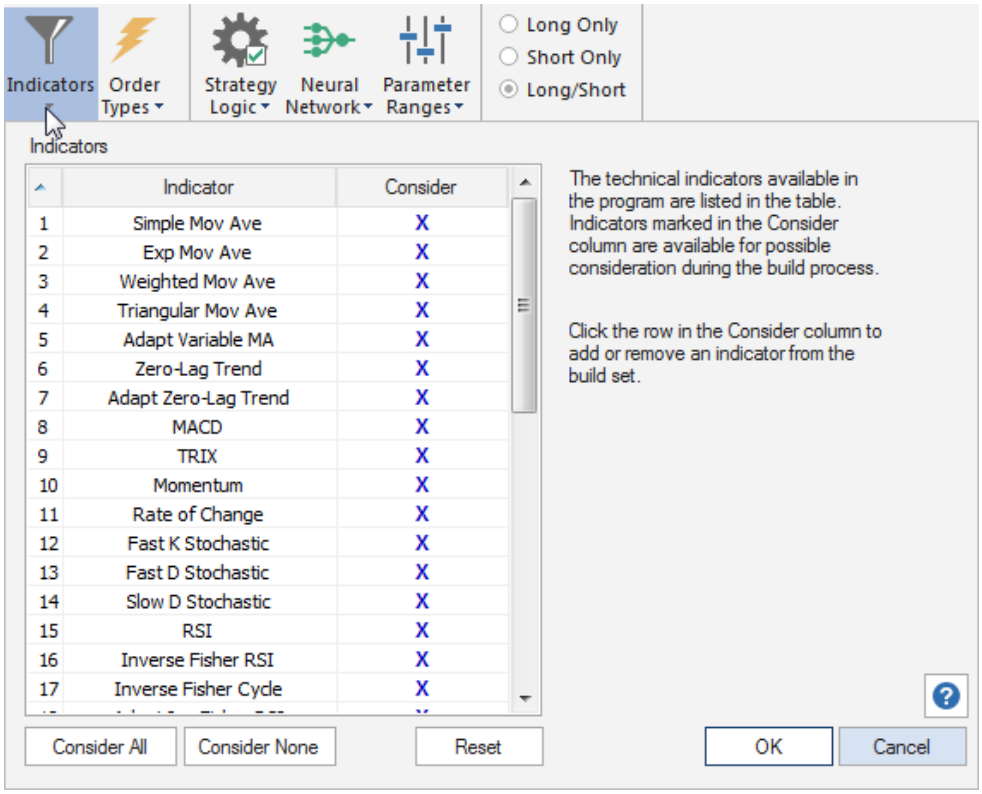


Figure 2.7. The indicators available in Builder are listed on the Indicators window. Indicators can be removed from the build set by un-checking the item in the "Consider" column.

Step 6. Select Indicators and Order Types

Indicators are selected on the Build menu in the ribbon by clicking the Indicators button, which opens the Indicators window, shown in Fig. 2.7. The available order types are listed in the table on the Order Types window, shown in Fig. 2.8. The tables on these two windows represent the build set, which contains the list of indicators and the list of order types that the program draws from during the genetic programming process. To remove a specific indicator or type of order from the build set, click the corresponding row in the Consider column of the table. Removing an indicator or order type from the build set means it won't be considered by the program when constructing strategies. Removing too many items may reduce the likelihood of finding viable strategies. Clicking an order type in the Include column in the Order Types table ensures that the order type will be included in each generated strategy.

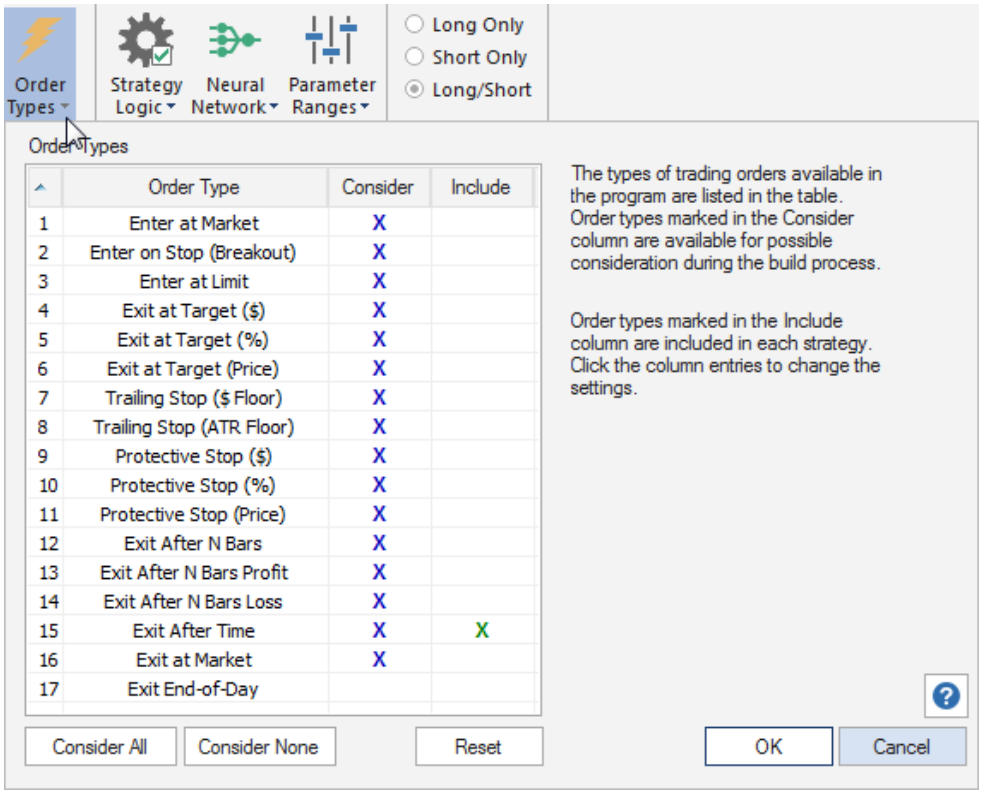


Figure 2.8. The types of trading orders available in Builder are listed on the Order Types window. Orders types can be added or removed from the build set using the Consider column and added to each strategy using the Include column.

Step 7. Select Strategy Options on the Build Menu

The Build menu is shown in Fig. 2.9. The settings in the Strategy Options panel control the types of strategies generated by Builder. Clicking the Strategy Logic button opens a drop-down window containing options for long/short symmetry, trade entry and exit time ranges, a limit on the number of entries per day, and other strategy logic options. The Neural Network drop-down window allows you to add a neural network to the strategy and set the associated parameters. Clicking the Parameter Ranges button opens a drop-down window that allows you to enter minimum and maximum values for constants used by the program, such as the multipliers for the average true range (ATR) and look-back lengths for indicators and price patterns. Also shown in Fig. 2.9 is the Market Sides panel, which allows you to restrict entries to either long or short trades only or to include both long and short trades in the same strategy.

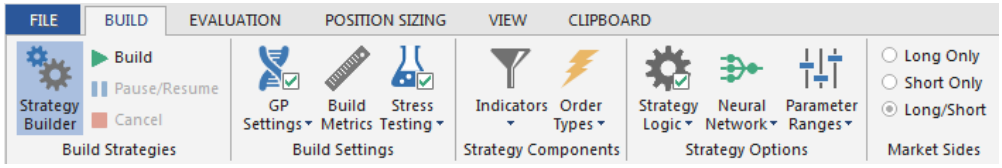


Figure 2.9. The Build menu provides access to most of the settings related to building strategies.

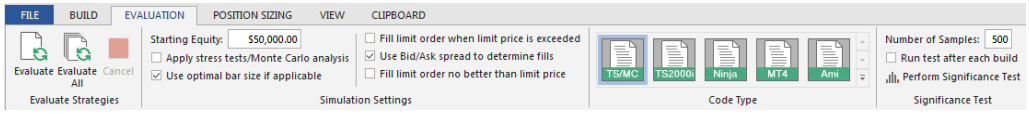


Figure 2.10. Options that affect how strategies are evaluated are set on the Evaluation menu.

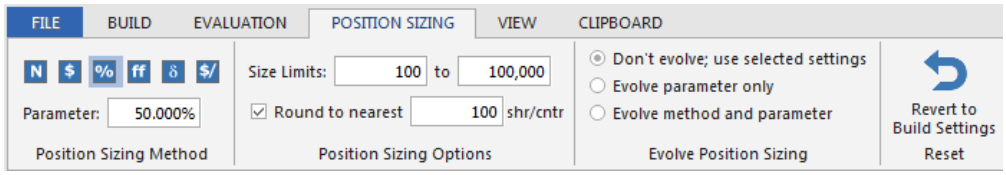


Figure 2.11. Position sizing options determine how many shares or contracts are traded.

Step 8. Select Evaluation and Position Sizing Options

Options that affect how strategies are evaluated are selected on the Evaluation menu, shown in Fig. 2.10. The principal options on this menu are the starting equity value, which can affect position sizing, and the code type. Position sizing settings are made on the Position Sizing menu, shown in Fig. 2.11. You can choose from six different position sizing methods. You can also choose whether you want the build process to select the method for you and/or whether the build process will select the position sizing parameter value, such as the fixed fraction for fixed fractional position sizing. Other options on this tab include the maximum number of shares or contracts that will be traded and whether or not to round the position size to the nearest value, such as rounding the number of shares to the nearest 100.

After making the preceding settings, it's good practice to save them by selecting Save Project from the File menu. This will prompt you to select or enter a file name for saving all the settings you've made up to this point. The resulting file will have the file extension ".gpstrat". This file will not include the price data but will save the name and location of the text file containing the price data. To return to the project file later, open it by selecting it from the list of recently used files on the File menu or select it using the Open Project command of the File menu.

Step 9. Start the Build Process

Click the Build button in the Build Strategies panel of the Build menu (Fig. 2.9) to start the build process. A message is displayed in the Messages window near the bottom of the main window during each step of the process. After each generation is completed, the results windows (Build Results, Performance Report, Build Report, Equity Curve, Trade List, and Strategy Code) are updated. The summary performance metrics for each of the strategies are displayed in the Build Results tables. Click on a row in the results table to display the results for the corresponding strategy in the Performance Report, Build Report, Equity Curve, Trade List, and Strategy Code windows. The build process can be cancelled at any time by clicking the Cancel button or paused by clicking the Pause/Resume button.

Step 10. Evaluate the Generated Strategies and Adjust if Necessary
After the build termination conditions are met or the Cancel button is clicked, the build process stops. The generated strategies are listed in the Build Results tables in order of decreasing fitness. Builder will save any number of strategies you specify on the GP Settings window up to the population size. Evaluate the saved strategies by reviewing the build and performance reports, equity curve, trade entry and exit points on the price chart, and trade-by-trade results in the Trade List table. If none of the saved strategies meet your requirements, change the build objectives and conditions on the Build Metrics window to address the deficiencies observed in the generated strategies. For example, if the drawdown is too large, you could try increasing the weight for the drawdown metric or increasing the weight for the correlation coefficient. Click the Build button to rebuild. If the Reset on Build box is checked, the current population will be discarded, and the population will be reinitialized randomly. If the box is unchecked, the saved strategies will be used to reinitialize the population.

Step 11. Transfer the Code to Your Trading Platform
When you're satisfied with the results in Builder, transfer the strategy code to your trading platform for any additional testing, such as real-time tracking, and for trading. The code in the Strategy Code window can be copied by right-clicking and selecting "Copy Strategy". In TradeStation or MultiCharts, open a new strategy window in the EasyLanguage editor, choose a name, then paste the code into the empty strategy window. Finally, compile the EasyLanguage code.

In NinjaTrader 7, right-click on the Strategy Code pane and select "Save NinjaScript Strategy to File". Choose a name for the strategy or accept the default, and save the strategy to the folder Documents\NinjaTrader 7\bin\Custom\Strategy\. Open the strategy in the NinjaTrader editor by selecting Edit NinjaScript from the Tools menu, and click the Compile button. The strategy should then be ready to back-test via the Strategy Analyzer in NinjaTrader.

In MetaTrader 4, open a new window in the MetaEditor, paste in the code from Builder, and click the compile button. Alternatively, you can save the MetaTrader 4 code directly to a .mq4 file by right-clicking in the code window in Builder and selecting "Save MT4 Strategy to File".

In AmiBroker, in the Charts pane, right-click on the Systems folder and select "New" and then "Formula". Enter a name then right-click on the name and select "Edit". Select "Paste" from the Edit menu to paste the code into the edit window, then click the save icon and, finally, click the AFL icon to verify the code.

To test the strategy in TradeStation/MultiCharts, insert it into the corresponding chart, such as the chart used to generate the price data file for analysis, and set the "Maximum number of bars study will reference" (in TradeStation, Format Strategies, Properties for All) to the MaxBarsBack value listed in the Build Results table.

In MultiCharts, the value is entered under Format Signal, Properties ("Maximum number of bars study will reference"). This ensures that the strategy has enough data to start calculating the indicators at the beginning of the chart.

In NinjaTrader, this value is entered on the Backtest tab of the Strategy Analyzer window ("Min. bars required").

In MetaTrader 4, select the strategy (Expert Advisor) on the Tester window (Settings tab), and select the symbol and date range. For best results in MetaTrader, select "Every tick" as the Model, then click the Start button to run the back-test.

In AmiBroker, right-click on the strategy in the Systems folder of the Charts pane and select "Analysis". On the Analysis window, reset the parameter values by clicking on the Parameters icon, and check the settings by clicking on the Settings icon. Finally, click the Backtest icon to run the test.

Note: *If you're pasting the strategy code over the code for an existing strategy, it will be necessary to reset the input values before running the back-test. In TradeStation, delete the strategy from the chart and re-insert it to reset the input values. In MetaTrader 4, this can be done by clicking the Expert properties button on the Tester window and clicking the Reset button on the Inputs tab. In AmiBroker, click the Parameters icon on the Analysis window and click "Reset all".*

To insure that you get the same results in the trading platform as in Builder, make sure that the basic settings, such as trading costs and point value, are set correctly. For example, in TradeStation, costs should be set to one-half the value in Builder since Builder deducts costs on a round-turn basis, whereas TradeStation deducts costs per-side. Also make sure the start and end dates of the chart are the same as in Builder and that the MaxBarsBack value in TradeStation/MultiCharts is the same. Small differences may still occur, due primarily to slight calculation differences. Because the series of trades in a back-test are rarely independent from one another, when one trade exits at a different bar, it can cause subsequent trades to enter and exit at different prices as well. See the section Common Questions (Usage Topics) for more information on possible sources of difference between the results in Builder and those in the trading platform.

To get help on any feature or command while using Builder, press F1 at any time.

The remaining chapters discuss the settings and features of Builder in detail.

Chapter 3
Market Symbols and Settings

Symbol Library

The Symbols pane, as shown in Fig. 3.1, contains the symbol library. Before market symbols can be added to the Build/Eval Process window for building strategies, they must be added to the symbol library through the Symbols pane. The Symbols pane organizes all the market symbols in Builder in a series of folders arranged in a tree structure, similar to the file system in Windows Explorer.

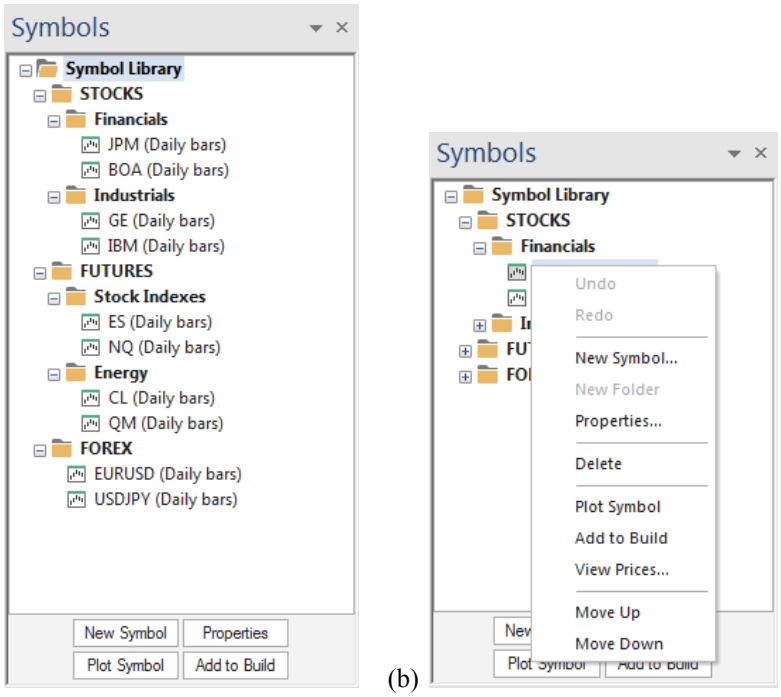


Figure 3.1. (a) The Symbols pane contains the symbol library. (b) The right-click (context) menu contains all commands that apply to symbols and folders.

The symbol library is stored in a separate file ("AB_SymbolLibrary.symlib") and is independent of the project files. The symbol library is accessible whenever the program is running, so that any symbol added to the library is available to any project. A back-up copy of the symbol library file ("AB_SymbolLibrary_backup1.symlib", " AB_SymbolLibrary_backup2.symlib", up to " AB_SymbolLibrary_backup10.symlib") is automatically made at program start-up if the same file has not already been backed up.

Under current versions of Windows, the symbol library and backup copies are stored in the folder C:\Users\user_name\AppData\Roaming\, where user_name is your user name. Under Windows XP, the path is C:\Documents and Settings\user_name\Application Data\. The symbol library is saved automatically whenever a change is made to it. Under normal circumstances, it should not be necessary to use the backup copies. The Undo command (see below) can be used to revert back to a prior state if changes are made to the library

unintentionally, such as accidentally deleting a symbol that you want to keep. However, commands cannot be undone once the program is closed. For example, if you were to delete a symbol, close Builder, and later decided you want to keep the deleted symbol, you could replace AB_SymbolLibrary.symlib with one of the backup copies.

Any number of folders can be added below the root-level "Symbol Library" folder, which cannot be changed. In each of the folders within the Symbol Library folder, any number of sub-folders can be added. The default configuration includes folders named "STOCKS", "FUTURES", and "FOREX". The name of any folder, including the default folders, can be changed by clicking on the name twice or by clicking the folder once and selecting "Properties" from the right-click (context) menu, shown above in Fig. 3.1b.

To add a folder, click the item below which you want to add the new folder and select "New Folder" from the context menu. New symbols are added similarly by selecting a symbol or folder in the tree and selecting "New Symbol" from the context menu. The new symbol defaults to the properties of the selected symbol, if any. Adding a new symbol or double-clicking an existing symbol opens the Symbol Properties window, shown previously in Fig. 2.2 in Quick Start Steps and in Symbol Settings, below. Adding a new symbol is discussed below. Symbols can be added to any folder, including the root folder.

Symbols can be moved from folder to folder by clicking and dragging or by using the Move Up and Move Down commands of the context menu. Undo and Redo commands allow any command from the context menu to be reversed. Up to 10 levels of undo are permitted. Other commands for working with the symbol library include deleting a symbol (Delete or Del key), plotting a symbol in a price chart (Plot Symbol), viewing the price data in a table (View Prices), and adding the selected symbol to the list of build symbols in the Build/Eval Process window (Add to Build).

The buttons at the bottom of the Symbols pane (New Symbol, Properties, Plot Symbol, Add to Build) provide one-click access to some of the more commonly used commands of the context menu.

Note to users of prior versions of Builder: When the program starts up, it checks the project file being opened to see if it contains a price data file that is not in the library. If it does, the program will ask if you want to add the symbol to the library. This is designed to make it easier to populate the symbol library from existing project files.

Obtaining Price Data

Builder can utilize price data obtained from any source provided the file is in comma-delimited text format and can be formatted under the Price File Format window, discussed below.

TradeStation

For TradeStation users, the easiest way to obtain the price data file for use in Builder is to save the data from a TradeStation chart window. This can be done through the Data Window. To display the Data Window, go to the View menu in TradeStation and select Data Window or, in TS 8 or above, right-click on a chart and select View Data Window. To save the price data to a text file, click the disk icon on the data window, or, for TS 2000i, right-click and select “Send to File”. In the Save-As dialog, select a file, then click the Save button. This will save the price data for the chart window to the text file you’ve selected.

MultiCharts

In MultiCharts, select "Export Data" from the File menu to save the chart data to a text file.

NinjaTrader
In NinjaTrader, use the Export tab on the Historical Data Manager window to save the data to a text file. The resulting file will contain 1 minute bars in semi-colon delimited format. Check the semi-colon delimiter box on the Price File Format window after selecting the file in Builder. Once in Builder, the bar type and size can be changed in the Market Symbols table of the Build/Eval Process window, as explained in Build Symbols, below.

MetaTrader 4
In MetaTrader 4, go to the Tools menu and select History Center. Select the symbol from the list at left and click the Export button. On the Price File Format window, select "French (Switzerland)" from the Data Format pull-down menu.

Third-Party Data Providers. If you obtain your price data from a data vendor, the vendor should have a software program that can be used to export the data to different formats and bar sizes. Builder requires data in a text file format, such as csv or txt files. Once in Builder, the bar type and size can be changed in the Market Symbols table of the Build/Eval Process window, as explained in Build Symbols, below.

Adding a Symbol

As explained above, market symbols are added to Builder through the symbol library. Selecting the New Symbol command in the Symbols pane opens the Symbol Properties window, as shown below in Symbol Settings. This is where all the properties describing the symbol are entered. Click on the name of each property to display a description at the bottom of the properties window. At a minimum, data for the following properties should be entered: Symbol, Price File Name, Bar Type, Bar Size (if applicable), Session Start Time, Session End Time, and Point Value. Each of the symbol properties is described in detail in Symbol Settings, below.

The price data for the symbol should be contained in a text-format file. To specify the text file associated with the symbol, click the "..." button in the Price File Name property. This will open a file dialog window, which will allow you to select the file of price data. After selecting the file, Builder will open the Price File Format window, shown below in Fig 3.2.

Price File Format Window
The Price File Format window is used to specify the format of the file of price data. To speed data loading, Builder only displays the first 200 lines of the price file in the table at the top of the window by default. To see all the lines in the file, uncheck the box below the table labeled "Display first 200 lines only".

The column headings identify the type of data contained in each column, which can be one of the following: date, time, open, high, low, close, volume, up-tick volume, down-tick volume, indicator, or "don't read/ignore". At a minimum, a price file should contain columns for the date and the closing price of each bar. To take advantage of all the features of Builder, a price file should contain the date, time, open, high, low, close, and volume (or up-tick and down-tick volumes). If the date and time are together in one field (e.g., 11/5/2012 13:15 or 20090531 13:15), the field should be labeled "date" and no "time" field should be present.

Builder is designed to read files of price data in several text file formats. An example of this data format, as obtained from the TradeStation Data Window, is shown below.

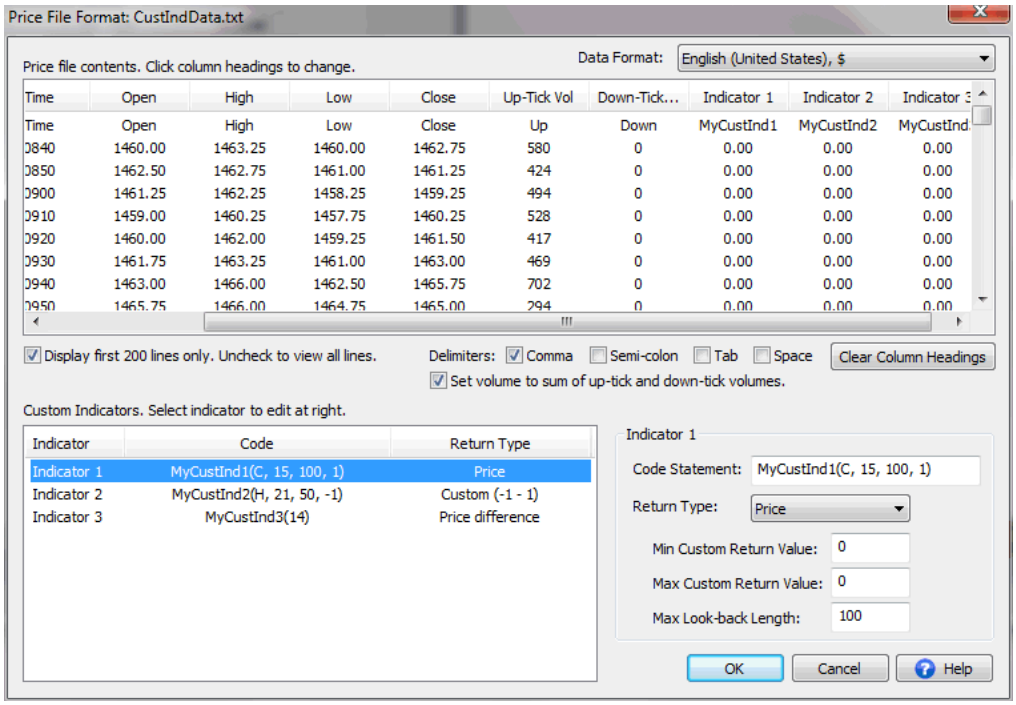


Figure 3.2. The Price File Format window allows you to specify the format of the file of price data.

"Date","Time","Open","High","Low","Close","Up","Down"
06/15/2009,0640,504.60,505.10,500.90,503.00,3655,3577
06/15/2009,0650,503.00,503.80,496.60,497.60,5245,6854
06/15/2009,0700,497.70,499.10,496.70,499.00,2275,2029
06/15/2009,0710,498.80,498.80,497.00,497.80,1980,2202
06/15/2009,0720,497.90,498.70,496.50,497.30,2153,2274
06/15/2009,0730,497.20,497.60,496.60,497.00,1453,1411
06/15/2009,0740,496.90,497.00,493.40,493.80,3057,4165

These data are stored in comma-delimited format, in which commas separate the different fields (date, time, open, high, low, etc.). Other field delimiters can be selected by checking the boxes below the table. Builder can read files delimited by commas, semi-colons, tabs, or spaces. When a new delimiter is selected, the table will be redrawn. If you're not sure how your data file is delimited, try the different delimiters until the fields are displayed in separate columns.

The “Up” and “Down” fields are the up and down tick data for intraday bars. For other bar types, a single volume field will be present. Builder does not use open interest.

To change the label for any column, click on the column heading and select the appropriate label from the pop-up window. Select "don't read/ignore" to have the program skip over a column of data; this corresponds to a blank column heading.

If the volume is not specified, it is set to zero. If any price field is not specified, it is set to the closing price. For example, if only the close is available, the open, high, and low are set to the close on each bar.

If the price file includes columns for both the up-tick and down-tick volume, check the box "Set volume to sum of up-tick and down-tick volumes" below the table of price data to

combine the two volume fields for the total volume. Generally speaking, the two fields should be combined in order for volume-based indicators to evaluate properly. If it appears that a volume-based indicator is not evaluating properly, try deselecting this option.

The first line of the price file can contain an optional line of text labels, which is skipped over if found.

Data Format Pull-Down Menu
Above the table of price data is an option to change how the program interprets the data it finds in the price file. The Data Format pull-down menu defaults to "English (United States)" format, which means dates are assumed to be given as MM/DD/YYYY, prices use a comma as the digit grouping symbol and a period as the decimal symbol (e.g., 1,000.01), among other conventions. If the data file employs other conventions, a different selection can be made using this pull-down. For example, to accommodate dates in the format DD/MM/YYYY, the format can be changed to "English (United Kingdom)". For reading data exported from MetaTrader 4, use "French (Switzerland)".

Clear Column Headings Button
The Clear Column Headings button removes all column headings from the table of price data and removes all custom indicator specifications from the table of custom indicators. This button can be used to initially clear the default column formatting prior to setting up the column headings and custom indicator settings. If you inadvertently remove key settings, such as custom indicator details, click the Cancel button to close the window without saving any changes.

Custom Indicators

Builder can include custom indicators in the build process. To use this feature, it's necessary to provide a column in the price file with the custom indicator value for each bar. In TradeStation and MultiCharts, this can be done by plotting the indicator on the price chart and saving the chart data to a text file. This adds a column to the text file with the indicator values.

To include the indicator in the build process, click on the column heading in the "Price file contents" table of the Price File Format window and select "Indicator" as the column heading. This will label the corresponding column as "Indicator 1", "Indicator 2", etc., as shown in Fig. 3.2. This also adds an entry to the Custom Indicators table, located below the table of price data in the Price File Format window.

Builder needs to know two things about each custom indicator you want to use: (1) the code statement needed to calculate the indicator values when the strategy is run, and (2) the return type of the indicator. For example, in Fig. 3.2, indicator #1 uses the code statement "MyCustInd1(C, 15, 100, 1)." This is the code that will be included in the strategies generated by Builder in which the custom indicator is used. This code should correspond to the indicator values in the price file. For example, evaluating the code statement MyCustInd1(C, 15, 100, 1) in a strategy should produce the values shown in the price file under the column labeled Indicator 1.

Note: If a custom indicator cannot be represented in the target language using a single function call, there are two options for using the custom indicator in Builder: (1) re-write the indicator so that it's values are generated by a single function call, or (2) edit the strategy code generated by Builder after the build process is complete.

The return type for Indicator 1 in Fig. 3.2 is "Price". This means the values produced by the indicator are equivalent to the symbol's price, such as the close, open, high, etc. The table

below lists the different allowable return types with examples of common indicators that return that type.

Return Type	Definition/Examples
Price	Any market price; C, Average(C, N), Highest(L, N), Keltner
Price difference	Difference between two prices; MACD, momentum, H - L, ATR
Price rate of change	Ratio of two prices (price 1/price 2); ROC
Oscillator, 0 - 100	Indicators scaled to return between 0 and 100; FastK, SlowD, RSI
Oscillator, -50 - +50	Indicators scaled to return between -50 and +50
ADX	ADX, DMI
Volume	volume, Average(volume, N)
Day of week	0 for Sunday, 1 for Monday, etc.
Time of day	HHMM format; e.g., 1425 for 2:25 pm
True/false	0 for false, 1 for true
Custom	User-specified min to max range; e.g., -0.1 to +0.4

The return type is used by Builder to determine which indicators can be meaningfully compared to other indicators. It's necessary to specify the correct return type in order for the program to properly incorporate the custom indicator into the logical conditions for entry and exit.

For each custom indicator in the table of custom indicators, select the indicator in the table and enter the code statement in the edit field to the right of the table and select the return type; see Fig. 3.2. For any indicator with a custom return type, enter the minimum and maximum values that the indicator can return. *It's best to avoid selecting a custom return type unless necessary because this will limit the ways in which the custom indicator can be used in the logical conditions.*

The maximum look-back length required to evaluate the custom indicator can be entered below the fields for the custom return values. For example, in Fig. 3.2, the first custom indicator looks back a maximum of 100 bars. This is the number of bars of data needed to evaluate the indicator and should be entered as the Max Look-back Length. The look-back lengths are used to calculate the Max Bars Back value, which is needed when inserting the strategy into a chart in TradeStation or MultiCharts.

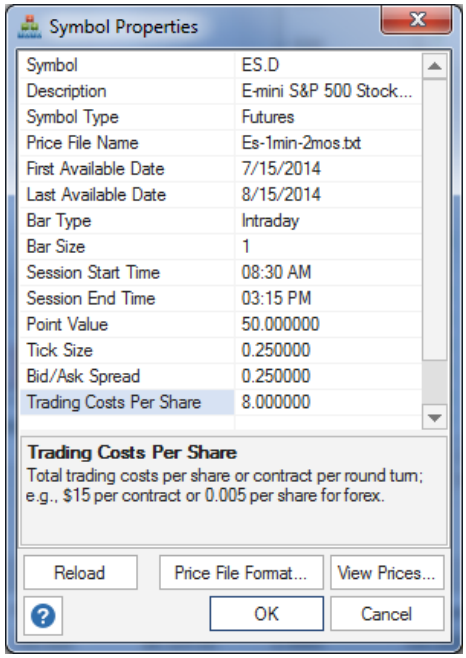
Note: Once a custom indicator has been included in a built strategy, changing the market and re-evaluating the strategy may cause errors if the data columns for the same custom indicators are not available in the new price file.

Note: If multiple markets (price files) are selected in the Market Data table and one file contains custom indicators, then all price files selected in the table must contain the same custom indicators (i.e., the same columns and specifications). Otherwise, the build process will fail when trying to apply the custom indicator(s) to markets for which the required data is not found.

Symbol Settings

As explained in Adding a Symbol, above, when adding a new symbol to the symbol library or viewing the properties of an existing symbol, the Symbol Properties window is displayed, as shown in Fig. 3.3.

This is where all the properties describing the symbol are entered. Click on the name of each property to display a description at the bottom of the properties window, as shown in Fig. 3.3 for Trading Costs Per Share. Most properties can be edited directly by clicking on them.



Please Note: This window represents the intrinsic properties of the symbol. Once defined, these properties should not need to be changed. When building or evaluating strategies, different values for the bar type, bar size, and trading costs can be specified on the Build/Eval Process window after adding the symbol to the Market Symbols table to suit your purposes at that time. Doing so will have no effect on the properties entered here.

Symbol
A text label can be entered for the Symbol setting to help identify the market and to provide a label for use in displaying results. Any valid text string can be entered. The symbol is used in the build report, trade list, and for other display purposes.

Figure 3.3. Symbol Properties window.

Description
Enter a text label for the Description setting to help identify the market.

Symbol Type
Reserved for future use.

Price File Name
The Price File Name specifies the name of the text file of price data. Please see Adding a Symbol, above, for details.

First Available Date, Last Available Date
The first and last available date properties display the date range for data read from the price file. These properties are for informational purposes only; they cannot be edited. To change the range of dates used for building or evaluating a strategy, use the date controls on the Build/Eval Process window.

Bar Type, Bar Size, and Range Bar Size
Clicking on the Bar Type entry will open a pull-down menu with the following choices: Intraday, Daily, Weekly, Monthly, Tick, Range, Unknown. Intraday bars are specified in minutes, such as 5 min bars or 60 min bars; the smallest allowable value is 1 minute. The Bar Size setting, which is only shown when the Bar Type is Intraday, should contain the number of minutes for intraday data. Range bars represent trading within a specified point range, such as five points. All bars in a range bar chart have the same range. For range bars, a Range Bar Size setting will be available, which should be set to the high-to-low range of the bars in points.

The Bar Type and, where applicable, Bar Size (for intraday data) or Range Bar Size (for range bars) should match the data in the file. Builder will try to properly infer the bar type, bar size, and session times from the data file. If any of these are incorrect, they should be manually corrected. For example, if the data in the price file represent 5 min bars, the Bar Type should be "Intraday" and the Bar Size should be 5.

The Daily, weekly, and monthly Bar Type options represent bars that span a day, week, and month, respectively. Tick bars are built up from a specified number of transactions or ticks and are typically used in futures trading. A single tick represents a transaction that took place at a certain price and time. It could be for any number of contracts. Single-tick data is not a valid input option in Builder. Tick bars contain multiple ticks so that each bar has an open, high, low, and closing price.

Session Start Time, Session End Time
The Session Start Time and Session End Time properties specify the trading session times. Only one session is defined in Builder for each symbol, although a combined session, such as day-plus-evening, can be used if the session times encompass both sessions. These times should exactly match the times found in the price data file. An incorrect session time can affect the end-of-day exit. Builder does not perform time zone conversion.

It's important to make sure the data used in the trading platform exactly match the settings made in Builder. For example, if the normal session times are 8:30 - 3:15 and are changed to 11:00 - 3:00 in Builder, the strategy should be executed on data that use session times of 11:00 - 3:00. Otherwise, much different results may be found in the trading platform than in Builder. To restrict trades to a range of times, it's almost always better to use the trade entry and exit time range options under Strategy Logic, rather than changing the session times.

Point Value
Each symbol should have a valid point value. For example, the E-mini S&P 500 futures have a point value of $50. This is the value that is multiplied by price to determine the value per contract. For stocks and forex, the point value should be set to 1. Note that when forex symbols have a point value of 1, the position size is typically 10,000 or 100,000 for one lot. The point value property has a default value of 1.

Tick Size
The tick size is the smallest allowable price change for the symbol, such as 0.25 for the E-mini S&P 500 or 0.01 (1 cent) for US equities. Builder will infer this from the price data file. If it's incorrect, it can be changed here.

Bid/Ask Spread
The bid/ask spread is the difference between the current price buyers are willing to purchase the instrument for and the price sellers are willing to sell it for. The bid is the lower price, whereas the ask is the higher price. Buy orders are always filled at the ask, and sell orders are always filled at the bid. **A price chart displays the bid price only.** In Builder, the bid/ask spread is only used if the Order Fill Rule option on the Evaluation menu ("Use Bid/Ask spread to determine fills") is checked. If so, market buy orders will be filled above the apparent market price (based on the chart), whereas market sell orders will be filled at the price seen on the chart. The bid/ask spread is part of the cost of the trade.

The bid/ask spread is intended for forex trading and is not typically used for trading futures. When developing forex strategies for MetaTrader 4, this option should be used because MetaTrader 4 uses the bid/ask spread when evaluating strategies. This is consistent with the common practice in forex trading of paying for the trade through the spread rather than paying the broker a fixed commission.

If the bid/ask option is selected, Builder also uses the bid/ask spread to determine if a pending order is filled. For example, a buy stop order is only filled if the ask price, which is above the chart price (bid), touches the stop price. If, for example, the price bar on the chart just touches the stop price, it may appear that the order should be filled, but Builder won't show the historical trade as filled unless the ask price reached the buy stop price. Similarly, a buy limit order will not be recorded as filled unless the ask price reaches down to the buy limit price. Sell stops and limits are filled at the bid, so, unlike buy orders, their fill prices directly correspond to the chart prices. This is also how MetaTrader 4 determines fills.

Note: In addition to the bid/ask spread, MetaTrader 4 applies a minimum price distance to determine if an order can be placed. If a pending order (stop or limit) is too close to the market at the time it's placed, the order will be rejected. This is based on the idea that there won't be sufficient time to place the order before the market moves through the order price. Builder doesn't reject such orders, which can sometimes cause a discrepancy in back-testing between Builder and MetaTrader 4.

Trading Costs Per Share
The Trading Costs Per Share property represents the total trading costs (commissions, fees, and slippage) deducted from each trade on a round-turn basis (i.e., deducted once per trade) per share or contract. For stock and forex trades, where the point value is 1, this value would typically be less than $1, depending on the share price (e.g., if the per-trade costs are $30 for a lot size of 100,000, the per-share costs in Builder would be 30/100000 or 0.0003), whereas for futures, which have point values greater than 1, the costs might be $5 - $75 per contract. *Note that TradeStation typically deducts trading costs on a per-side basis, so you should use one-half the trading cost amount in TradeStation that you enter in Builder.*

Trading costs should always be included though they need not be precise. The purpose is to insure the strategies generated during the build process overcome trading costs. Entering a slightly higher cost value than anticipated in reality may guide the process towards more robust strategies. However, setting trading costs too high may prevent the program from finding viable strategies that have a low average trade profit/loss.

This property represents the default value for costs that is used when adding the symbol to the Build/Eval Process window for building or evaluating strategies. The cost value can be changed on the Build/Eval Process window when the symbol is added to the Market Symbols table.

Reload Button
The Reload button on this window scans the price file for the first and last available dates and updates those fields.

Price File Format Button
The Price File Format button opens the Price File Format window, which enables you to edit or change the format specifications for the price data file, as explained in Adding a Symbol.

View Prices Button
The View Prices button opens a tabular display of the contents of the price data file.

Build Symbols

When building or evaluating trading strategies in Adaptrade Builder, the strategies are applied to the market symbols in the Market Symbols table of the Build/Eval Process

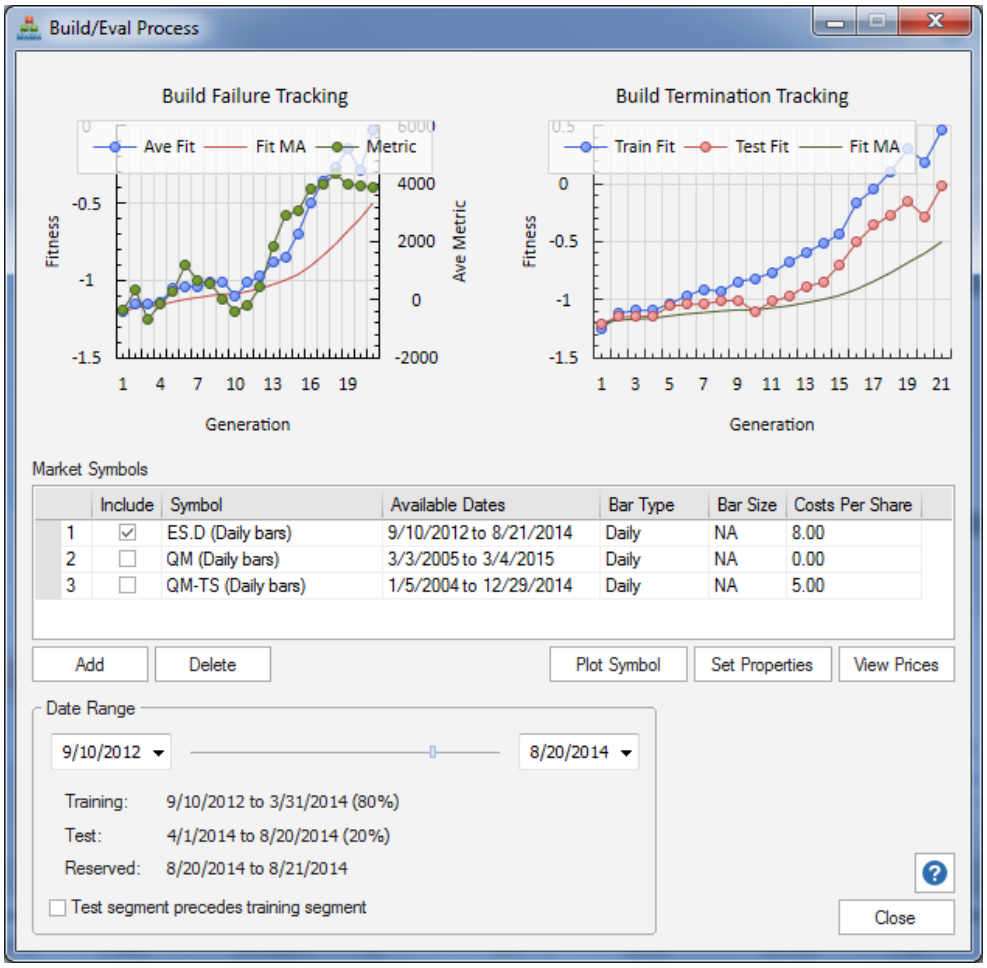


Figure 3.4. The Build/Eval Process window is used to specify the markets and settings for building and/or evaluating strategies.

window, as shown in Fig. 3.4. Any symbol in the symbol library can be added to the Market Symbols table.

The Market Symbols table allows you to change the bar type, bar size, and costs per share settings as desired for purposes of building and/or evaluating strategies. Changes here have no effect on the symbol's properties, which can be seen by double-clicking the symbol to open the Symbol Properties window. Symbols in the Market Symbol table are copies of those in the symbol library, so any change to the settings made here has no effect on the properties in the symbol library. However, as explained in Symbol Settings, above, the properties entered on the Symbol Properties window are the intrinsic properties of the symbol and must match the data in the price data file.

To change the symbol settings to the values you want to use when building and/or evaluating a strategy, simply click on the entry in the Market Symbols table. For example, if the data file contained 30 minute bars, you could change the bar type to daily bars for building and/or evaluating strategies on that time frame.

Any valid bar type selection can be made, provided the price data in the file can be converted to the selected type. Price data provided as 1 minute intraday bars allow for the most flexibility because they can be converted to any other intraday size, as well as to range bars,

daily, weekly, and monthly bars. No data type can be converted to tick bars since none of the data types includes information on the number of ticks in the bar.

The program will attempt to convert the available data to the selected bar type and will display a warning message to the Messages window if the conversion may not be accurate. For example, if the price data are provided as tick bars and the selection is for 5 min bars, there is no way to guarantee that accurate 5 min bars can be constructed because the tick bars may not be smaller than 5 min bars and/or the tick bars may not close at the precise closing time of the 5 min bars. As another example, converting from 3 minute bars to 10 minute bars will not be accurate because there is no even multiple of 3 minute bars that can be used to construct a 10 minute bar. *It's the user's responsibility to make sure the selected data settings are sufficiently accurate and that they match the data used in the target platform when executing a strategy in real time.*

Note: When selecting the range bar size for range bars, the size should be large enough compared to the interval of the available data to capture the normal oscillations of the data. For example, if the available price data consist of 5 min bars, the size of the range bars should be as large as the normal range of movement that occurs within 5 minutes. Otherwise, more range bars will be formed in real time than in back-testing.

Please note that the Symbol field in the Market Symbols table is a property of the symbol, so it cannot be changed directly in the table. If you want to change the symbol label, double-click on the symbol to open the Symbol Properties window. Similarly, the Available Dates field is informational only; it shows the available dates in the price data file. To change the date range for building or evaluating strategies, use the Date Range controls.

Add button

To add a symbol to the table, either use the Add to Build command or button in the Symbols pane or click the Add button below the Market Symbols table, as shown in Fig. 3.4. Clicking the Add button opens the Select Symbols window shown in Fig. 3.5. This window displays all available symbols in the symbol library. You can select multiple symbols by dragging the mouse across the symbols or by using the Ctrl-Click or Shift-Click key/mouse combinations. The selected symbols will be added to the Market Symbols table.

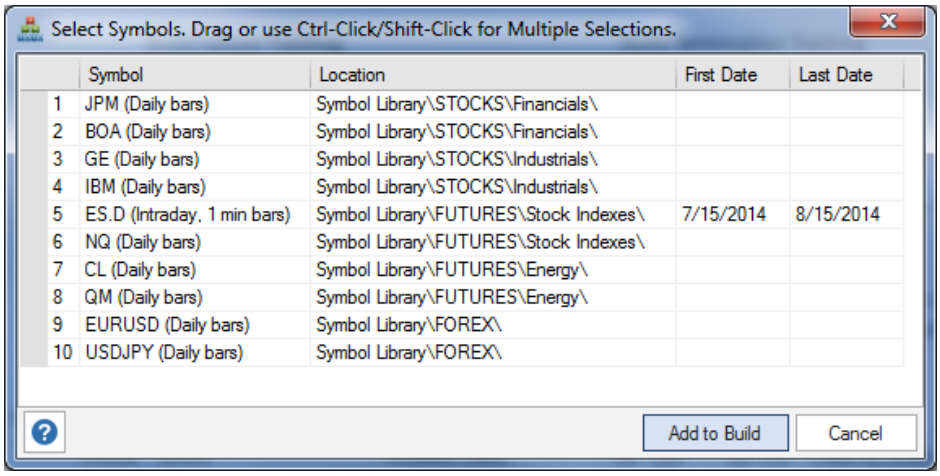


Figure 3.5. The Select Symbols window allows you to add one or more symbols from the symbol library to the Market Symbols table of the Build/Eval Process window.

When multiple markets are in the Market Symbols table, any or all of the markets in the table can be selected by checking the box in the Include column for the respective market. When

more than one market is selected, each strategy in the population will be evaluated over all selected markets together as a portfolio; i.e., the performance results will represent the simulation of the strategy across all selected markets simultaneously.

Delete Button

Symbols can be deleted from the Market Symbols table either by clicking the Delete button or by pressing the Del key.

Plot Symbol Button

To create a price chart displaying the selected symbol in the Market Symbols table, click the Plot Symbol button.

Set Properties Button

To set the properties for multiple symbols together -- for example, to set the trading costs to $5 per contract for all selected symbols -- select multiple rows in the table and click the Set Properties button.

View Prices Button

Click the View Prices button to display a window listing the data that have been read. The Price Data window displays the data in the format selected in the Market Symbols table. For example, if the data file contains 1 minute bars, but the Bar Type in the Market Symbols table has been changed to Range, range bars will be shown in this window.

This window also allows you to save the data to a csv (comma-delimited text) file via the File menu or copy the data to the clipboard via the Edit menu. If the Copy command is chosen, the data will be copied in tab-delimited format, which permits it to be pasted directly into a spreadsheet.

Date Range Settings

The Build/Eval Process window also includes controls for changing the start and end dates for analysis as well as the training/test dates. To change the start and end dates for building or evaluating a strategy, click on the calendar controls at either end of the slider control or type the desired date directly into the date box.

Move the slider to change the dates for training and test analysis. The training data are used in building the strategy. Test data are used in evaluating the strategies following the build and in evaluating the build process while it's ongoing. Generally speaking, a ratio of between three and five to one for training to test data is recommended. When selecting Evaluate or Evaluate All from the Evaluation menu, both training and test data are used. Any data not included in the training/test set are shown as "reserved". These data can be used as a third, manual validation segment. Following building, set the last date in the date range to the end of the reserved date range and re-evaluate the strategy to pick up the validation results in the reserved data.

The check box below the slider control allows you to specify whether the test period follows the training period or precedes it. Leave the box unchecked to perform testing on data following the training period or check the box to perform testing on data prior to the training period.

There can only be one test period at a time. Builder stores the dates for the training period over which the strategies were built. Once the strategies in a given project file (.gpstrat) have been built, these build dates cannot be changed unless you rebuild the strategies. If you change the start and end dates after building and select Evaluate from the Evaluation menu, Builder will use the stored build dates to determine the dates for the training and test periods. If by changing the start and end dates, the date range is extended both before and after the

build (training) period, there may be two test periods, one prior to the build dates and one following them. Because the program can only have one test period, it will use the larger of the two periods when reporting and plotting the test results.

If multiple market have been selected in the Market Symbols table, the date range selections apply to all markets. The default dates shown in the calendar controls represent the earliest starting date and latest ending date over all selected markets.

Build Failure Tracking and Build Termination Tracking Plots

The two plots at the top of the Build/Eval Process window display the progress of the build process at each generation. The Build Failure Tracking plot depicts the results of the Build Failure Rules defined on the GP Settings window (Build menu). The curve labeled "Ave Fit" is the average fitness of the population members on the test segment at each generation. The "Fit MA" curve is the moving average of the Ave Fit curve, where the look-back length is defined on GP Settings. The "Metric" curve shows how the average of the selected metric over the top N strategies on the test segment changes from generation to generation during the build process. Generally speaking, all three curves should be sloping upward to the right as the build progresses, indicating improving performance on the test segment. The Build Failure Rules on GP Settings allow you to reset the build if this is not the case.

The Build Termination Tracking plot depicts the build termination rules on the GP Settings window. The curve labeled "Train Fit" shows how the average population fitness on the training segment progresses from generation to generation. The "Test Fit" curve shows the same results for the test segment. "Fit MA" is the moving average of the test fitness curve, as defined on GP Settings.

For a good quality build, the fitness on both the training and test segments should be increasing at each generation. When the fitness starts to drop on the training segment, no further improvement should be expected in the strategies. More importantly, if the fitness on the test segment starts to level off or decline while the fitness on the training segment is still increasing, this can suggest that the strategies are being over-fit. In this case, the build process should be terminated, which is the purpose of the build termination rules on GP Settings.

Chapter 4
Price Charts

Creating and Using Price Charts

Project files in Adaptrade Builder can contain one or more price charts, which are shown in tabbed windows, as illustrated in Figs. 1.1 and 2.1. There are two ways to add a price chart to the project file. From the Symbols pane, select the symbol in the symbol library and click the Plot Symbol button. Alternatively, select a symbol from the Market Symbols table on the Build/Eval Process window and click the Plot Symbol button on that window. In either case, the Plot Symbol command is also available in the context menu. To remove a chart from the project file, click the close button on the chart tab.

When a price chart is created, it includes all the data read from the associated price file. It also includes a volume bar chart directly below the price chart. The chart can be scrolled left or right by holding down the left mouse button and dragging left or right. Clicking the scroll bar at the bottom of the chart will move the chart to that position. The bar spacing can be increased or decreased by moving the mouse scroll wheel. Other formatting options and features will be added in later versions of Builder.

The context (right-click) menu for charts contains three commands: **Show Strategy Trades**, **Show Trading Orders**, and **Reload**. The **Show Strategy Trades** command displays the trade entry and exit markers on the price chart provided the strategy currently selected in the Build Results table contains trades for the same symbol. The trade entry and exit markers are shown in Fig. 4.1.

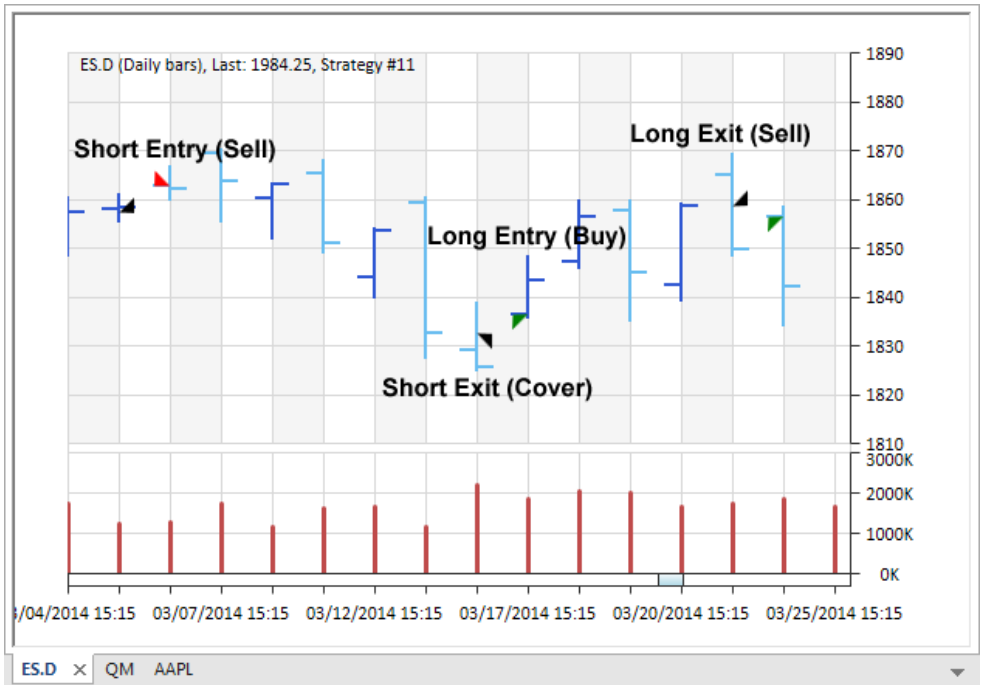


Figure 4.1. Trade entry and exit markers on a price chart.

The triangular trade markers can by distinguished by both color and shape. There are four different markers: short entry, short exit, long entry, and long exit. The orientation of the triangle is meant to signify the trade direction and type of order (entry or exit). Entry markers are on the left side of the price bar, whereas exit markers are on the right side of the bar. The long entry and exit markers point upward, whereas the short entry and exit markers point downward. Long entry markers are green, short entry markers are red, and both exit markers are black.

If a different strategy is selected in the Build Results tables, the price chart will be updated automatically to display the trades for the selected strategy, provided the symbols still match. This makes it easy to review the trade entries and exits for different strategies on the price chart. If the selected strategy has been applied to multiple symbols, only the trades for the symbol matching the chart are displayed. Charts for the other symbols can be opened to show the trades for those symbols.

The **Show Trading Orders** command displays the Trading Orders window, which displays the trading orders for the currently selected strategy. The Trading Orders window is discussed in the next section.

The **Reload** command causes the program to read the file of price data and update the chart display. Also, if the option to show the strategy trades has been selected, the selected strategy is re-evaluated and the trade entry and exit markers are updated. This command can be useful when using Builder as a trading platform. When new price data come in, the reload command can be used to update the chart along with the orders in the Trading Orders window.

Provided the end date in the Date Range section of the Build/Eval Process window is set to the last available date shown in the Market Symbols table, the date range for analysis will be automatically updated to the new last date in the price data file, and the strategy evaluation will include this new data. If the Trading Orders window is open, the trading orders will be updated as well. If, for some reason, the last date for analysis is not set to the last available date, the date controls should be used to set the date to the last available date prior to selecting the Reload command. Otherwise, the trading orders will not be updated.

Trading Orders

The Trading Orders window displays the trading orders for the currently selected strategy, as shown in Fig. 4.2.

The trading orders are for the strategy currently selected in the Build Results tables as of the last date of analysis. This is the last date in the date range selected in the Date Range section of the Build/Eval Process window. The strategy is identified by its member number, shown in the title bar of the window (e.g., #1843 in Fig. 4.2). If the strategy was last evaluated on multiple symbols, orders for all symbols will be included in the window. For example, in Fig. 4.2, strategy #1843 has open positions and orders for symbols EMD, TF, and ES.

The Trading Orders window contains two sections: Open Positions and New Orders. Any open positions are shown in the first section. If there is no open position for a symbol, it will be shown as "Flat". Open positions are either "Long" or "Short". The "from" price is the entry price for the position.

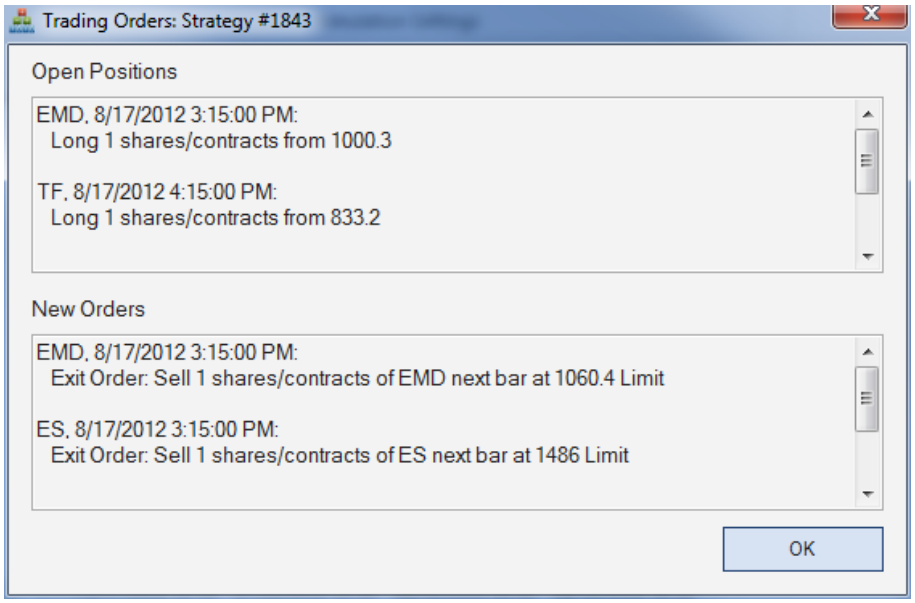


Figure 4.2. The Trading Orders window displays the trading orders for the selected trading strategy.

The New Orders section contains any trading orders that should be placed for the next bar. The orders are shown as either "Exit Order" or "Entry Order". The date and time shown for all listed positions and orders is the date of the last bar of data analyzed.

The Trading Orders window can be opened or closed by selecting "Trading Orders" on the View menu in the ribbon. Alternatively, it can be displayed by right-clicking on a price chart and selecting "Show Trading Orders". The window can be kept open while working elsewhere in the program. As explained in Creating and Using Price Charts, above, the trading orders can be updated when the data in the price file changes by selecting the Reload command of the price chart context (right-click) menu. The orders will also be updated if the selected strategy is re-evaluated by selecting Evaluate from the Evaluation menu.

Position Sizing

The trading orders include the position size of open positions and the position size for new orders. The position size is based on the position sizing settings currently in effect. For open trades, this will be the same size as shown in the Trade List table for the last trade in the list. Builder back-tests the strategy by applying the position sizing starting with the initial account equity and accumulating the profits and losses as it tests forward to the most recent bar. This means that the size for the most recent trade will be based on the accumulated equity over the entire back-test period, which may be a much higher equity value than in your trading account. For this reason, position sizing should either be handled separately, or you should choose either "Fixed Size" or "Constant Value" position sizing, neither of which is based on the account equity value.

Please Note: Reversal entries don't include the exit order for the open position when listing the orders under New Orders. A reversal entry, such as found in a stop-and-reverse strategy, is one in which there is no separate exit, so that the entry reverses the current position. For example, in a stop-and-reverse strategy, all the entries are reversal entries, and the trades alternate between long and short positions. You are always in the market in this case. With a reversal entry, only the entry order for the next trade is shown in New Orders. The exit order for the current position is not shown. As a result, the entry order will list the position size for the new entry only. In actuality, to reverse an open position, you would need to place an

order that includes twice as many contracts or shares. For example, if you're long 3 contracts and the new order is to sell short 3 contracts, you would need to sell short 6 contracts: 3 to close out the long position and 3 to enter the short trade. In this case, the Trading Orders window would only show a new order to sell short 3 contracts, and you would need to recognize that it's a reversal entry and adjust the position size accordingly.

Chapter 5
Build Settings

Before starting the build process, there are a number of settings that can be made to guide the process and influence the types of strategies generated during building. Most of these settings and options are selected on the Build menu of the ribbon, shown previously in Fig. 2.9 in Quick Start Steps. The remaining settings are made on the Evaluation (Fig. 2.10) and Position Sizing (Fig. 2.11) menus.

On the Build menu, the settings can be made by starting at the left with the GP Settings button and working left to right, clicking each button in turn. Most of the buttons have an associated window that drops down when the button is clicked, such as the GP Settings window (Fig. 2.5). All the way to the right is the Market Sides setting, which allows you to restrict entries to either long-only, short-only, or both long and short trades. The settings and options for the other buttons of the Build menu and for the Evaluation and Position Sizing menus are described below.

When all the settings have been made, click the **Build** button in the Build Strategies panel of the Build menu to start the build process. The **Pause/Resume** button can be used to pause the build process temporarily without cancelling it. Click the button a second time to resume. The **Cancel** button will stop the build process and display the results for the last completed generation.

GP (Genetic Programming) Settings

The options that influence the build process are selected on the GP Settings window, shown in Fig. 2.5 in Quick Start Steps.

Population Settings

The **population size** is the number of strategies in the genetic programming population. Strategies are generated by evolving the population. The larger the population, the longer the process will take, but the more diversity will be introduced into the solution. More diversity generally increases the probability of finding a good strategy. With large intraday price files, a population as small as 100 members may be necessary to achieve reasonable solution times, depending on the bar size, time span, and computer hardware specifications. Files of daily data generally allow for population sizes of 1000 or more.

The number of strategies saved in the project file is specified using the **After building, save [] fittest strategies** option. This is the number of members from the population that are stored. Builder selects the strategies to store based on fitness. For example, if the population size is 200 and you enter a value of 100 for this setting, the top 100 strategies ranked by fitness will be stored. You can only store as many members as are in the population. If you enter a number larger than the population size, the entire population will be stored.

The option to **Save generation with the highest average fitness on the test segment** is designed to reduce the risk of over-fitting. When the results on the test segment start to decline, it can indicator over-fitting, which means the strategies may be starting to fit the market noise, rather than the tradable features (i.e., signal). By saving the strategy with the highest fitness on the test segment, this risk may be lessened. When this option is checked, the stored strategies are from the generation with the highest fitness on the test segment,

regardless of how many generations were completed. Otherwise, the stored strategies are from the last completed generation or from the initial population if the build was cancelled before the first generation was completed.

Note: The number of stored strategies doesn't affect the build process, which takes place over the number of members in the population, regardless of how many strategies you elect to save. However, once the build process is complete, only the saved strategies are available.

The **number of generations** is the number of steps in the evolution of the population of trading strategies. During one generation, the GP process generates a number of new population members (strategies) equal to the size of the population. A higher number of generations generally results in better strategies. However, after a number of generations, the population members may start to converge so that little additional benefit is achieved by continuing the build process. When this happens, most of the top strategies will be the same, indicating that fewer generations can be used. It's usually better to start with a smaller number of generations, such as 5 - 10, and continue building if the results are promising and have not yet converged.

Hint: To explore the variety of strategy logic that can be generated by Builder, try setting the number of generations to zero. This will stop the build process after the initial population is generated. Because the initial population is generated randomly and has not been modified by crossover and mutation, the resulting strategies will display a wide variety of trading logic.

The **Reset on Build** option determines whether the results from the prior build are used to initialize the population for the next build. To incorporate the best strategies from the prior build into the next build, uncheck the Reset on Build box before building. This will cause Builder to initialize the population with the saved strategies from the prior build. If the number of saved strategies is at least as large as the population size, this is equivalent to resuming the build after pausing it.

It's not necessary to save as many strategies as the population size. If you have a population size of, say, 500, you might want to save the top 100 strategies. Stopping the build (or waiting for it to end) and clicking the build button again with the Reset on Build box unchecked will then initialize the first 100 members of the population with the saved strategies from the prior build. The other 400 members will be initialized randomly. In this case, the build includes the best results from the prior build in the new build while still allowing for new members to influence the results.

If the Reset on Build box is checked, the current population will be discarded, and the population will be initialized randomly. This is the default setting and is the same as starting a new build from scratch.

Advanced GP Settings

The crossover percentage (**Crossover Pct**) is the percentage of members of the population generated from crossover. Crossover is an operation that takes part of one member and combines it with part of a different member to create a new member of the population. Most members should be generated via crossover, such as 60% - 90%. Members not generated via crossover are generated via mutation. To introduce more randomness into the population, try decreasing this percentage, which will increase the percentage of members generated from mutation.

The mutation percentage (**Mutation Pct**) is the probability that a given element of the population member being created by mutation will be modified. Mutation operates on an element-by-element basis. During mutation, each element, such as part of an entry rule or part

of the exit logic, is randomly modified with a probability equal to this value. To introduce more randomness into the population, try increasing this percentage.

The entry rules in Builder are represented by tree structures, as explained in Chapter 1; see Fig. 1.3. The **tree depth** is the number of levels in the tree. For example, the tree in Fig. 1.3 has a depth of five. The default value of tree depth in Builder is 3. To increase the potential complexity of the entry rules, a higher tree depth can be used. The tree depth will tend to increase over successive generations as a result of the crossover operations, which may result in a tree depth greater than the value specified here. To prevent the entry rules from becoming overly complex, the complexity metric can be included as part of the build metrics; see Appendix: Performance Metrics for a discussion of the complexity metric.

Setting the tree depth to zero will result in trivial entry conditions that are set to "true". In this case, the entry conditions will have no effect on the trading strategy logic. This might be desirable if you want to generate strategies that have the minimum number of inputs. The entry logic for strategies of this type will be limited to the entry order logic. For example, a strategy might be generated with an entry stop order that contains a stop price calculated from a multiple of the average true range. This would be the only entry logic for that strategy.

As explained in Chapter 1, the parent members for crossover and mutation are chosen by randomly selecting members of the population and choosing the member with the highest fitness score. This is known as tournament selection. The **tournament size** is the number of population members randomly selected for the tournament. The default value is 2, which means that two members of the population are randomly selected, and the one with the highest fitness score is selected as the parent. A so-called *negative tournament* is used to select the member of the population to replace by the newly generated population member. In a negative tournament, the member of the tournament with the lowest fitness score is replaced. The tournament size selected here governs both types of tournaments.

Build Failure Rules

If the build process is not going well, the build failure rules can be used to reset it and start over. There are two optional rules. If selected, the rules are applied once after the specified generation. For example, you might elect to apply the rules following generation number 10. If either of the rules applies, the build process will be reset and will start over.

The Fitness Failure Rule calculates the average population fitness on the test segment and takes a N-period moving average, where N is the specified number of generations. It compares the moving average for the current generation to the value M generations ago. If the current value is less than it was M generation ago, the build process is reset. N and M can be any number of generations less than the maximum specified under Build Termination Options.

The Performance Failure Rule calculates the average value of the specified performance metric on the test segment over the top N strategies in the population. If the calculated value is less than (greater than) the specified value, the build process is reset.

Note that both rules are based on the test segment performance. This is because the test segment is designed to monitor the training segment. For a good quality build, the results on the test segment should be increasing, just as they normally do on the training segment. These rules can detect when that is not the case, which may imply that the build process should be reset.

Build Termination Options

The build termination options define the normal conditions under which the build process should be stopped. There are two ways to stop the build process. First, you can specify both

the minimum and maximum number of generations. The build process will run for at least the minimum number of generations and for no more than the maximum number, regardless of the other rules.

Secondly, you can specify two optional build termination rules. Both of these rules are designed to detect when the results are no longer improving so that further building would be fruitless at best and might result in over-fit strategies at worst. The first rule stops the build when it detects a decline in the moving average of the population average fitness on the test segment. Specifically, if the moving average is less than it was N generations ago, the build process is stopped. The second rule stops the build when the fitness (i.e., average population fitness) on the test segment falls below its moving average.

Both the Build Failure Rules and the Build Termination Rules are depicted graphically on the Build/Eval Process window while the build process is ongoing. Please refer to Build Symbols in the chapter Market Symbols and Settings for more information.

Build Metrics

The Build Metrics tab is shown in Fig. 2.6 in Quick Start Steps. This is where you select the build objectives and conditions that will guide the build process. Strategies are ranked during the genetic programming process according to the *fitness*, which is a combination of the build objectives and conditions selected on this tab. The objectives are metrics that you want to minimize (e.g., drawdown) or maximize (e.g., net profit). The conditions are expressed as inequality or equality statements, such as a correlation coefficient greater than or equal to 0.95 or complexity less than or equal to 10. The third list box is for selecting conditions for filtering the strategies for the Top Strategies results.

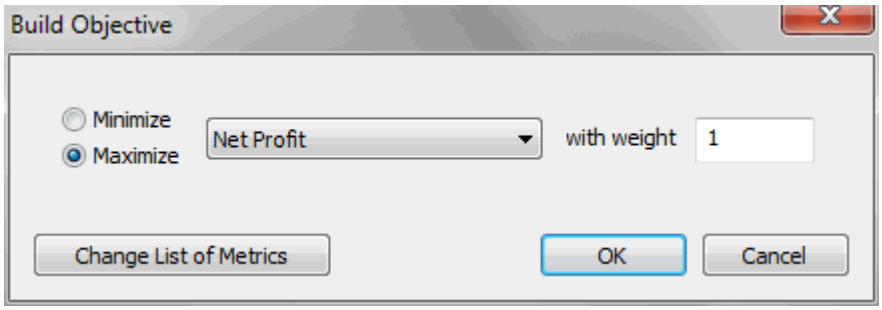


Figure 5.1. The Add and Edit buttons adjacent to the Build Objectives list open the Build Objective window for adding a new build objective or editing the current selection.

To add a new objective to the Build Objectives list, click the Add button adjacent to the list. This will open the window shown above in Fig. 5.1. Select the metric to minimize or maximize and enter the weight value. The weight values are all relative to one another. To weight the metrics evenly, a weight value of 1.0 can be entered for each build objective. The Minimize/Maximize selection will automatically change to the typical choice when the metric is selected. For example, it will change to "Maximize" if you select Net Profit as the metric or to "Minimize" if you select Drawdown as the metric. Click OK to add the new objective or click Cancel to discard it.

To edit a build objective, double-click the metric in the list or click it once and click the Edit button. This will bring up the same window as shown in Fig. 5.1. Make any desired changes and click OK to update the objective in the list or Cancel to leave the objective unchanged.

To add a new condition to the Build Conditions list, click the Add button adjacent to the list. This will open the window shown below in Fig. 5.2. Select the metric for the condition from the pull-down menu, then select the type of relationship (>=, <=, =, or "between"). Finally, enter the value or values. For the "Between" condition, the values can be entered in either order. Click OK to add the new condition to the list or Cancel to discard it. To edit a build condition, double-click the metric in the list or click it once and click the Edit button. This will bring up the same window as shown in Fig. 5.2. Make any desired changes and click OK to update the condition in the list or Cancel to leave the condition unchanged.

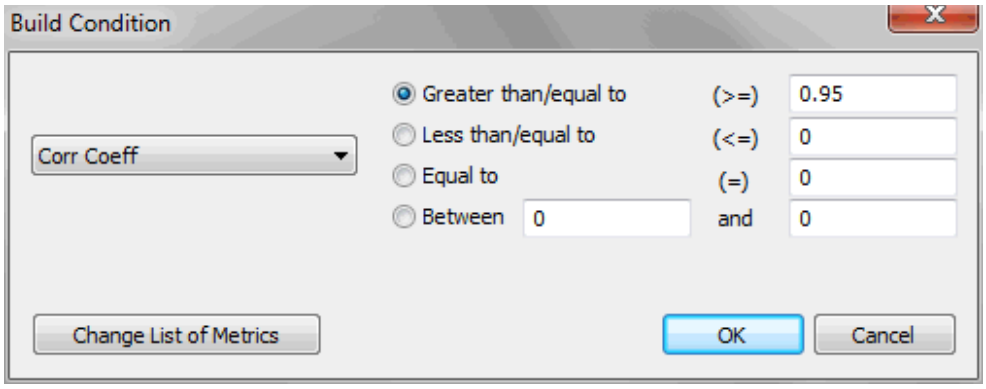


Figure 5.2. The Add and Edit buttons adjacent to the Build Conditions list open the Build Condition window for adding a new build condition or editing the current selection.

The strategy fitness is calculated from a combination of the build objectives and build conditions. The part of the strategy fitness calculated from the build objectives is a weighted sum of the metrics shown in the Build Objectives list. The metrics are normalized to the interval [0, 1] over all members of the population and weighted according to the entered weight values. The resulting values are then scaled so that the maximum value over the population has the value 1. The scaling is performed relative to the initial population, and the same scaling factors are used for each generation so that the fitness values can be compared across generations.

The build conditions are used to *penalize* the fitness when the conditions are not met. The size of the penalty is proportional to the extent to which the condition has not been met. For example, if the condition is that the drawdown should be less than 5000, and the actual drawdown is 7800, the penalty will be 2800, which is then scaled so that the maximum penalty value for that condition over the population members has the value 1. If the condition has been met, the penalty value is zero. Penalty values are subtracted from the fitness. This means that the maximum penalty value that can be subtracted from the fitness is -1 for each build condition. Since the maximum value of the contribution to the fitness from the build objectives is 1.0, the maximum possible value of the fitness is 1.0, which will happen if all of the build conditions are met for the strategy with the maximum value of the build objectives. Negative values of fitness imply one or more build conditions have not been met.

Adding build conditions helps the algorithm converge to a solution in which the build conditions are met. However, it does not guarantee that the build conditions will be met; it's always possible to specify conditions that exceed the maximum performance potential of the market. It's usually better to select build conditions that represent realistic performance goals. If the metric values representing realistic performance goals are not apparent, a few trial runs can be used to better gauge the potential of the market.

The fitness is calculated over all segments, but only the fitness on the training segment is used by the genetic programming algorithm to evolve the strategies. The fitness value on the test segment is used to monitor the build process according to the rules defined on the GP Settings window.

The values of the metrics used in the build objectives and conditions are the same as the ones listed in the Build Results table. By monitoring the results in the results table, as well as the equity curve, you can get a good idea of which objectives or conditions may need to be added or changed to improve the results. It's usually best to start with a small number of objectives and conditions, such as three or four. The default selections are often a good starting point. After a few generations, you can add or remove items, change the weights, and so on based on the reported results. An incremental approach usually works better than selecting objectives and conditions arbitrarily and letting the build process run for an extended period of time without intervention.

The list labeled **Conditions for Selecting Top Strategies** contains conditions used to filter or select members of the population for the Top Strategies results. If all the conditions in the list are met, the strategy is added to the Top Strategies table. Each member of the population is checked against this list as each generation is evolved. The conditions are defined the same as in the Build Conditions table except that you can specify the data segment over which the condition will be evaluated.

To add a new condition to the Top Strategies conditions list, click the Add button adjacent to the list. This will open the window shown below in Fig. 5.3. Select the metric for the condition from the pull-down menu, then select the type of relationship (>=, <=, =, or "between") and enter the value or values. Finally, select the data segment over which the condition will be evaluated (in-sample, out-of-sample, or all segments). Click OK to add the new condition to the list or Cancel to discard it. To edit a condition, double-click the metric in the list or click it once and click the Edit button. This will bring up the same window as shown in Fig. 5.3. Make any desired changes and click OK to update the condition in the list or Cancel to leave the condition unchanged.

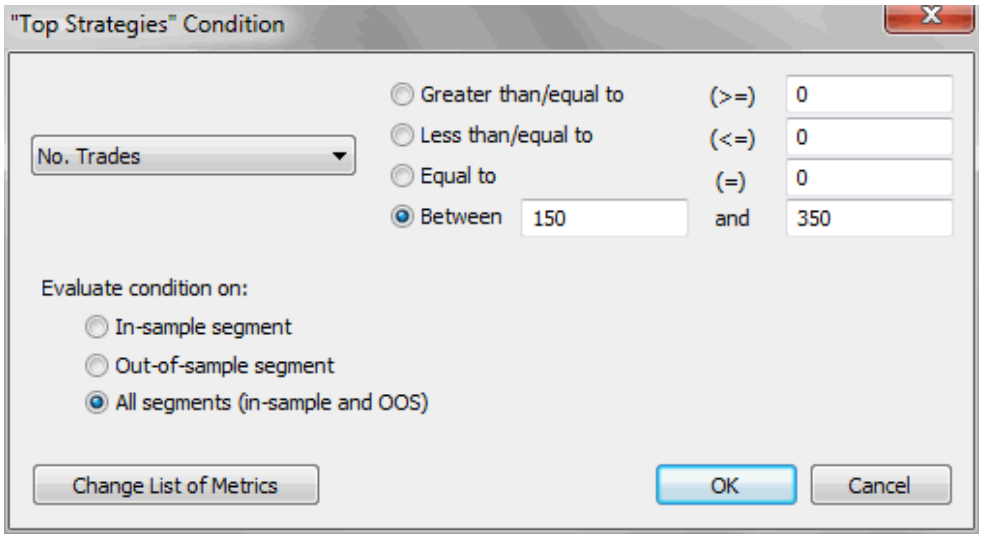


Figure 5.3. The Add and Edit buttons adjacent to the Top Strategies conditions list open the "Top Strategies" Condition window for adding a new condition or editing the current selection.

See Appendix: Performance Metrics for a description of each available metric.

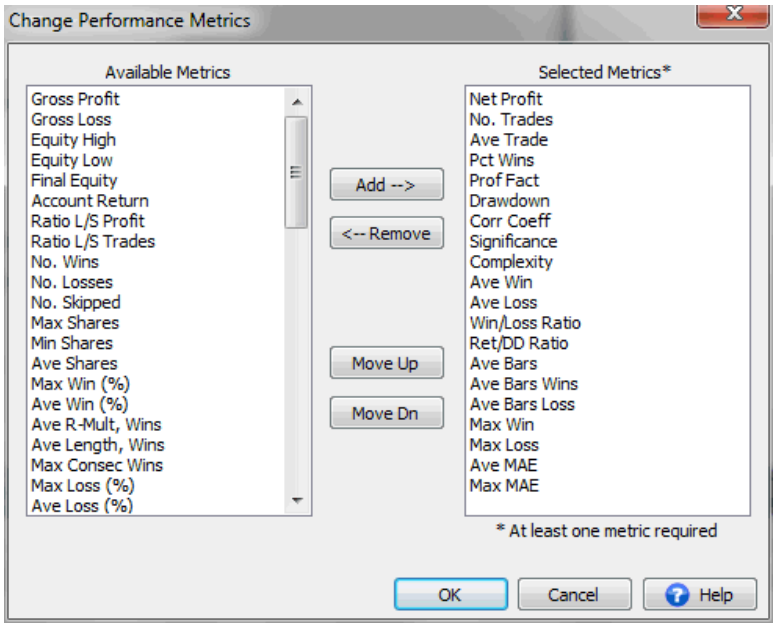


Figure 5.4. The Change Performance Metrics window is used to add or remove performance metrics available on the Metrics tab and shown in Build Results.

The list of metrics available for any of the lists on the Metrics tab can be changed by clicking the "Change List of Metrics" button, which is available on each of the Edit/Add windows (Figs. 5.1, 5.2, 5.3). This will bring up the Change Performance Metrics window, as shown in Fig. 5.4.

To add a metric, select it from the list of "Available Metrics" then click the Add button. The metric will be added to the end of the list by default. If you want to add the new metric to a specific location in the list of selected metrics, select a metric from the right-hand list before adding the new metric. When you click the add button, the new metric will be placed above the metric you selected in the right-hand list. To remove a metric from the list of selected metrics, select it from the right-hand list, then click the Remove button. To move a metric up or down in the list of Selected Metrics, use the Move Up/Dn buttons. The Add/Remove/Move Up/Move Dn buttons can also be accessed by right-clicking.

Changing the metrics here also changes them in the Build Results table and in the pull-down menu for the Performance Failure Rule on the GP Settings window.

Stress Testing

The options for stress testing and Monte Carlo analysis are available on the Stress Testing/Monte Carlo Analysis window, which drops down when the Stress Testing button on the Build menu is clicked, as shown in Fig. 5.5.

This group of options allows you to select the settings for stress testing and Monte Carlo analysis, which are explained in detail in the chapter Usage Topics. Stress testing involves making multiple sets of small, random changes to the trading strategy and/or market prices and evaluating the results using Monte Carlo analysis.

Stress testing can either be applied during the build process or after-the-fact when re-evaluating a strategy using the Evaluate command. To apply stress testing as part of the build process, make sure the option "Apply stress tests/Monte Carlo analysis" is selected on the Evaluation menu and that at least one of the stress testing methods is selected.

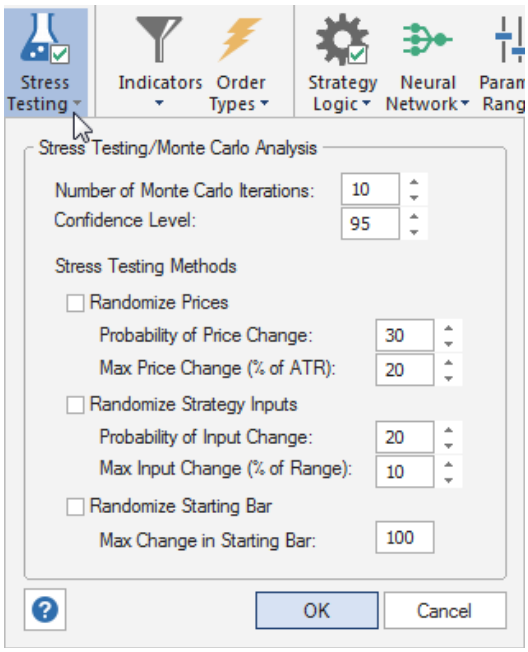


Figure 5.5. Stress testing/Monte Carlo analysis options.

The number of Monte Carlo iterations is the number of evaluations made for each Monte Carlo analysis in addition to the analysis for the original data and settings. Each iteration is a separate stress test, in which the parameters of the test are randomly chosen according to the settings under Stress Test Methods. The equity curve corresponding to each stress test will be displayed in the Equity Curve window; for example, if 10 is entered for the number of Monte Carlo iterations, 11 equity curves will be shown in the Equity Curve window, one for each stress test plus the original equity curve. The results of all iterations are reported at the confidence level entered for Confidence Level. For example, if a value of 95 is entered, the Monte Carlo results of the stress tests will be reported at a confidence level of 95%.

There are three optional stress testing methods: randomizing prices, randomizing strategy inputs, and randomizing the starting bar. Check the box next to each method to include it as part of the stress test for each Monte Carlo iteration. At least one box must be checked for a valid stress test.

To randomize the prices, check the box and enter values for the probability of changing a price and for the maximum amount by which the price is changed. The probability is applied to determine whether or not to change each price (open, high, low, close). If a price is changed, it will be changed by a randomly chosen amount not greater than the maximum amount entered as a percentage (positive or negative) of the average true range.

To randomize the strategy inputs, check the box and enter values for the probability of changing the inputs and for the maximum amount by which an input is changed. The probability is applied to determine whether or not to change each input. If an input is changed, it will be changed by a randomly chosen amount not greater than the maximum amount entered as a percentage (positive or negative) of the range for that input. The range for each input is determined from the ranges set on the Parameter Ranges drop-down window (Build menu).

To randomize the starting bar, check the box and enter a value for the maximum change in the starting bar. If the starting bar is changed, it will be changed by a randomly chosen value not greater than the value entered.

Indicators and Order Types

Indicators are selected on the Indicators drop-down window, shown in Fig. 2.7 in Quick Start Steps. The available order types are listed on the Order Types drop-down window, as shown in Fig. 2.8. The tables on these two windows represent the *build set*, which contains the indicators and order types that the program draws from during the genetic programming process. To remove a specific indicator or type of order from the build set, click the corresponding row in the Consider column of the table. To restore the previous settings, click the Reset button. To include all items for consideration during the build process, click the "Consider All" button, which will place an "X" in the Consider column for each item. To remove all items from consideration, click the "Consider None" button. Removing an indicator or order type from the build set means it won't be considered by the program when constructing strategies. Removing too many items may reduce the likelihood of finding viable strategies. The list of indicators is shown in Table 1 in Entry and Exit Conditions, Introduction chapter. The indicators themselves are described in the appendix. The different types of entry and exit orders were discussed in Order Types, Introduction chapter.

The table of order types on the Order Types window includes a column labeled "Include". Clicking an order type in the Include column ensures that the order type will be included in each generated strategy. For example, to make sure each strategy includes a protective (money management) stop, click the Include column entry for one of the Protective Stop order types.

Note: If an indicator or order type is not available for the chosen trading platform, as determined from the code type selection on the Evaluation menu, the table entry will be grayed-out and will not be available for selection.

Strategy Logic Options

Options affecting the types of strategies generated by Builder can be made on the Trading Logic Options window, which drops down when the Strategy Logic button on the Build menu is clicked, as shown in Fig. 5.6.

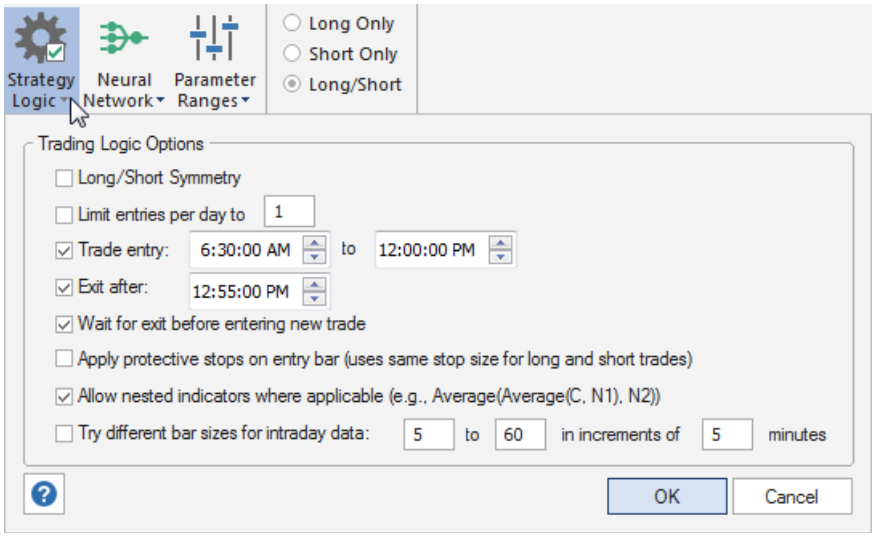


Figure 5.6. Trading Logic Options window on the Build menu.

The **Long/Short Symmetry** option, if checked, constructs the short-side entry condition by logically reversing the rule for the long side. This will reduce the system complexity, which may increase the reliability of the strategy. However, some markets have a clear directional bias, such as stock indexes, which tend to have an upward bias. In such cases, it may be better to use different rules for long and short trades.

For intraday strategies, you can specify the maximum number of trade entries per day by checking the box **Limit entries per day to []** and entering the desired maximum number of daily entries in the box. Limiting the number of entries per day can often improve results for intraday strategies because it reduces the number of different market conditions that must be accommodated.

Entry times for intraday trades can be restricted to a time range using the **Trade entry** option. Enter the starting and ending times using the time selectors. This will restrict entries to the time range chosen. To force trades to exit by a certain time, enter the desired exit time in the **Exit after** option. If an intraday trade is open at that time, it will be closed at market on the next bar. The **Exit after** option uses the "Exit at Time" order type, as shown on the Order Types tab. Consequently, selecting this option also selects the "Exit at Time" order type. If you subsequently de-select this order type on the Order Types tab, you will have to select the **Exit after** option again to re-establish it.

The option to **Wait for exit before entering new trade** is checked by default. This adds an entry condition that only allows an entry if the current position is flat. If this option is unchecked, a long entry may reverse a short position and vice-versa. Uncheck this option to create "stop and reverse" strategies that are always in the market, either long or short.

The option to **Apply protective stops on entry bar** immediately applies the protective stop order upon trade entry. This means the protective stop will be applied on the bar of entry, rather than waiting until the close of the bar like most orders. In TradeStation, selecting this option applies the protective stop order using the SetStopLoss EasyLanguage command. This option only applies to existing protective stop orders; it does not add a protective stop if one does not already exist. Also, because this option must accommodate the SetStopLoss command in EasyLanguage, it uses the same size stop for both long and short trades.

Indicator nesting can be turned on or off using the option **Allow nested indicators where applicable**. If checked, this option allows indicators to take other indicators as input, such as Momentum(TriAverage(L, N1), N2). The number of levels of nesting is determined by the tree depth, which is determined for each strategy during the build process. Indicator nesting is not available for MetaTrader 4 strategies. In this case, the option is ignored.

The intraday bar size can be included as a parameter in the build process by selecting the option **Try different bar sizes for intraday data**. Provided the price data for the selected market support intraday bars, this option will temporarily set the data type to Intraday during the build process and vary the bar size between the range of values chosen as part of this option. For example, you might enter a bar size range of 5 to 60 in increments of 5 minutes. Builder will try different bar sizes ranging from 5 minute bars to 60 minute bars in increments of 5 minutes (i.e., 5, 10, 15, 20, …, 60). In this case, the selected price file in the Market Symbols table should contain 5 minute price bars or smaller. For example, 1 minute bars would also work well in this example, but 3 minute bars would not give accurate results for some of the bar sizes, such as 10 and 20 minute bars.

Builder will also permit this option if the underlying data are range or tick bars, although the resulting intraday bars may not be accurate in this case. The most versatile type of price data to use with this option is 1 minute bars, although larger minute bars are fine, provided the

selected bar size range and increment result in bars that are an even multiple of the bar size in the price file. To ensure this is the case, the bar size range values and increment entered as part of this option should be integer multiples of the bar size in the price file. For example, if the price file contains 4 minute bars, the range and size increment should be multiples of 4, such as 4 to 40 in increments of 4.

When the intraday bar size is part of the build process, the bar size is evolved as part of the strategy, just like any other strategy feature or parameter. The resulting optimal bar size is reported in the build report under Strategy Description, Other Strategy Features, as well as in the Build Results table ("Opt Bar Size"). The reported results will be based on this optimal bar size. This will be true even if the currently selected bar type in the Market Symbols table is other than intraday or if the intraday bar size in the Market Symbols table is different than the optimal value. When selecting "Evaluate" or "Evaluate All" from the Evaluation menu, a strategy with an optimal bar size will be evaluated at that bar size only if the option "Use optimal bar size if applicable" is selected on the Evaluation menu. If this option is unchecked, the strategy will be evaluated using the settings currently in effect in the Market Symbols table, which may include a different bar type and/or bar size than the optimal one found during the build process.

Neural Network Settings

A neural network can be included in each strategy by selecting the option **Include a neural network in entry conditions** on the Neural Network Settings drop-down window in the Build menu, as shown in Fig. 5.7. As explained in the section Neural Networks in the Introduction chapter, a neural network is a nonlinear function of one or more inputs, which Builder will select and evolve along with the entry and exit conditions if this option is included. The output of the neural network will supplement the entry conditions. Enter the settings that affect the definition of the neural networks, as shown in Fig. 5.7. Please refer to the Introduction chapter for more information.

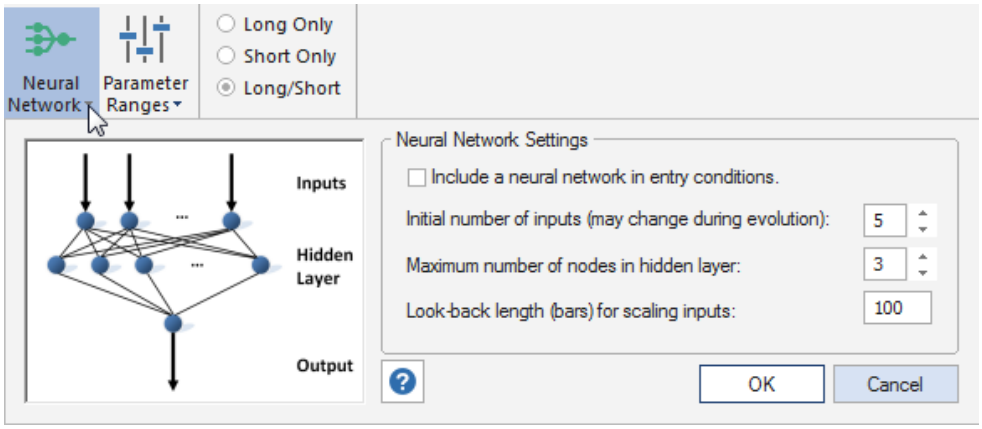


Figure 5.7. Available settings for the optional neural network feature.

Parameter Ranges

The Parameter Ranges drop-down window of the Build menu, shown in Fig. 5.8, allows you to optionally set the minimum and maximum values for constants used by the program, such as the sizes of the protective stops, multipliers for the average true range (ATR), and look-back lengths for indicators and price patterns. For example, if you find that the strategies generated by the program contain fixed stops that are too large, you can reduce the upper value for the **Fixed Stop Size**.

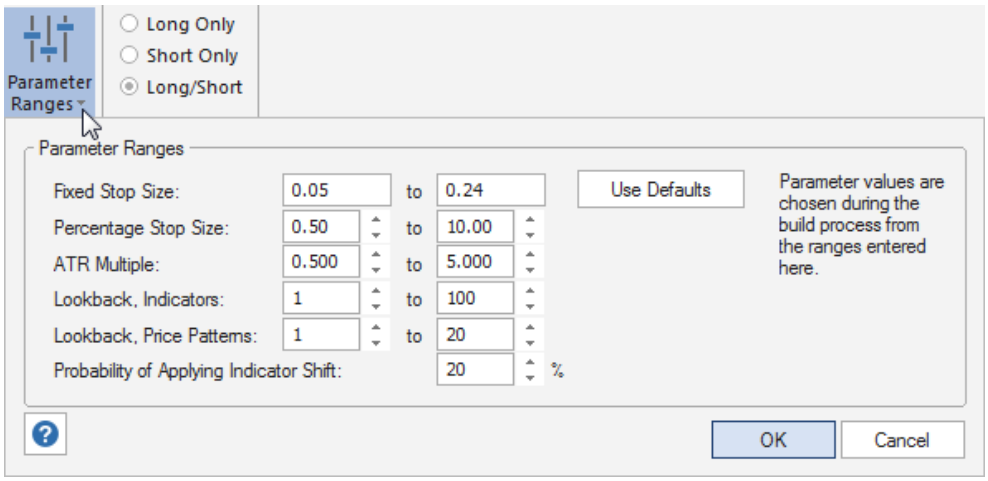


Figure 5.8. The Parameter Ranges drop-down window of the Build menu.

The range for fixed size stops is given in the currency in which the account is denominated. For example, for US dollar-denominated accounts, you might choose a range of stop sizes from 100 to 1000, representing stop sizes from $100 to $1000.

Note that the size of a fixed sized stop is per share or contract, not per trade. A default range for the fixed sized stops is calculated automatically based on multiples of the average true range (ATR) for the selected price series. The lower limit is based on a multiple of 0.25 of the ATR, rounded down to the nearest tick, and the upper limit is based on a multiple of 4.0 of the ATR, rounded down to the nearest tick. If you change from the default values, you can revert to them by clicking the **Use Defaults** button. If multiple markets have been selected, the range is based on the current selection, which is the market last clicked on. To see if the range changes significantly for other markets, click on a different market in the Market Symbols table and click the Use Defaults button.

The range of values for **ATR Multiple** is used when constructing ATR-based protective stops, entry orders based on price differences (ATR, true range, or the difference between two price-based indicators), and trailing stops.

The different types of protective stops are discussed in Order Types in the Introduction chapter.

The parameter range for **Lookback, Indicators** applies to all indicators requiring a lookback length with the exception of price patterns; e.g., the averaging length of a moving average.

The lookback length for price patterns is chosen from the range of values given by **Lookback, Price Patterns**. This applies to individual prices; i.e., it's the "N" in O[N], H[N], L[N], and C[N].

Whether or not an indicator is shifted depends on the **Probability of Applying Indicator Shift**. A shifted indicator returns the value N bars ago, where N is the shift. For example, in EasyLanguage, XAverage(C, 14)[N] returns the value of the exponential moving average N bars ago. If the probability is set to 20%, for example, there is a 20% chance that any indicator that can be shifted will be shifted. The shift value itself is chosen from the indicator look-back parameter range. Set the probability to 0% to turn indicator shifting off.

Evaluation Options

The Evaluation menu is shown in Fig. 2.10 in Quick Start Steps in the Getting Started chapter. This menu contains options that are applied when a strategy is evaluated, which occurs during strategy building and when the Evaluate or Evaluate All commands are selected. In this context, "evaluation" means performing a back-test on the selected strategy, which simulates trading the strategy over the markets selected in the Market Symbols table on the Build/Eval Process window.

Unlike most of the settings on the Build menu, which affect how the strategies are built but can't change them after they're built, the options on this menu are applied whenever a strategy is evaluated. As a result, you can change the options on this tab, such as an order fill rule or the code output option, and re-evaluate an existing strategy to see the effect. **Re-evaluating a strategy recalculates the performance results and rewrites the code without changing the strategy itself.**

Evaluate Strategies Panel

This panel of the Evaluation menu contains the Evaluate and Evaluate All buttons. Clicking the Evaluate button will perform a back-test of the strategy currently selected in the Build Results table. A message will be displayed in the Messages window when the evaluation is complete, and the results windows will be updated to display the results. Clicking the Evaluate All button will evaluate all the strategies in the population. The progress of the evaluation will be displayed in the Messages window. The process can be cancelled by clicking the Cancel button.

Simulation Settings Panel

This panel contains settings that affect the back-test results of the evaluation. The **Starting Equity** is the value of the account equity at the start of the back-test. Simulated account equity is accrued during the back-test and is used for the calculation of performance metrics.

The option **Apply stress tests/Monte Carlo analysis** optionally evaluates the strategy results using the stress testing and Monte Carlo options on the Stress Testing window; see the section Stress Testing and Monte Carlo Analysis under Usage Topics for a more detailed explanation of the stress testing process. Briefly, stress testing involves evaluating the strategy multiple times, each time under slightly different conditions; for example, using randomized prices or randomized input parameter values. When stress testing, the different evaluations are combined using Monte Carlo analysis, and the results are reported at the confidence level specified on the Stress Testing window.

The option **Use optimal bar size if applicable** works in conjunction with the option on the Strategy Logic window to try different bar sizes for intraday data when building. If that option is selected, the option here will evaluate the strategy using the optimal intraday bar size found during the build process. On the other hand, if the option in this section is unchecked, the strategy will be evaluated using whichever market data settings are currently in place in the Market Symbols table on the Build/Eval Process window. This option has no effect unless the strategy being evaluated has an optimal intraday bar size found from using the option to try different intraday bar sizes.

The option **Fill limit order when limit price is exceeded** only fills limit orders when the limit price is exceeded. If unchecked, limit orders will be shown as filled when the limit price is touched. For strategies applied to small bars, such as 1 minute or tick bars, it will usually be more accurate to assume that a limit order is not filled unless the limit price is exceeded. In practice, a limit order may not be filled if the limit price is only touched because there

may be insufficient volume to fill all the orders at that price or better. Therefore, it's prudent to select this option when the volume on a typical price bar is expected to be small.

The option **Use Bid/Ask spread to determine fills** uses the bid/ask spread to determine fill prices and whether or not stop and limit orders are filled. The default setting is "off". Since MetaTrader 4 uses the bid/ask spread in this manner, this option should always be selected when building and evaluating strategies for MetaTrader 4. Please see Symbol Settings in the Market Symbols and Settings chapter for more information on the bid/ask spread.

The option **Fill limit order no better than limit price** prevents a limit order from being filled at a more favorable price due to a gap opening. For example, if an order to buy on a limit is in effect and the next bar opens below the limit price, it's possible that you would get filled at or near the open of the bar, which would be a more favorable fill than the order price. However, it's also possible that the order would not be filled until the market went back up to your order price. This option assumes the worst-case scenario of being filled at no better than the order price. Selecting this option will provide conservative fill estimates for limit orders.

Code Type Panel
The code type panel allows you to choose the type of code generated when the strategy is evaluated. Select TradeStation/MultiCharts for TradeStation version 6 and above and for recent versions of MultiCharts, TS 2000i for TradeStation version 2000i, NinjaTrader for NinjaScript code for NinjaTrader 7, MetaTrader 4 for MQL4 code, or AmiBroker for AFL code. The code for all of the saved strategies listed in the Build Results table is stored in the project file (extension .gpstrat). If you want to generate code for a different platform, change the selection here, select the desired strategy from the Build Results table, and select Evaluate from this menu. The code will be re-written for the new code type as part of the evaluation process.

Note: As shown in Table 1 in the Introduction chapter, not all indicators are available for all code types. Also, some indicators give different results in each platform. For this reason, the same results may not be found if the code type is changed and the strategy is re-evaluated. Also, if an indicator is not available for one platform, converting to a different code type may result in invalid code. This can also happen due to indicator nesting, which is unavailable in MetaTrader 4. Invalid code may also result if a strategy with both long and short trades is converted to AmiBroker code, which does not support both long and short trades in the same Builder-generated strategy.

Significance Test Panel
This panel allows you to perform a unique test of statistical significance that's designed to uncover when a strategy's apparently good performance is, in fact, the result of good luck rather than effective trading logic. This test should not be confused with the so-called "Significance" metric that's part of the set of performance metrics calculated by Builder. The Significance metric performs a traditional *t* test on the average trade for a strategy. This can provide a measure of strategy quality but cannot assess whether the results for the strategy are statistically significant because such a test does not take the data mining process into account.

The significance test in this panel takes the build process into account to construct a valid sampling distribution for each strategy in the population. The sampling distribution is based on the total number of strategies constructed as part of the build process, including any resets due to the Build Failure Rules. For example, if 10,000 strategies were generated before arriving at the final population, then each point on the sampling distribution will be produced

by generating 10,000 random strategies and taking the best one. This process is repeated M times, where M is the number of samples.

The randomly generated strategies have no predictive power. However, the best one among a sample of 10,000 is likely to generate good results simply due to luck. We want to know if the strategy in the population is significantly better than the best random strategy, so the sampling distribution is constructed from M strategies, each of which is the best strategy among all the (e.g., 10,000) randomly generated strategies. Please refer to the article **Is That Back-Test Result Good or Just Lucky?** under the Newsletter link at www.Adaptrade.com for more information.

The **Number of Samples** entry is the number of samples comprising the sampling distribution; e.g., M in the example above. The option **Run test after each build** will cause this test to be run automatically at the conclusion of each build. If this option is not selected, you can manually run the test at any time by clicking the button **Perform Significance Test**. Builder stores the total number of strategies generated during the build process, which it will use in constructing the sampling distribution when the test is run at a later time.

The test is applied to each strategy in the population. The strategy's fitness, as evaluated over the combined training and test segments, is used as the test statistic. The results of the test are displayed in the Build Results table, listed under "Build Sig", in the right-most column in the table. The result is listed as the probability value (0 - 1) with a Pass/Fail label in parentheses; for example, "0.961 (Pass)". A significance level of 0.95 (95%) is the threshold for passing the test. In other words, a probability value of 0.95 or greater is considered statistically significant.

Please note: The test is very time consuming. Each sample requires a large number of strategies to be randomly generated, similar to generating a very large initial population. For example, if there are 10,000 strategies in each sample and 500 samples, a total of 5,000,000 strategies must be generated to construct the sampling distribution. If the test is taking too long, it can be cancelled by clicking the Cancel button.

Position Sizing Settings

The Position Sizing menu is shown in Fig. 2.11 in Quick Start Steps in the Getting Started chapter. Position sizing determines how many shares or contracts are traded on each trade. The position sizing method used when evaluating a strategy is also implemented in the strategy code generated by Builder, so that when running the code in the trading platform, the same position sizing should be seen as in Builder.

As with the options on the Evaluation menu, changes to the position sizing can be made after the strategy is built. To see how different position sizing settings affect the results, change the position sizing here and select Evaluate from the Evaluation menu. When the strategy is re-evaluated, the strategy code will be re-written to include the new position sizing settings.

Position Sizing Method Panel

Builder includes six different position sizing methods. Each method has an associated parameter value, which is entered in the **Parameter** field.

Fixed size. This method simply uses the value you enter as the number of shares or contracts for each trade. A fixed size of 1, for example, will trade one contract or share for each trade. For forex trading, a typical fixed size would be either 10000 or 100000. It's important to set the upper size limit to a value at least as big as the fixed size entered here.

Constant value. With constant value position sizing, each position is sized so that it has a specified value, such as $1000 per trade. This method can be used when you want to allocate a specified amount of equity to each trade. The constant value method will determine the number of shares or contracts corresponding to your specified amount. For example, if you plan to purchase a stock at a price of $25 and you want to spend $35,000, you would trade 35000/25 or 1400 shares. In this case, the constant value amount is 35000; each trade will be sized so that the position value is $35,000.

Percent of equity. In this method, the number of shares or contracts is chosen so that the value of the position is equal to the selected percent of account equity. For example, if the percent of equity is 40%, the position size will have a value equal to 40% of the account equity. If the account equity were $30,000, the position would have a value of 0.4 x 30000 or $12,000. If the share price were $25, the position size would be 12000/25 or 480 shares. In other words, a position size of 480 shares at $25 per share has a value of $12,000, which is 40% of the equity value of $30,000.

Fixed fractional. In fixed fractional position sizing, the number of shares or contracts is based on the risk of the trade. For example, you might risk 2% of account equity on each trade. Fixed fractional position sizing has been written about extensively by Ralph Vince. See, for example, his book "Portfolio Management Formulas," John Wiley & Sons, New York, 1990.

The risk of a trade is defined as the dollar amount that the trade would lose per contract or share if it were a loss. In Builder, the trade risk is taken as the size of the money management stop applied, if any, to each trade. If the strategy doesn't use protective (money management) stops, the trade risk will be taken as the largest historical loss per contract or share. The largest loss is the largest loss up until the point at which the trade is taken. If subsequent losses are larger, the trade risk will be larger for subsequent trades.

As an example, consider a stock trading system that uses a 2 point stop. It might enter long at a price of 48 with a sell stop at 46. The risk per share would be $2. With a fixed fraction of 5% and account equity of $20,000, fixed fractional position sizing would risk 0.05 * 20000 or $1,000 on the next trade. Since the risk per share is $2, this means 1000/2 or 500 shares would be traded.

Fixed ratio. In fixed ratio position sizing the key parameter is the delta. This is the amount of profit per share or contract to increase the number of shares or contracts by one. A delta of $3,000, for example, means that if you're currently trading one contract, you would need to increase your account equity by $3,000 to start trading two contracts. Once you get to two contracts, you would need an additional profit of $6,000 to start trading three contracts. At three contracts, you would need an additional profit of $9,000 to start trading four contracts, and so on. Fixed ratio position sizing was developed by Ryan Jones in his book "The Trading Game," John Wiley & Sons, New York, 1999.

Normally, the delta is the amount per share or contract, as in the example above. For some instruments, such as forex, this would be inconvenient because forex uses a point value of 1 and typically trades in increments of 10,000 or 100,000 shares. To accommodate this, the delta is specified per multiples of shares when the option to round the share size to the nearest number of shares (see below) is selected. For example, if the "round to.." option is selected with an increment of 10,000 shares (i.e., "Round to nearest 10,000 shares"), then the delta would be specified as the amount per 10,000 shares.

The fixed ratio method will start trading with a position size equal to the minimum number of shares/contracts specified in the Position Sizing Options panel (see below). For example,

if the minimum number of shares for a forex strategy is set to 10,000, this will be the position size calculated by the fixed ratio method for a profit of zero. As profits are accrued, the position size will increase, based on the delta, in increments specified by the "round to.." option.

Fixed amount per share. In this position sizing method, you choose the amount of account equity required to trade each share or contract. For example, if the dollar amount is $5,000, you would trade one contract for every $5,000 in the account. If the account equity is currently $50,000, the position size would be 10 contracts for the next trade.

When Builder evaluates a strategy, it tracks the account equity and simulates how the account equity changes from trade to trade, starting with the first date in the trading period and accumulating the profits and losses up through the last date in the date range. The starting equity value, entered on the Evaluation menu, is the value of the simulated trading account at the start of trading. The default value of starting equity is $100,000. As the equity changes, the position size will generally change as well. In all position sizing methods except for fixed size and constant value, the position size increases as the account equity rises and decreases when the account equity drops.

Note: When building over multiple market together (i.e., a portfolio), the same position sizing (including parameter values) is used for each market. Also, the portfolio equity is used in the position sizing calculations. This is the accumulated equity from trading over all markets in the portfolio.

Position Sizing Options Panel
In the Position Sizing Options panel, you can enter the minimum and maximum number of shares or contracts that the strategy will trade by entering values for the **Size Limits** entries. The minimum value, which defaults to 1, is applied to all trades. After the position size is calculated, the position size is increased to the minimum if the position size would otherwise fall below the minimum. Likewise, the maximum, which defaults to 100, is applied to all trades. After the position size is calculated, the position size is reduced to the maximum if the position size would otherwise exceed the maximum.

The option **Round to nearest** rounds the position size to the nearest number of shares or contracts. For example, if you enter a value of 100, the number of shares will be rounded to the nearest 100 shares. The default value is 1. For forex trading, this can be used to trade in even lot sizes of 10,000 or 100,000 by setting the rounding value to 10,000 or 100,000, respectively. In this case, the minimum number of shares should be set to the same value and the maximum value to some multiple of the minimum.

Evolve Position Sizing Panel
You can optionally choose to have Builder evolve the position sizing as part of the build process. There are three options. The first option, **Don't evolve; use selected settings**, uses the settings you specify for each strategy. If you select **Evolve parameter only**, the program will evolve only the parameter value (e.g., the fixed fraction) while using the selected position sizing method. If you select **Evolve method and parameter**, then Builder will evolve both the position sizing method (i.e., one of the six available methods) along with the associated parameter value.

Reset Panel
To return to the position sizing that was selected or evolved with the strategy when it was built, click the **Reset to Build Settings** button then select Evaluate from the Evaluation menu to rewrite the code and re-calculate the results.

Chapter 6
Build Results

The results generated from running Builder include the strategy code for each of the saved strategies along with the performance results for each one. The docking windows (panes) described below display the different types of program output. The Getting Started chapter discussed working with windows and panes in Builder.

Messages Window

The Messages window displays messages generated by the program while performing build and evaluate operations, reading price files, and so on. For example, when building strategies, a message is displayed in this window several times per second indicating which member of the population has been recently initialized or created. This window will also display an error message if the price file cannot be found.

Memory Allocation Errors. The following message will be displayed in the Messages window if the program runs out of memory:

```
>> Insufficient memory. Try reducing population size, tree depth, or price
file size.
```

This error occurs when the program's memory requirements exceed the computer's available memory. When this happens, the program is designed to detect the lack of available memory and stop processing before a program crash occurs. When this happens, it can be resolved by reducing either the population size or the size (length) of the file of price data. If the tree depth has been increased beyond the default value, lowering it may also help.

Build Results

The Build Results table displays summary results for the saved population members. A pull-down menu at the top left allows you to select among Population, Training; Population, Test; Population, Combined; Top Strategies, Training; Top Strategies, Test; and Top Strategies, Combined. The first three options list performance results for each of the saved strategies in the current population. The performance is tabulated separately for the training and test periods. "Combined" refers to the entire period – training and test combined. The performance metrics displayed in the table are defined in the previous chapter. Click on a row in the results table to display the results for the corresponding strategy in the Performance Report, Build Report, Equity Curve, Trade List, and Strategy Code windows. The strategies in the these tables are listed in order of decreasing fitness. Builder saves and displays the number of strategies you specify on the GP Settings window up to the population size.

Note that if the training period ends with an open trade that exits in the test period (or vice-versa if the training period follows the test period), then the trade will be included in the metrics for the test period.

While the build process is ongoing, the program updates the results in Build Results after each completed generation. If the build is cancelled before the first generation is completed,

the initial population will be displayed. The table results can be sorted by any column by clicking on the column heading. For example, to sort the results by net profit, click on the Net Profit column label. The results in related tables are sorted the same way. For example, if you sort the training results by drawdown, the test results will appear in the same order.

When "Top Strategies…" is selected from the pull-down menu, the table lists performance results for strategies that meet the filtering criteria specified on the Build Metrics window in the list "Conditions for Selecting Top Strategies". The population of top strategies is updated after each generation is completed for every build within the project file. Top Strategies may come from different builds if multiple builds have been run. Top Strategies are saved in the project file, along with the saved members of the population.

To remove a strategy from the table of Top Strategies, click on the entry then right-click and select **Delete Selected Strategy**. The table can be cleared by right-clicking and selecting **Delete All Strategies**. Neither delete operation will affect the table of Population results. A strategy can be copied from the Population table to the Top Strategies table by selecting the strategy in the Population table then right-clicking and selecting **Copy Selection to Top Strategies**. This can be used to save an interesting strategy that wasn't picked up by the filtering rules before re-building the population.

The entries in the Top Strategies table are listed in the order in which they were added to the table. Since strategies can come from different builds, two different strategies may have the same Member number. To see how different strategies in the table compare to one another, click any strategy in the table then select **Evaluate All** from the Evaluation menu. This will re-evaluate each of the strategies in the Top Strategies table and re-compute their fitness values. You can then sort by fitness by clicking on the Fitness column heading.

The Build Results table can be copied to a spreadsheet by right-clicking on the table and selecting **Copy**. Open a blank spreadsheet page and select Paste to insert the table results into the spreadsheet. There is also a right-click menu option to **Change Metrics**, which opens the Change Performance Metrics window, discussed in the previous chapter under Build Metrics.

If stress testing has been applied, the results shown in Build Results will be the Monte Carlo results at the confidence level specified on the Stress Testing window. ***Note:*** *Monte Carlo results of stress testing are calculated metric-by-metric at the specified confidence level and therefore are not directly related to one another. For example, the Monte Carlo net profit is not necessarily the sum of the long Monte Carlo net profit and short Monte Carlo net profit because the long and short net profit are each calculated at 95% confidence. This applies to all metrics.*

Performance Report Window

The Performance Report window displays a detailed performance report for the strategy selected in Build Results. The performance report can be copied to the clipboard, printed, or saved to a file in several different formats by right-clicking and selecting from the popup (context) menu (**Copy, Save to File, Print, Help**).

An example of part of the performance report is shown in Fig. 6.1. The performance report includes results for all trades together, long trades only, and short trades only. The results are over all data used in the build, both training and test combined. The metrics displayed in the report are described in Appendix: Performance Metrics.

The market or markets used in evaluating the strategy are shown at the top of the report under Markets. If more than one market was selected in the Market Symbols table, the results will represent the performance of the selected strategy over the combination of markets (i.e., portfolio). To see the results for a different market or markets, change the selections in the Market Symbols table, then select **Evaluate** from the Evaluation menu. The strategy will be evaluated over all markets that have been selected in the Include column of the Market Symbols table.

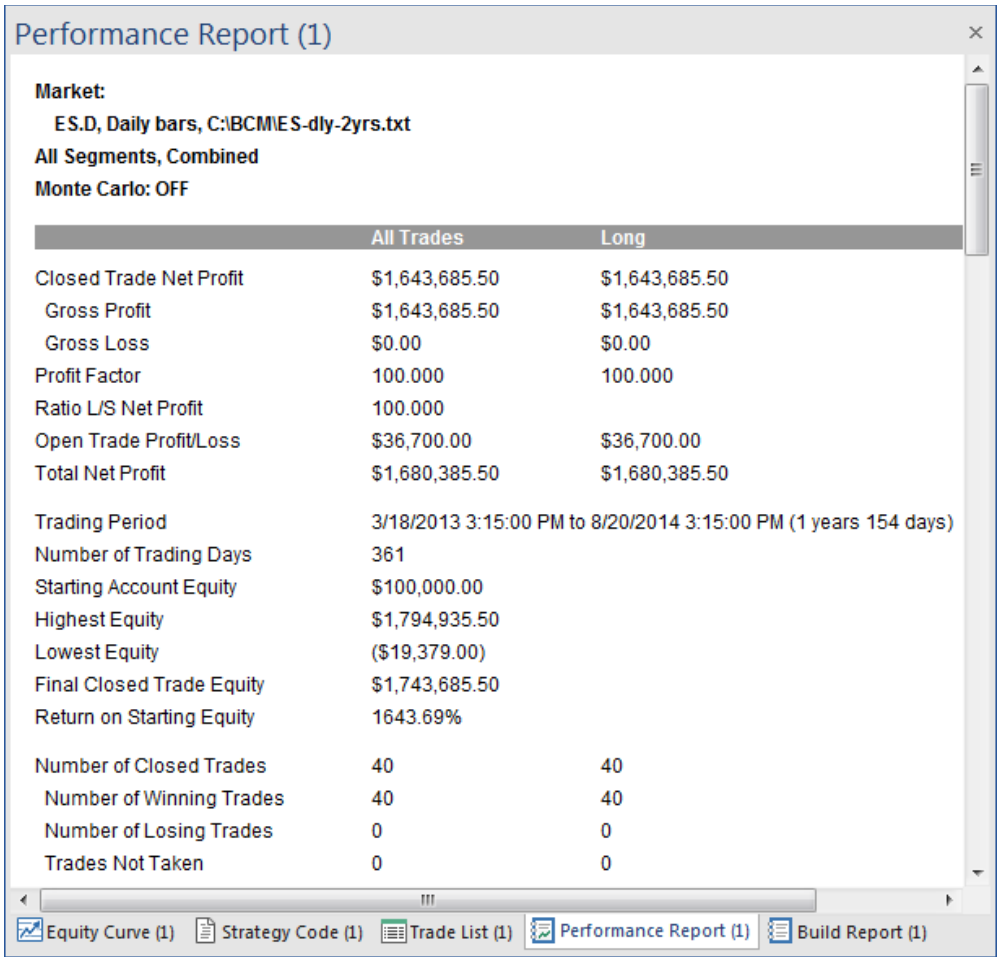


Figure 6.1. Performance report for selected strategy (population member 1).

If stress testing has been applied, the reported results will be the Monte Carlo results at the confidence level entered on the Stress Testing window, and the report will indicate "Monte Carlo: Stress Test Results at x% Confidence", where x is the selected confidence level.

Note: *Monte Carlo results of stress testing are calculated metric-by-metric at the specified confidence level and therefore are not directly related to one another. For example, the Monte Carlo net profit is not necessarily the sum of the long Monte Carlo net profit and short Monte Carlo net profit because the long and short net profit are each calculated at 95% confidence. This applies to all metrics.*

Build Report Window

The Build Report window summarizes the results of the build process for the strategy selected in the Build Results table. The build report can be copied to the clipboard, printed, or saved to a file in several different formats by right-clicking and selecting from the popup (context) menu (**Copy, Save to File, Print, Help**).

An example of part of the build report is shown in Fig. 6.2. The build report consists of three sections: Build Summary, Strategy Description, and Build Settings. The Build Summary includes items such as the build date, time required to build the population, number of generations, etc. The Strategy Description lists all elements of the strategy, including indicators, order types, and other strategy features. The Build Settings section records all the settings made by the user that were in place when the build commenced; i.e., all settings that affected the build process.

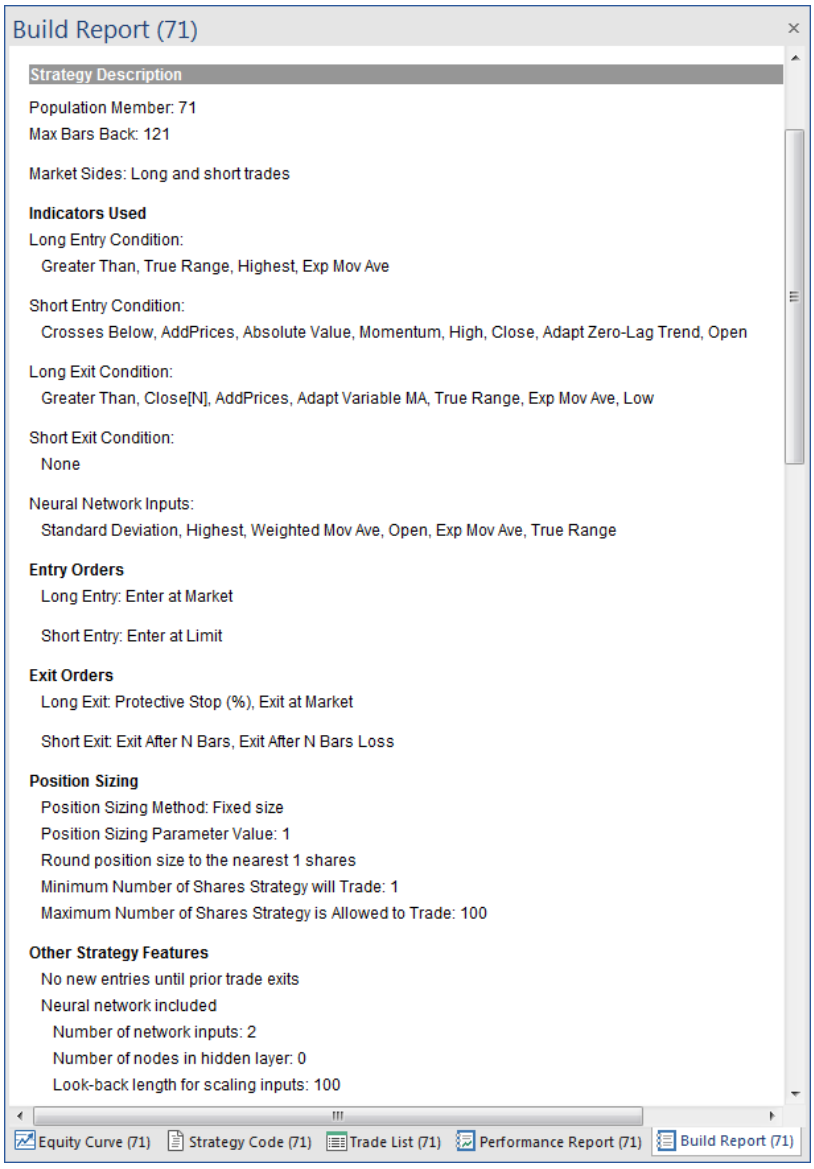


Figure 6.2. Build report for selected strategy (population member 71).

Strategy Code Window

The code for the selected strategy is displayed in the Strategy Code pane. To view the code for a different strategy of the population, select the strategy in the Build Results table. The code in the Strategy Code window can be copied to the clipboard by right-clicking and selecting **Copy Strategy** or by selecting **Strategy Code** from the Clipboard menu. To copy only part of the strategy code, click and drag the mouse over the part you want to copy, then right-click and select **Copy** to copy the selected text to the clipboard. MetaTrader 4 code can be saved directly to a .mq4 file by right-clicking in the code window and selecting "Save MT4 Strategy to File".

Similarly, select "Save NinjaScript Strategy to File" to save the strategy code for NinjaTrader directly to a file in the required folder for NinjaTrader. Once selected, the folder location for NinjaTrader strategies is stored in the registry, so it only needs to be selected once. Builder initially defaults to the folder Documents\NinjaTrader 7\bin\Custom\Strategy\, which is the customary location for NinjaTrader strategies under NinjaTrader 7. Builder creates a default strategy name for each NinjaTrader strategy of the form projectname_member#_#inputs_maxbarsback. For example, for a project with the file name "MyProject.gpstrat", a typical strategy name might be MyProject_3_7_72, which indicates the strategy is from population member 3 with 7 inputs and a MaxBarsBack requirement of 72. When saving the file, a new name can be entered, which will become the name for both the file and the strategy.

The strategy code cannot be edited directly in Builder. To edit the code, copy the code to your trading platform (e.g., TradeStation or MultiCharts), and use the editor in the trading platform.

Unless saving the strategy code directly to a file, to transfer the code to your trading platform, copy the code from the Builder code window and paste it into the strategy editor of the trading platform. In TradeStation or MultiCharts, open a new strategy window in the EasyLanguage editor, choose a name, then paste the code into the empty strategy window. Finally, compile the EasyLanguage code by pressing F3. In MetaTrader 4, open a new window in the MetaEditor, paste in the code from Builder, and click the compile button. In AmiBroker, in the Charts pane, right-click on the Systems folder and select "New" and then "Formula". Enter a name then right-click on the name and select "Edit". Select "Paste" from the Edit menu to paste the code into the edit window, then click the save icon and, finally, click the AFL icon to verify the code.

If you're pasting the strategy code over the code for an existing strategy, it will be necessary to reset the input values before running the back-test. In MetaTrader 4, this can be done by clicking the Expert properties button on the Tester window and clicking the Reset button on the Inputs tab. In TradeStation, delete the strategy from the chart and re-insert it to reset the input values. In AmiBroker, click the Parameters icon on the Analysis window and click "Reset all".

To test the strategy in TradeStation/MultiCharts, insert it into the corresponding chart, such as the chart used to generate the price data file for analysis, and set the ”Maximum number of bars study will reference” (in TradeStation, Format Strategies, Properties for All; in MultiCharts, Format Signal, Properties) to the **MaxBarsBack** value listed in the results table.

To test the strategy in NinjaTrader 7, first open the strategy in the NinjaTrader editor by selecting Edit NinjaScript from the Tools menu, and click the Compile button. The strategy should then be ready to back-test via the Strategy Analyzer window. Select the strategy on

the Backtest tab of the Strategy Analyzer window and set the "Min. bars required" to the MaxBarsBack value listed in the results table. Click the button "Run Backtest".

To test the strategy in MetaTrader 4, select the strategy (Expert Advisor) on the Tester window (Settings tab), and select the symbol and date range. For best results in MetaTrader, select "Every tick" as the Model, then click the Start button to run the back-test.

To test the strategy in AmiBroker, right-click on the strategy in the Systems folder of the Charts pane and select "Analysis". On the Analysis window, reset the parameter values by clicking on the Parameters icon, and check the settings by clicking on the Settings icon. Finally, click the Backtest icon to run the test.

Equity Curve Window

The closed-trade equity curve for the strategy selected in the Build Results table is displayed in the Equity Curve pane. To view the equity curve for a different strategy of the population, select the strategy in the Build Results table. The equity curve is based on the most recent evaluation. If you want to see the curve for a different range of dates, change the date range on the Build/Eval Process window, then select **Evaluate** from the Evaluate menu. Similarly, the selected strategy can be evaluated over a different market or markets by selecting the market(s) in the Market Symbols table and re-evaluating the strategy.

If multiple markets are selected in the Market Symbols table, multiple curves will be plotted. The portfolio equity curve (i.e., the equity curve for the combination of markets) will be plotted with a slightly thicker line, which is blue for training data and either green or red for test data depending on whether the test results are profitable (green) or not (red). There will also be a separate curve plotted for each individual market, which plots the equity over only the trades from that market. A color-coded key consisting of the symbol names for each market is drawn in the lower right part of the plot to help identify which curve corresponds to which market.

A vertical line is drawn on the chart to divide the test part of the equity curve from the training part. The line is drawn in green if the test results are profitable or red if they’re not.

If stress testing is applied, a separate equity curve will be shown for each stress test, and each curve will be drawn in a different color. The equity curve for the original data will be plotted with a slightly thicker line. If stress testing is applied to a portfolio, only the portfolio equity curve will be shown for each stress test.

The equity curve can be copied to the clipboard by right-clicking and selecting **Copy Equity Curve** from the popup (context) menu or by selecting **Equity Curve** from the Clipboard menu.

Trade List Table

The Trade List table displays the trade-by-trade results for the selected strategy. To view the trade list for a different strategy of the population, select the strategy in the Build Results table. The trade list table includes the following fields: symbol, entry date, signal price, entry price, entry signal name, exit date, signal price, exit price, exit signal name, stop price, direction, quantity, profit/loss, costs, net profit/loss, risk and equity.

Entries and exits have both a signal price and the price at which the simulated trade was filled (i.e., Entry Price and Exit Price). The signal price is the price calculated by the strategy and will often be different than the fill price because of where the next bar opened. For

entries using stop or limit orders, the signal prices are given by the code variables EntPrL and EntPrS for long and short trades, respectively. For entries at market, the signal price will be the close of the bar on which the order was generated. For exits, the signal price may be a stop price (code variables LStop, SStop), target price (code variables TargPrL, TargPrS), or market price. For exits at market, the signal price will be the close of the bar on which the order was generated. The entry and exit signal names are as shown below in the table.

Order Type	**Signal Name in Trade List Table**
Enter at Market	Market
Enter on Stop (Breakout)	Stop
Enter at Limit	Limit
Exit at Target ($)	Fixed Target
Exit at Target (%)	Percent Target
Exit at Target (Price)	Price Target
Trailing Stop ($ Floor)	Trail $
Trailing Stop (ATR Floor)	Trail ATR
Protective Stop ($)	Fixed Stop
Protective Stop (%)	Percent Stop
Protective Stop (Price)	Price Stop
Exit After N Bars	N Bars
Exit After N Bars Profit	Bars Profit
Exit After N Bars Loss	Bars Loss
Exit After Time	Time
Exit at Market	Market
Exit End-of-Day	End-of-Day

The stop price field will read “NA” if there was no money management (protective) stop for that trade. The direction field is either “Short” or “Long”. Quantity is the number of shares or contracts that were traded. The profit/loss field is the closed trade profit or loss before costs, which are the total costs for the position. The net profit/loss is the profit/loss amount after costs. The risk is the potential loss per share or contract based on the protective stop, if any, and includes costs. The equity field displays the cumulative closed trade equity, as shown in the equity curve plot. Note that a trade that enters during the training period but exits in the test period will be listed in the test section of the list (or vice-versa if the training and test periods are reversed). For any trade that did not exit before the end of the trading period, the word "open" will be displayed in the Exit Price column. Open trades are not included in the calculations shown in the Performance Report.

Training results in the trade list table are shown against a white background, with profitable trades written in green text and unprofitable trades in red text. The test trades are written in black text with a colored background. The background is green if the test trade is profitable or red if the test trade is unprofitable.

The trade list table can be copied to a spreadsheet by right-clicking on the table and selecting **Copy** or by selecting **Trade List** from the Clipboard menu. Open a blank spreadsheet page and select **Paste** to insert the table results into the spreadsheet. To save the table contents to a comma-delimited text file (.csv file), right-click and select **Save to file**. This file is formatted so that it can be read by **Market System Analyzer (MSA)** position sizing software as a trades file. In MSA, select the WriteTrades format when selecting the file under Data Source or when importing the file.

To save the trades directly to a MSA (extension .msa) file, right-click and select **Save to MSA file**. The program will prompt you to enter a name for the MSA file as well as a name for the text file to which the trades will be saved. The resulting .msa file can be opened

directly by MSA version 3.3 or higher and will include all current Builder settings that are applicable to MSA. If more than one market was used in the build process, the point value and trading costs stored in the MSA file will be the ones for the currently selected market.

Chapter 7
Usage Topics

The basic steps to using Adaptrade Builder were outlined in the Quick Start Steps section in Chapter 2 (Getting Started). This chapter delves into various topics related to using Builder, including an explanation of stress testing and Monte Carlo analysis, a discussion of out-of-sample performance, factors that affect the build time and how to reduce it, considerations for after you've built a strategy, common questions, and various tips and hints for strategy building.

Stress Testing and Monte Carlo Analysis

Testing a trading strategy for robustness is often referred to as sensitivity analysis or **stress testing**. The basic idea is to see what happens when small changes are made to the strategy inputs, price data, or other elements of the strategy or the trading environment. A robust strategy exhibits a proportional and relatively muted reaction to such changes, whereas a strategy that is not robust will react disproportionally and sometimes fail outright when small changes are made to its inputs or environment.

Why is This Important?

Strategy robustness is important because the markets never stay the same. Consider the strategy inputs, for example. Inputs such as the look-back length for a moving average might be optimal over the back-test period, but going forward, different values might be optimal. How will the strategy perform when the inputs are no longer optimal? One way to answer that is to see how the results change when the input values are changed.

Robustness is related to strategy over-fitting. The strategy should not have been fit so tightly to the market during the development process that it can't withstand any changes to the market. Generally speaking, to test for over-fitting, the market can be changed, the strategy can be changed, or both can be changed. A strategy that does not stand up well to relatively small changes is not robust and is likely to be over-fit. Such a strategy should not be expected to do well in the future.

Types of Stress Testing

There are many different ways that a strategy can be stress tested. Changes can be made to the strategy itself or to the price data on which it's back-tested. The trading costs, such as the amount of slippage, can be changed or the position sizing can be changed. In principle, anything that affects the strategy back-testing results can be varied. In Builder, the following three types of stress testing are available (see Stress Testing the Build Settings chapter):

1. Changing the strategy inputs.
2. Changing individual prices.
3. Changing the starting bar.

The rationale for changing the strategy inputs was discussed above. Two settings are available to randomly change the input values. One is the probability of changing an input. For example, if the probability is 10%, that means there's a 10% chance that an input will be changed. The second setting is the maximum percentage change that will be applied to an input that is being changed. The actual amount of the change is randomly chosen between -

Max and +Max, where Max is the maximum percentage change and might be on the order of 5% or 10%. This percentage is applied to the range of values for each input. For example, if the look-back length for an indicator is selected from the range of values from 1 to 100, then the range would be 100. If the Max value is 10, the randomly chosen change percentage might be, say, -3%, which means a value of -3 (i.e., -3% of 100) would then be added to the original input value to obtain the changed input value.

One way that a strategy can be over-fit, and therefore not robust, is if it's fit too closely to specific prices in the back-test. For example, if the strategy enters long on a stop and several large, profitable trades enter at the high price of the day, that should raise a red flag. What would the results look like if the high had been one tick lower on those days? If such a small change would ruin the results, the strategy is clearly not robust. A stress-testing technique to detect that kind of over-fitting is to make random changes to individual prices and evaluate the results.

Two settings are available to randomly change the price data. One is the probability of changing a price. For example, if the probability is 50%, that means there's a 50% chance that a price -- open, high, low, close of each bar -- will be changed. The second setting is the maximum percentage change that will be applied to a price that is being changed. As with the input values, the actual amount of the change is randomly chosen between -Max and +Max, where Max is the maximum percentage price change. The value of Max is taken as a percentage of the average true range over the past 100 bars. For example, if the average true range is 10 points and the maximum percentage change is 20%, then the change amount is a randomly chosen number between -2 and +2 points. Let's say the actual number is -1.25 points, and the closing price is 1250.50. The modified close would then be 1249.25. Finally, it's possible that changing a price will invalidate the normal price ordering, such as reducing the open so that it's below the low. To prevent that, the prices will be adjusted if necessary after making the change to keep the open and close within the high/low range.

The last available stress testing method involves changing the starting bar. It's probably obvious that a good strategy should not fall apart when you start the back-test on a different bar. It might be less obvious how this can happen. Consider a hypothetical strategy that enters long on a moving average crossover. It then holds the trade exactly five bars before exiting at market. Putting aside the suitability of the logic, imagine what the trade history might look like on a price chart. If the moving average entry condition uses a short-term average crossing above a long-term average, it's entirely possible that in a sustained up-trend, the entry condition could be true for a long period of time; i.e., the short-term average might be higher than the long-term average for many bars in a row.

If the back-test were started during that period, the first trade would enter on the next bar after the starting bar, and each trade would last five bars, followed immediately by the next entry, and so on. Now consider what would happen if the starting bar were changed. If the starting bar were one bar later, for example, the whole series of trades would be shifted one bar to the right. It's entirely possible that some of those series of five-bar trades would be much more profitable than others, depending on how the trades aligned with any underlying five-bar trend cycle that existed. So, depending on the starting bar, the strategy might be highly profitable or unprofitable because of where the trades started and ended. It might not be obvious during development that the strategy logic had this type of dependency on the starting bar, particularly for more complex types of logic.

To test for the effect of the starting bar, the bar on which the strategy back-test is started can be varied by a random number chosen between 1 and N. For example, if N is chosen to be 300, the starting bar will be varied by adding a randomly chosen number between 1 and 300 to the original starting bar number.

Monte Carlo Analysis

Varying the inputs, prices, and/or the starting bar by a random amount only provides one alternative to compare against the original results. To get a more complete picture of how robust a strategy is, the process can be repeated many times to create a distribution of results. Generally speaking, varying the input variables randomly over a large number of iterations in order to generate a statistical distribution of results for the function that depends on those inputs is called Monte Carlo analysis.

In this case, the function is the trading strategy and the function inputs are the strategy inputs, market prices, and/or the starting bar. By repeating the stress test many times, multiple sets of trading results are generated. To understand how the Monte Carlo process works, consider the equity curve shown below.

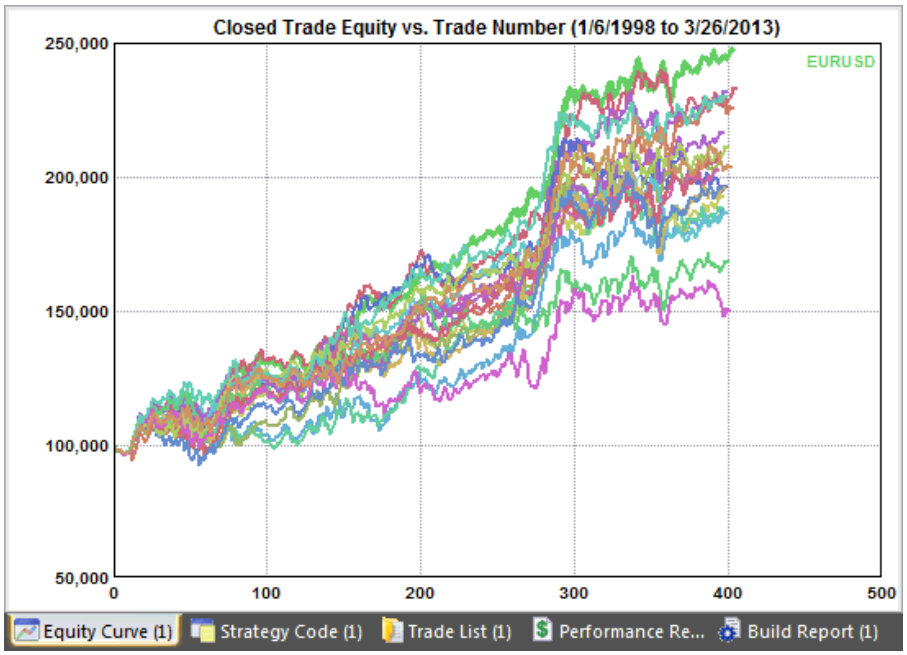


Figure 7.1. Stress test results based on Monte Carlo analysis.

Each equity curve depicted in the figure corresponds to a separate stress test. Along with the original curve, shown as the thicker green line, there are a total of 20 sets of results. The total net profit corresponding to each equity curve is as follows:

147855.00
133286.00
87771.00
92707.00
132149.00
88384.00
126019.00
96581.00
105466.00
102946.00
86753.00
96127.00
116611.00

68459.00
109427.00
96242.00
111020.00
50201.00
130076.00
104181.00

The highest value, $147,855, corresponds to the original file of price data. The lowest value is $50,201. The Monte Carlo analysis can be used to estimate the likely net profit with a specified degree of confidence given the variety of results. A confidence level of 95% is typical, which means there would be a 5% chance of the net profit being lower than the estimated value. To obtain the value of net profit at 95% confidence, the list above is sorted from highest to lowest, and the value 95% of the way down the list is selected. Since there are 20 items in the list, the 19th item in the sorted list is selected, which would be a net profit of $68,459; i.e., the second lowest value in the list.

This result can be interpreted as follows: if the randomization of the price data is representative of the kind of random differences expected in the market, then 95% of the time, the net profit can be expected to be at least $68,459.

Builder applies the same approach to all performance metrics tracked by the program. If the metric is one where a lower value is better, such as maximum drawdown, the value is selected 95% of the way up the list.

In summary, stress tests measure how robust a trading strategy is, which is an indication of whether or not the strategy is over-fit. The stress test results are analyzed using Monte Carlo analysis, which makes it possible to quantify the results and provides an estimate of performance that is generally more conservative (i.e., less favorable) than the back-test results based on the original data.

It's also possible to apply stress testing in Builder as part of the strategy development process. Instead of using the performance obtained from back-testing the strategies on the original data, the Monte Carlo results at 95% confidence from the stress tests can be used when evolving the strategies. The top strategies in the population will be the ones with the best Monte Carlo results, which will tend to drive the population towards robust strategies. The downside is that if each Monte Carlo analysis is based on N simulations, the build process will take N times as long using this approach.

Along with out-of-sample testing and other methods discussed in this guide, stress testing provides another tool to help identify robust trading strategies and avoid over-fitting. If applied as part of the strategy building and/or evaluation process, stress testing may help weed out strategies that are overly sensitive to changes in the trading environment, which could help avoid losses and increase the likelihood of success.

Out-of-Sample Performance

Genetic Programming (GP) is a type of optimization, similar to but generalized and more complex than the simple strategy input optimization that most systematic traders are probably familiar with. When a strategy is developed based on GP, the optimization process fits the strategy to the data used to develop it. The question is whether the strategy will perform well on data not used in the development, such as in real-time trading. Data not used in the development is referred to as out-of-sample data. Clearly, we want good performance

on out-of-sample data. This section discusses the factors that affect out-of-sample performance and what can be done to improve it.

Poor out-of-sample performance can be due to several factors. In a program like Builder, which uses a sophisticated search process to find the best strategies, the results are biased by the fact that the search process selects the best results out of all strategies generated. This introduces the so-called *data mining bias*. Builder includes a suitable test of statistical significance to detect this and determine if the strategies are in fact unduly biased in this way. If they are, a strategy that appears to generate good results may be benefitting mostly from good luck (technically, from random, sampling error), which suggests that it won't be likely to hold up well out-of-sample. This test was discussed in Evaluation Options in the Build Settings chapter.

Another factor that can degrade out-of-sample performance is *over-fitting*, which refers in this case to the problem of optimizing a strategy so that it fits the training data well but doesn't generalize well to the out-of-sample segment. Any part of the data that can be traded profitably can be considered the *signal*, while everything else can be considered *noise*. Over-fitting is fitting the noise, rather than the signal.

There are two general approaches to dealing with over-fitting. One approach is to detect over-fitting after-the-fact and discard any strategies that are over-fit. The other is to take steps to avoid developing over-fit strategies in the first place. The previous section discussed using stress testing to avoid over-fitting by building based on the Monte Carlo results of stress testing. It was also discussed how stress testing can be used after-the-fact to assess strategies for over-fitting.

Another approach to avoid over-fitting is provided via the Build Failure Rules and Build Termination Options on the GP Settings window of the Build menu. Typically, optimization is performed over one segment of data, called the training or in-sample segment, and tested on a separate segment of data, called the validation or out-of-sample segment. A third segment can also be added. In this case, the training segment comprises the data used to build the strategies. The second segment, known as the test segment, is used to monitor the build process and minimize over-fitting. Any remaining data can be used for validation; that is, out-of-sample testing.

The Build Failure Rules and Build Termination Options help avoid over-fitting by allowing you to define rules that stop or reset the build process when the results on the test segment start to decline. If the performance on the training segment continues to improve as the build process progresses, but the results on the test segment start to level off or decline, it suggests that the strategies are being over-fit. In other words, they're fitting the data used to develop them better but are not generalizing well to other (i.e., test) data. These rules can be used to detect this situation and either reset the build or terminate it.

Another way to avoid over-fitting is to guide the build process towards better quality strategies by targeting metrics related to over-fitting and general strategy quality. One factor is the so-called *number of degrees-of-freedom*. The number of degrees-of-freedom, which is equal to the number of trades minus the number of rules and conditions of the strategy, is related to how tightly the strategy fits the data. Provided inputs are added for each parameter in the strategy, the number of strategy inputs can be used as a proxy for the number of rules and conditions. For example, if a strategy has 100 trades and 10 inputs, it has 90 degrees-of-freedom. The more degrees-of-freedom, the less likely it is that the strategy will be over-fit to the market and the more likely it is that it will have good out-of-sample performance.

The number of degrees-of-freedom can be increased during the build process by adding requirements for the number of trades and/or the strategy complexity. All other things being equal, adding a build condition for the number of trades will result in strategies with more trades and therefore more degrees-of-freedom. Likewise, adding a build condition for the complexity metric will result in strategies with fewer inputs, which will also increase the number of degrees-of-freedom.

The degrees-of-freedom can also be targeted indirectly via the Significance metric (not to be confused with the statistical significance test discussed above). The Significance metric is based on the Student's t test applied to the average trade. The *t* test is based on the number of degrees-of-freedom but is a more complete measure of strategy quality than the number of degrees-of-freedom alone. One way, then, to reduce the likelihood of over-fitting is to use the significance metric to generate strategies that have a high Significance, such as greater than 95%.

Another measure of strategy quality is consistent results across different periods. One way to measure this is with the correlation coefficient of the equity curve, which measures how closely the equity curve approximates a straight line. If the equity curve is a straight line, it implies that the performance is uniform over all segments of the data. Obviously, this is desirable if the goal is to achieve good performance over as many different types of market conditions as possible. The correlation coefficient for the strategies generated by Builder can be increased by adding this metric as a condition and requiring a high value, such as 0.95.

Another factor affecting strategy quality is the variety of market conditions in the training segment. Generally speaking, it's better to optimize over data that includes a wide variety of market conditions, such as up trending and down trending markets, periods of consolidation, high and low volatility, etc. The more variety in the training segment, the more likely it is that the strategy will perform well on other data, including out-of-sample data and in real-time trading. While this doesn't necessarily relate to over-fitting -- you could still fit the noise in each of the different market conditions -- a strategy that is trained on a wide variety of market conditions and is not over-fit has a better chance of generalizing well to new data than a strategy that was trained on only one set of market conditions.

Unfortunately, there will be cases where even with good performance metrics, a wide variety of market conditions in the training segment, and no evidence of over-fitting, the out-of-sample performance will be poor. This can happen for several reasons. First, the strategy might be *under-fit*. While over-fitting is probably more common, it's possible that the strategy might not be complex enough to capture the underlying market dynamics. This would usually show up as poor performance in the training segment, which would result in rejected strategies. However, there may be cases where the market dynamics extend into the out-of-sample segment and are not captured by the training data. An analogy would be fitting a straight line to a scatter plot that appears to be linear based on the first half of the data but can be seen to be curving upward when all the data are seen together. Secondly, the market dynamics on which the strategy logic is based (i.e., the signal) may have changed in the out-of-sample segment enough to negatively impact performance. This is sometimes due to a fundamental change in the market, such as the switch from floor-based to electronic trading. However, more subtle changes, often related to the trading patterns of market participants, are also possible, particularly for shorter-term trading.

If this appears to be the problem, the solution may be as simple as rebuilding the strategy with new trading logic. Another possible solution is to re-optimize the strategy inputs without rebuilding the strategy, including the most recent data in the optimization. Then test the new strategy inputs out-of-sample by tracking the performance in real-time. In most cases, a strategy that has a large number of trades, a high significance value and good

performance on the training segment will continue to perform well for some period of time post-optimization. The next question is how long it will continue to perform before requiring re-optimization or rebuilding. This issue is discussed below in the section Post-Build Testing and Optimization.

Build Time

The GP algorithm is very computationally intensive. There are several factors that can affect the time it takes to build and evaluate a strategy:

- Length of the price data file. A file of 10 years of daily data for the EURUSD currency is about 138k in size. One year of 5 min data for the E-mini S&P is ten times as large. The build time is proportional to the file size, so a file that is 10 times as large will generally take about 10 times as long to process.
- Population size and number of generations. These parameters determine how many strategy simulations are performed. One simulation is performed for each member of the population for each generation.
- Tree depth. This setting determines in part the complexity of the entry conditions for the strategies. Strategies that are more complex take longer to evaluate.
- Long/short symmetry. If the short side is the mirror image of the long side, Builder can save time both in building the strategy and evaluating it. Strategies in which the long and short sides are different are more complex and take longer to build.
- Number of trades. Strategies with a large number of trades take longer to evaluate. One factor that can result in an unusually large number of trades is not specifying adequate trading costs. With zero or small trading costs, a large number of very short-term trades with very small or even zero profit/loss values will not negatively impact the fitness. For example, with zero trading costs, a top strategy could have thousands of trades that enter and exit at the same price, resulting in zero profit/loss with no impact on the strategy's fitness. To avoid this, always specify a reasonable value for the trading costs and/or select the option to use the bid/ask spread to determine fills on the Evaluation menu.
- Hardware and software considerations. Obviously the build process will run faster on a faster processor. The build algorithm is a parallel processing algorithm that takes advantage of multi-core processors. The more cores the better. It’s also the case that if multiple programs are running together on the same computer at the same time as Builder, fewer processor cycles will be available for Builder, and the build process will take longer.

Depending on these factors, the build process may take anywhere from several minutes to several hours or longer. If the build process seems to be taking too long, it can be cancelled and restarted at a later time. To restart the build process later, make sure to save the current results before exiting the program by selecting Save Project from the File menu. Upon opening the file, uncheck the Reset on Build box (GP Settings, Build menu). This will instruct the program to initialize the population using the saved strategies from the prior session. Builder saves the top number of strategies specified on the GP Settings window. To restart the build process exactly where you left off, the number of saved strategies should be set to the population size prior to the initial build. That way, Builder will save the entire population for the last completed generation. Note that at least one generation must be completed for the results to be saved.

Post-Build Testing and Optimization

As discussed above, genetic programming (GP) is an optimization process. As such, it’s important to perform validation (out-of-sample) testing on any strategy generated by the program that you intend to trade. If the Build Failure Rules and Build Termination Options are not used, the test segment will be out-of-sample, and Builder will perform the out-of-

sample testing calculations automatically. All you need to do is decide how much data to use for training and how much to use for the test segment. As mentioned elsewhere, a good ratio of training to test data is often between three and five to one. For example, setting the slider control on the Build/Eval Process window to 80% training is often reasonable.

If either the Build Failure Rules or Build Termination Options are used, the test segment will not be out-of-sample. In this case, additional data should be set aside for validation testing. If this extra data is part of the price data file, it will be shown on the Build/Eval Process window as "Reserved". To perform a validation test after building, use the Date Range controls to include this reserved data. Then click the Evaluate button on the Evaluation menu to evaluate the strategy. The results will include the reserved/validation data. Review the results to confirm that the strategy's performance held up on the new data.

Keep in mind that the most unbiased form of out-of-sample testing is real-time tracking, in which you follow the strategy for some period of time following the optimization and record the performance as new price data are generated in real time. This could either be done in Builder by loading new price data, or you could track the strategy directly in the trading platform.

Another approach that some traders may prefer is to load a different price series into Builder and test the strategy on that file. This can easily be done by adding another market to the table on the Build/Eval Process window. After adding the new market, select the strategy to evaluate and select Evaluate from the Evaluation menu. For example, you might want to build a strategy for wheat futures then test it on corn futures. Similarly, you could build a strategy on the SPY ETF then test the strategy on various large-cap stocks. Keep in mind, however, that this approach is more demanding of your strategy and may not always produce acceptable results. The suggestions in the previous section can be used to help generate more robust strategies that may have a greater likelihood of performing well on multiple markets.

In addition to out-of-sample testing, the strategies generated by Builder can be optimized in the traditional way; i.e., parameter optimization. As noted above, an input has been added for each parameter in the strategy. These inputs are assigned values during the GP process and are modified by the mutation operator, but in some cases, further improvement may result from optimizing these inputs separately. This can be done in TradeStation using the built-in genetic optimizer of TS 8.5 or later. To set the range for each input, refer to the settings in the Parameter Ranges window on the Build menu in Builder. For example, if an input represents a multiple of the average true range, you can use the range of values under ATR Multiple in the Parameter Ranges window. Likewise, if an input is a look-back length for a price pattern, you can use the range of values under Lookback, Price Patterns. As with GP, any results generated from optimizing the strategy inputs should be tested out-of-sample.

The other important issue regarding post-build testing and optimization is monitoring the strategy during real-time trading and re-optimizing or rebuilding if necessary. As discussed in the section on out-of-sample performance, market dynamics can change in such a way that the strategy logic may no longer work. This will tend to happen more frequently for strategies that are optimized over shorter time periods. However, performance can start to decline at any time for any strategy, regardless of its back-tested performance or how long it has been used successfully in real time trading. This is simply one of the risks of trading.

To address this risk, the performance can be monitored over the most recent trade history and compared to the long-term average performance of the strategy. This approach is sometimes referred to as *statistical process control*, which is a method used in manufacturing to make sure the manufacturing processes stay within prescribed error limits. In the context of trading, you might, for example, calculate the percentage of winning trades for the most

recent 30 trades and compare this to the percentage for the entire trade history. If the percentage for the most recent period deviates from the long-term average by more than two or three standard deviations, the strategy can be rebuilt or re-optimized. Any performance metric could be used for this calculation, including the average trade, profit factor, and so on.

If a strategy starts to show declining performance, it might be possible to re-optimize the inputs in TradeStation rather than rebuilding in Builder. If that doesn't work, a new strategy can always be built in Builder.

Common Questions

In some cases, the results displayed by Builder in the Strategy View don't match the results I get when I run the strategy in my trading platform. What's wrong?
There are several possible explanations. One possibility is that the date ranges of the price series are different between Builder and the trading platform. It's also important to set the "Maximum number of bars study will reference" in TradeStation (Format Strategies, Properties for All) to the MaxBarsBack value listed in the Build Results table. In MultiCharts, the value is entered under Format Signal, Properties ("Maximum number of bars study will reference"). This will insure that the calculations start on the correct bar. This is not necessary in AmiBroker since the code itself contains the MaxBarsBack setting.

MetaTrader automatically starts the indicator calculations so that the first bar of trading is on the first day you specify. This means you don't need to enter a "max bars back" value. However, it also makes it difficult to align the starting date in Builder with that of MetaTrader. Sometimes, the bar on which the calculations start can make a substantial difference. For example, if trading starts two bars earlier in MetaTrader than in Builder and each trade lasts exactly five bars, each trade could be starting and ending two bars earlier in MetaTrader, which could significantly affect the results.

Trading costs can also be a factor. Note that Builder deducts the trading costs once per trade, whereas TradeStation deducts costs once "per side". For example, if your trading costs are set to $25 in Builder, they should be set to $12.50 in TradeStation.

If you're re-using a strategy name in the strategy editor by pasting the strategy code over the code for an existing strategy, it will be necessary to reset the input values before running the back-test. Otherwise, the trading platform may be using the prior strategy's input values with the new strategy. In TradeStation, delete the strategy from the chart and re-insert it to reset the input values. In MetaTrader 4, reset the input values by clicking the Expert properties button on the Tester window and clicking the Reset button on the Inputs tab. In AmiBroker, click the Parameters icon on the Analysis window and click "Reset all".

MetaTrader 4 applies a minimum price distance to determine if an order can be placed. If a pending order (stop or limit) is too close to the market at the time it's placed, the order will be rejected. This is based on the idea that there won't be sufficient time to place the order before the market moves through the order price. Builder doesn't reject such orders, which can sometimes cause a discrepancy in back-testing between Builder and MetaTrader 4.

Another source of difference in MetaTrader involves the accumulation/distribution indicator. The values of this indicator depend on the bar on which the calculations start. In MetaTrader, while you can specify the starting and ending dates for the strategy, the indicators are evaluated starting at the beginning of the available data. This means that the accumulation/distribution values may be very different in MetaTrader than in Builder.

In TradeStation, another possible source of difference is how Builder and TradeStation use trading volume on intraday data. If your strategy uses volume in an indicator for either an entry or exit condition and your price data is intraday data, TradeStation may be using only the "up volume", rather than the total (up plus down) volume. On the Markets tab in Builder, there is an option on the Price File Format window (click on the Format button) to "Set the volume to the sum of up-tick and down-tick volumes." Try changing this option then re-evaluate the strategy using the Evaluate command on the Build menu.

For forex trading, one source of discrepancy is the so-called "roll over credit", which TradeStation calculates on foreign exchange trades. This is currently outside the scope of Builder. In most cases, these credits are small amounts that do not affect the overall results substantially.

Even with all the settings correct, there may be differences. Oftentimes, these result from rounding errors and other small differences that are unavoidable. For example, if an oscillator is compared to a fixed value, such as 80.0, using the less-than-of-equal (<=) operator, there may be a bar where the value calculates as exactly 80.0 in Builder but as 80.0000001 in TradeStation. This seemingly insignificant difference can result in a trade that is not taken in TradeStation but is taken in Builder. This could then affect subsequent trades because the presence or absence of a trade can either prevent or allow another trade to be taken. This is particularly true when entries are taken at market, especially when the entry condition is "true". Such strategies rely on the exit logic, so that if one trade is off by a bar, the next trade will be delayed by one bar, and so on. In this way, a small calculation difference can lead to entirely different results. One way to handle this possibility is to stress test strategies after building them. Strategies that do poorly under stress testing may be too "fragile" for real life trading.

When I tried to run a strategy in TradeStation, I got an error message "Tried to reference more bars than allowed by current Max bars back setting." In MultiCharts, the error is "Tried to reference back more bars than allowed by current MaxBarsBack setting."

The max bars back (MaxBarsBack) setting in TradeStation and MultiCharts refers to the number of bars required to start the calculations. You need to set this to the value listed in Builder in the results table under MaxBarsBack. The same value is also listed in the comment block at the top of the strategy code. In TradeStation, you enter the value under "Maximum number of bars study will reference" in Format Strategies, Properties for All. In MultiCharts, the value is entered under Format Signal, Properties ("Maximum number of bars study will reference"). This will insure that the calculations start on the correct bar.

I selected the exit end-of-day order type, but my trades don't exit at the end of day in real time trading. What can I do?

First, the exit end-of-day order type is only available in TradeStation and MultiCharts. For other code types, the "Exit after" option on the Strategy Logic window should be used to exit intraday strategies at the end of the day or at a specified time. For TradeStation and MultiCharts, the "Exit end-of-day" order type on the Order Types window in Builder causes the program to include the SetExitOnClose command in strategies. This command is mostly for back-testing purposes. In real time trading, it causes a market order to be generated on the close of the last bar of the current session. However, by the time the order is sent, the market has already closed, so the order is not filled. A work-around technique that some traders use is to define a custom session that ends a few minutes prior to the actual session close. Then the SetExitOnClose command will have time to exit your position prior to the end of the actual session. You just need to make sure to correctly set the session end time in Builder for the custom session, and, of course, the chart in TradeStation/MultiCharts has to use the same

custom session as in Builder in order to avoid discrepancies between the results in Builder and those in TradeStation/MultiCharts.

A simpler approach is to use the "Exit after" option on the Strategy Logic window. Set the time to at least one bar prior to the end of the session. That will trigger an exit prior to the end of the session.

I want my strategies to have smaller losses. How do I get tighter stops in Builder?
If the stops are too large, the easiest solution is to reduce the maximum stop size on the Parameter Ranges window. For ATR stops, you would want to reduce the size of the max ATR Multiple, which controls the range of values used to define the size of ATR stops. You can also set a target for the Max Loss metric. For example, if you want no more than 9 points loss on trades in the E-mini S&P, you can set a target for the Max Loss metric of $450 (i.e., 9 points x $50 per point). Alternatively, you can try including the Ave MAE (maximum adverse excursion) in the build goals. The Ave MAE is a measure of the intra-trade drawdown. There is also a Max MAE metric (maximum value of the MAE over all trades).

If the problem is that you're not getting protective stops in your strategies, you can include any selected exit type in all strategies. To include a protective stop, just select the protective stop in the "Include" column on the Order Types window.

Why do my trades exit past the time I set in the "Exit after" option?
The exit time option allows you to set an exit time for your trades. If, for example, you set the time to 3:00 pm, the strategy logic will be modified so that exits take place after this time. However, it's important to keep in mind that the time stamp on bars is typically the time the bar closes. For example, if you're using 30 minute bars, a bar time of 3:30 pm means the bar closes at 3:30. Since it's a 30 minute bar, that means it opens at 3:00 pm. The exit time option causes a trade to exit on the next bar's open if the time of the current bar is greater than or equal to the exit time. So if you've specified an exit time of 3:00 pm, the trade will exit on the open of the 3:30 pm bar (assuming 30 minute bars). The exit time will be listed as 3:30 pm because that's the time stamp on the bar, but the actual time will be a moment after 3:00 pm, which corresponds to the open of the 3:30 pm bar.

Also keep in mind that a trading strategy can only trade the bars of price data it has. If you're using 60 minute bars that end on even hours (e.g., 2:00 pm, 3:00 pm, 4:00 pm, etc.), and you specify an exit time of 3:15 pm, your trades will not end at 3:15 pm because there's no bar with that time. In this case, the trade would exit on the open of the 5:00 pm bar, which would be a moment after 4:00 pm.

If your data has been exported from MetaTrader 4, the bar time is the time the bar opens. However, the logic works the same way as described above, and the results should be the same for the same exit-time value.

I specified no more than three entries per day but get four. Why?
The option to limit the number of entries per day uses the EntriesToday function in EasyLanguage or the equivalent custom-provided function for MetaTrader 4. The strategy code checks to make sure the current value is less than the specified limit before placing the orders. However, it can still place two orders – one long and one short – if both entry conditions apply, either of which or both may be filled, depending on the market. That means you could get up to two entries if both are filled, which could result in as many as four entries for the day.

Why does Builder sometimes seem to replace my top population member during the build process?
The program never replaces the top strategy in the population. However, after new strategies are added, the top strategy may change, which means the top strategy from a prior generation may no longer be the stop strategy in the current generation. The strategy to replace at each step is chosen as the least fit member among a small number of randomly chosen members. The number of such members is given by the so-called tournament size, which can be changed on the GP Settings window. To decrease the likelihood that one of the top strategies might be replaced, you can increase the tournament size. The default size is 2. Increasing it to a high number is not recommended and may hurt the performance of the program.

Why are most of my final strategies the same?
If many or all of your final strategies are the same or similar, you probably need to reduce the number of generations. After a number of generations, the results will often tend to converge, resulting in duplicate strategies. This can also happen if insufficient variety is in the initial population. To get more variety in the initial population, either increase the population size or make sure that the build sets (indicator and order) have not been overly restricted by removing too many items. It may also be possible to increase diversity in the final set of strategies by increasing the mutation rate and decreasing the crossover rate.

How do you know when a strategy is broken and needs to be rebuilt or re-optimized?
Depending on the market, time frame, and other factors, it's always possible that a trading strategy will stop working at some point and need to be rebuilt or re-optimized. Please see the section Post-Build Testing and Optimization. One approach involves tracking the trailing performance characteristics of the strategy and rebuilding or re-optimizing when the results start to differ significantly from the long-term averages. A simpler approach is to track the equity curve and look for deviations from straight-line performance. If the strategy needs to be rebuilt, it's just as easy with Builder to create a new strategy as it was to develop the original one.

One point to keep in mind: if you try to re-optimize a strategy's parameter values before the strategy starts to underperform, there's no reason to think you'll get different results (assuming it's already optimized). It's only if the strategy has been underperforming that the optimization process is likely to find better parameter values than those you already found from the last optimization.

Does changing the settings in the middle of a build affect the build process?
No. Any changes made to the settings, such as build goals or strategy options, have no effect on an ongoing build. However, if you stop the build then restart it, any changes you've made will be picked up and used in the new build.

When I compile my MT4 strategy, I get warning messages about functions that have been deleted from the file. Is there something wrong?
No. Those messages can safely be ignored. The include file for MetaTrader 4 contains functions for all the different order types any strategy created by Builder might need. No single strategy will use all the different order types, so the MT4 compiler removes the functions for the order types that are not used. The warnings are simply telling you that those functions have been removed from the compiled strategy code. The functions have not been removed from the include file itself.

Why are some options not available when I select "AmiBroker" as the code type?
The AmiBroker Formula Language (AFL) makes it very easy to write simple strategies, provided they're consistent with the underlying design of AFL. However, more complex strategies can be very difficult, if not impossible, to construct. The degree of complexity

required by Builder-generated strategies makes it impractical to allow AFL strategies that include both long and short trades in the same strategy. Of course, you can generate separate populations for long-only and short-only strategies if you plan to trade both sides of the market. Because strategies can only be long-only or short-only in AmiBroker-generated Builder code, the option to "Wait for exit before entering new trades" is always checked. Unchecking it would only be useful for stop-and-reverse strategies containing both long and short trades.

Tips and Hints

The best way to become proficient at using Adaptrade Builder is to spend some time using it to build strategies. Don't expect that each and every build process will result in a strategy that meets your requirements. It's more likely that after the first run, you'll want to adjust some of the metrics and build again. Nonetheless, you'll soon find the combination of settings that generates the performance results you want.

The following tips and hints for building strategies with Adaptrade Builder may help you come up with better strategies in less time. Some of these suggestions were also mentioned in previous chapters.

Good strategy results for small intraday time intervals, such as 1 min or tick bars, over long time periods, such as several years, can be difficult to find and take multiple days to build. A better approach may be to build over a shorter time period and be prepared to rebuild the strategy every few months to keep up with changing market dynamics.

The option of removing indicators and/or order types from the build set is intended to allow users with specific preferences for or against specific strategy elements to restrict the build set to the desired elements. Removing too many items from the build set may reduce the likelihood of finding viable strategies.

The complexity weight can be used to "break ties" among strategies that give the same performance results with different numbers of inputs. Setting this weight to a relatively small value can help to keep the entry conditions from getting too verbose.

Whether or not you use the Significance metric, **a Significance value of at least 95% is generally desirable**. This implies adequate average trade size, low standard deviation of the trades, and a sufficient number of trades.

A correlation coefficient of at least 0.9 will help ensure that the performance is fairly uniform over the price history. Lower values often indicate extended flat or down periods.

If you'll be running the program overnight or while it's unmonitored for an extended period of time, consider using the "Performance Failure Rule" on the GP Settings window to reset the build process after every N generations so that the program will keep working if it doesn't find good results initially. Used in conjunction with the Top Strategies conditions, you can set up the program to save good strategies continuously.

The settings on the GP Settings window for Crossover Pct, Mutation Pct, Tree Depth, and Tournament Size can be considered advanced settings. The default values usually suffice. However, don't hesitate to experiment with other values.

Limiting the number of entries per day can often improve results for intraday strategies because it reduces the number of different market conditions that must be accommodated by a single strategy.

To get a feel for how difficult it will be to find viable strategies for your market, consider setting the number of generations to zero, and save the entire population. The GP process will stop after the initial population is randomly generated. You can then sort the results by net profit to see how many members of the initial population are profitable. The more profitable results you see from these randomly-generated members, the more likely it is that you'll get good results from the build process.

To maximize the chance of finding viable strategies, it's usually better to start with the most general set of strategy options and narrow the options only after finding a good solution. For example, start with the symmetry option unchecked (off), so that you can get different entry conditions and order types for long and short trades. Provided that works, try applying the symmetry option to simplify the logic if desired.

To find the simplest possible strategies, set the tree depth to zero. This will effectively remove the entry conditions, so that the only entry logic is in the entry orders themselves.

When choosing the build metrics, keep in mind that some metrics are related to each other. For example, the average trade size is related to the number of trades. If you use an objective for the average trade, you'll probably end up with fewer trades. Likewise, both drawdown and correlation coefficient are related to the straightness of the equity curve. Similarly, minimizing the average losing trade could tend to bias the results towards strategies with a small average trade (i.e., both wins and losses are smaller) or towards strategies with a higher profit factor.

The maximum adverse excursion (MAE) tells you how far trades go against you before they exit. Minimizing the Ave MAE or Max MAE may result in tighter stops. This can be a good build goal if you have trouble trading strategies that have large open losses, even if the trades usually exit profitably.

When setting the build metrics, it's usually best to start with a small number of metrics, such as three or four. The default selections are often a good starting point. After a few generations, review the results and add or remove metrics, change the weights, and add or remove conditions in order to correct any shortcomings you see in the reported results. An incremental approach usually works better than setting the build metrics once and letting the build process run for an extended period of time without intervention.

Chapter 8
Ribbon Menu

File Menu

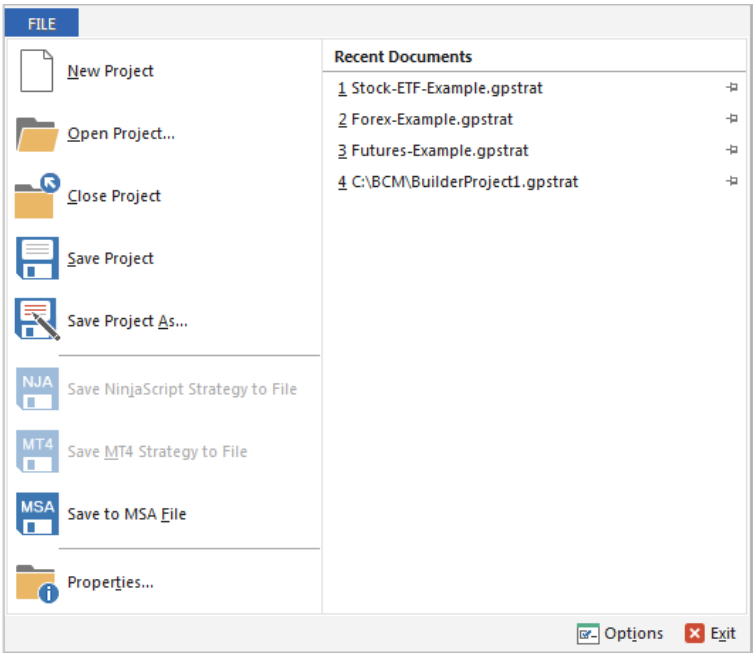


Figure 8.1. File menu commands.

The File menu is shown in Fig. 8.1. The file menu commands are listed below.

New Project	Creates a new project file.
Open Project	Opens an existing project file.
Close Project	Closes an open project file.
Save Project	Saves an opened project file using the same file name.
Save Project As	Saves an opened project file to a specified file name.
Save NinjaScript Strategy to File	Saves currently selected NinjaTrader strategy code to a file.
Save MT4 Strategy to File	Saves currently selected MetaTrader 4 strategy code to a file.
Save to MSA File	Saves trades and settings for currently selected strategy to a Market System Analyzer (MSA) file.
Properties	Display file properties.
Options	Use this command to customize the ribbon menu and the Quick Access Toolbar.
Exit	Exits Builder.

The Recent Documents list shows the 15 most recently opened project files. These project files can be opened by selecting them from the list.

If any command in the File menu is not applicable, the icon and associated text will be dimmed. For example, if no project file is open, the Close command will be dimmed. In Fig. 8.1, the commands for saving NinjaScript and MT4 strategies are dimmed because the selected strategy in the open project file is in EasyLanguage code. Most of the File menu commands will be dimmed while the build process is running.

New Project Command

Use this command to create a new project file in Builder. The new project will be blank, and all input settings will be set to their default values. If a project file is currently open, you will be prompted to save it if necessary before the new project file is initialized.

You can open an existing project file with the **Open Project** command.

Open Project Command

Use this command to open an existing project file. These documents have the file extension .gpstrat; e.g., MyBuilderFile.gpstrat.

You can create new project files with the **New Project** command.

File Open Window

The following options allow you to specify which file to open:

File Name

Specifies the file you want to open. This field lists files with the extension you select in the pull-down menu to the right of this field.

Files of Type

Specifies the type of file you want to open. Builder creates and opens files of type .gpstrat. You can also select “All Files” in this box, but only files of type .gpstrat can be opened.

Close Project Command

Use this command to close the project file. When you close a project file, Builder prompts you to save the document if it has any unsaved changes. After a project file is closed, it's necessary to open an existing project or create a new project before any further project work can be done in the program.

Save Project Command

Use this command to save the active project to its current file name and directory. When you save a document for the first time, Builder displays the **Save As window** so you can name your project file. If you want to change the name and directory of an existing document before you save it, choose the **Save Project As** command.

Save Project As Command

Use this command to save and name the active project. Builder displays the **Save As window** so you can name your document.

To save a project with its existing name and directory, use the **Save Project** command.

File Save As Window

The following options allow you to specify the name and location of the file you are about to save:

File Name

Specifies a file name to save a document with a different name. Builder adds the extension you specify under **Save As Type**.

Save NinjaScript Strategy to File Command

Use this command to save the currently selected NinjaTrader strategy code to a .cs file. The selected strategy must be in NinjaScript code format.

Save MT4 Strategy to File Command

Use this command to save the currently selected MetaTrader 4 strategy code to a .mq4 file. The selected strategy must be in MetaTrader 4 (MQL4) code format.

Save to MSA File Command

Use this command to save the trades and settings for the currently selected strategy code to a Market System Analyzer (MSA, extension .msa) file. Market System Analyzer (MSA) is position sizing and money management software for trading. Builder will prompt you to enter a name for the MSA file as well as a name for the text file to which the trades will be saved. The resulting .msa file can be opened directly by MSA version 3.3 or higher and will include all current Builder settings that are applicable to MSA. If more than one market was used in the build process, the point value and trading costs stored in the MSA file will be the ones for the currently selected market.

Properties Command

Use this command to display information about the currently open project file, including the file size and path, created and modified dates, date of last build, and the list of price files associated with the project, as in Fig. 8.2. The Builder File Version is the version of Builder that was last used to save the project file, which can be opened with that version or later of Adaptrade Builder. The Project Notes box allows you to enter notes describing the project.

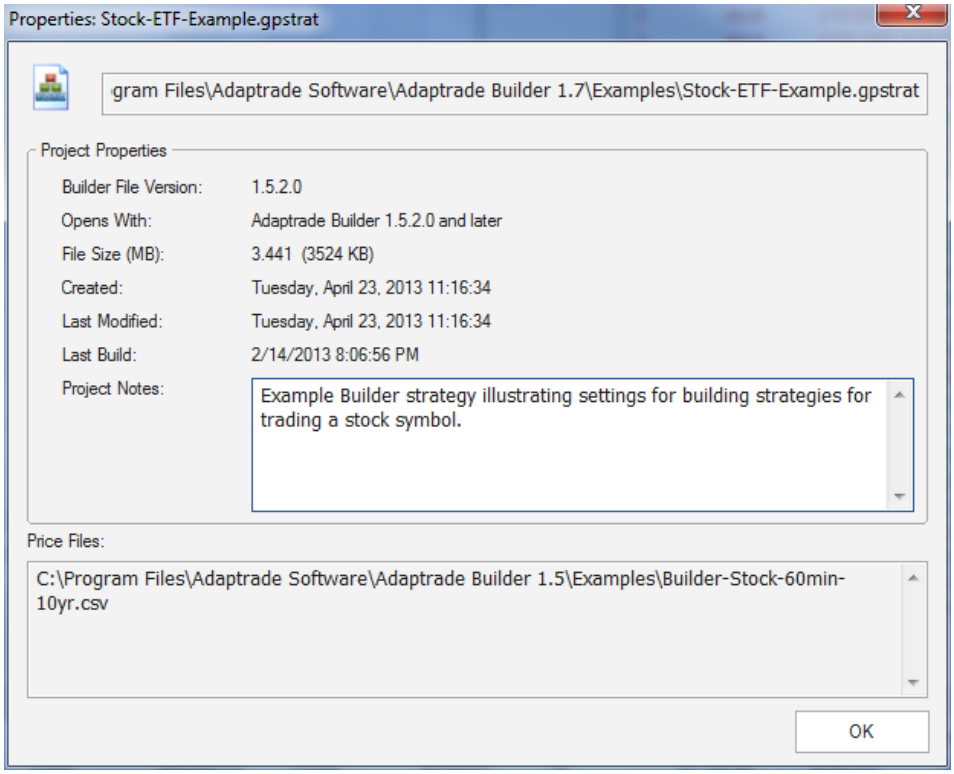


Figure 8.2. File Properties window.

Options Command

Use this command to add, remove, or rearrange items on the ribbon menu and to add or remove item from the Quick Access Toolbar (QAT). The QAT is the row of small icons in the

upper left-hand corner of the title bar of the main frame window, above the ribbon. It is typically used to display icons for frequently used commands.

Exit Command

Use this command to end your Builder session. Builder prompts you to save the open document if it has unsaved changes.

Build Menu

The Build menu is shown in Fig. 2.9 in Quick Start Steps in the Getting Started chapter. The settings and options of the Build menu were discussed throughout the Build Settings chapter .

Evaluation Menu

The Evaluation menu is shown in Fig. 2.10 in Quick Start Steps in the Getting Started chapter. The settings and options of the Evaluation menu were discussed in the Evaluation Options section of the Build Settings chapter.

Position Sizing Menu

The Position Sizing menu is shown in Fig. 2.11 in Quick Start Steps in the Getting Started chapter. The settings and options of the Position Sizing menu were discussed in the Position Sizing Settings section of the Build Settings chapter.

View Menu

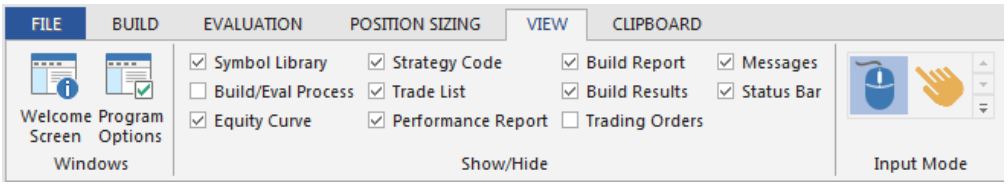


Figure 8.3. View menu of the ribbon.

The View menu, shown in Fig. 8.3, consists of three panels.

Windows Panel

The **Welcome Screen** button displays a window that contains information to help you get started using the program. The Welcome screen is normally displayed when the program starts up. Options on the Welcome screen include buttons to open example files, a button to open the Quick Start Steps help topic, and tips for using the program. To prevent the screen from being displayed when Builder starts up, click the box "Don't display this screen at startup".

Clicking any of the three buttons for Example Projects will open the corresponding project (.gpstrat) file and display accompanying text in the text box. If Builder was installed in a folder other than the default presented during installation, it will be necessary to select the location of the example projects. By default, the example projects are stored in the Examples folder in the installation folder for Builder. The default path is C:\Program Files\Adaptrade Software\Adaptrade Builder x.x\Examples, where x.x is the version number (e.g., 1.5).

Clicking the View Next Tip button will randomly display one of approximately 35 tips for using Builder.

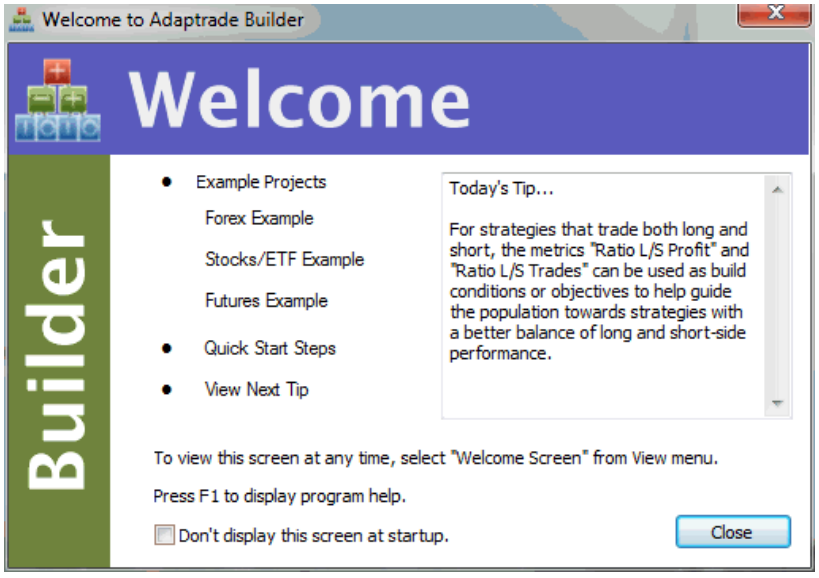


Figure 8.4. The Welcome screen displays instructional information.

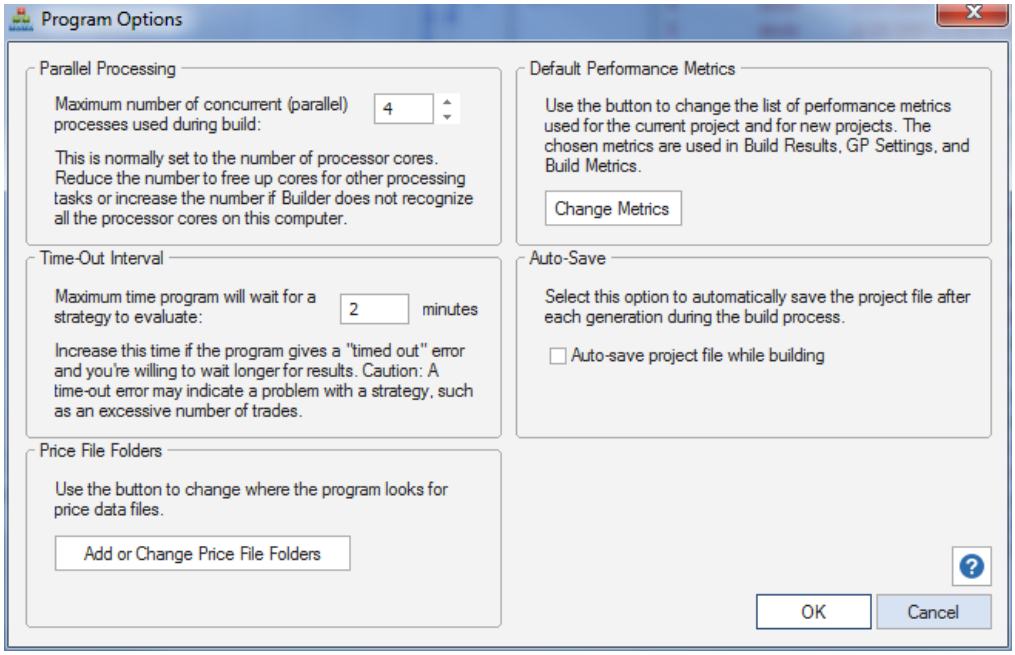


Figure 8.5. Program options are selected on the Program Options window.

The **Program Options** button opens the Program Options window, shown in Fig. 8.5, which allows the user to select program options. Options selected on this window are stored in the Windows registry and affect all project files.

There are currently five available program options. The first available option is the number of concurrent parallel processes used while building strategies. The default value is the number of available processor cores recognized by Builder. Set this to a lower number if you want to free up processing power for other programs running concurrently with Builder. Set this to a higher number if Builder has not recognized all the available cores on your computer, such as sometimes occurs with hyperthreaded processors.

The second option allows you to choose the set of performance metrics used with new projects. As explained in Build Metrics in the Build Settings chapter, the set of build metrics can be changed for any open project by right-clicking on the results table. The default set of build metrics, which is used for new projects, is selected here. Clicking the Change Metrics button opens the Change Performance Metrics window, as shown in Fig. 5.4. After modifying the list of selected metrics, click OK on the Program Options window to save the list in the Windows registry. The updated list will be used the next time a new project is created from the File menu.

The third option controls the length of the so-called time-out interval. This is the maximum length of time the program will spend to evaluate a single strategy before terminating the process and displaying an error message. The default value is 2.5 minutes. If it takes longer than this to evaluate a strategy, there may be a problem with the build settings. For example, there may be too many trades in the strategy. If a strategy has hundreds of thousands of trades, it can take more than a few minutes to evaluate. This sometimes happens if the trading costs have been set to zero. In this case, a strategy will not be penalized for a large number of trades with zero profit/loss. See Usage Topics, Build Time, for more on this topic.

The Auto-Save option, if selected, automatically saves the project (.gpstrat) file at each step during the build process. The project file is saved following population initialization and after each generation. The project file name must exist (i.e., the file must have been saved previously). A message is displayed in the Messages window during building to indicate that this option has been selected.

The Price File Folders option allows you to change where the program looks for price data files. Whenever a price data file is added to the Markets Symbols table on the Build/Eval Process window, the path to the selected file is stored in the list shown here. When Builder reads the price data file, it looks for the price data file in one of the folders in the list. To view or modify this list, click the button "Add or Change Price File Folders". This will open the window shown below in Fig. 8.6.

If Builder cannot find a price data file shown in the Markets Symbols table, either re-select the file on the Build/Eval Process window or select the file here using the Add Folder button. To remove a folder from the list, select the folder and click the Delete Folder button. When opening a price data file, Builder looks in the folders in the order they're listed in the Price File Folders window. Use the Move Up and Move Dn buttons to change the order of the folders if desired to put folders where your price data files are more commonly stored near the top of the list.

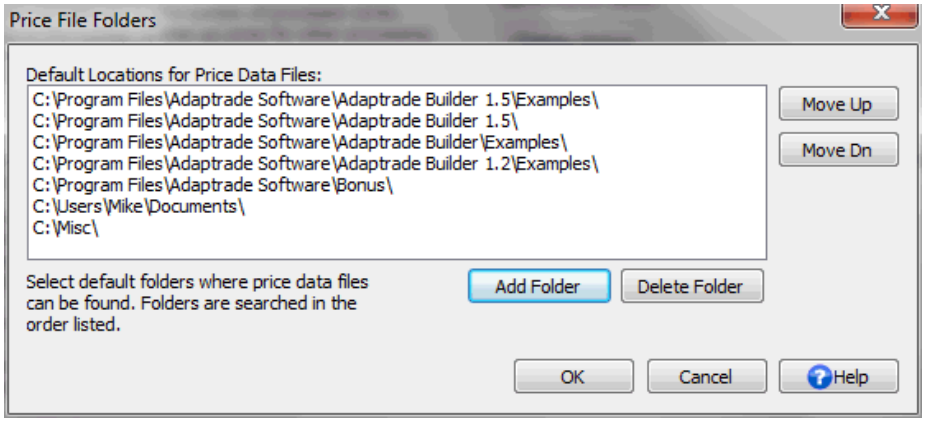


Figure 8.6. The Price File Folders window lists the folders where Builder will look for price data files.

Show/Hide Panel
The Show/Hide panel displays panes and windows in the program that can be optionally opened or closed. Aside from the **Status Bar**, discussed below, each of these windows has been described elsewhere in the documentation. Click the check box to show or hide the window. If the box is checked, the window will be shown. Unchecking the box hides the window.

The **status bar** is displayed at the bottom of the main window. The left area of the status bar describes actions of right-click (context or popup) menu items as you move the mouse over them. On the right side is a Memory Usage bar, which shows the percentage of the computer's total available memory that is currently in use. Move the mouse over the indicator bar to see the numeric value.

Input Mode Panel
The Input Mode panel allows you to switch between mouse input and touch input. Click the mouse icon for normal input via a computer mouse. To use Builder with a touch-screen display, click the hand icon, which will expand the layout format of the ribbon to make it easier to select elements on a touch-screen display.

Clipboard Menu

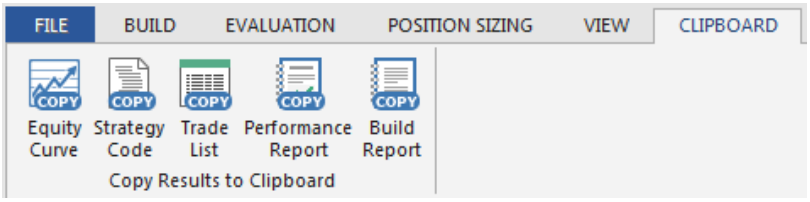


Figure 8.7. Clipboard menu of the ribbon.

The Clipboard menu, shown in Fig. 8.7, contains the following buttons to copy results for the currently selected strategy to the clipboard:

Equity Curve	Copy the equity curve as an image (bitmap) file to the clipboard.
Strategy Code	Copy the entire strategy code to the clipboard.
Trade List	Copy the list of trades from the Trade List window to the clipboard in tab-delimited format.
Performance Report	Copy the performance report to the clipboard in plain-text, tab-delimited format.
Build Report	Copy the build report to the clipboard in plain-text, tab-delimited format.

Ribbon Tab Buttons

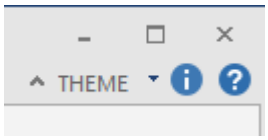


Figure 8.8. Ribbon tab buttons.

The ribbon tab buttons, shown in Fig. 8.8, are small buttons located in the upper right-hand corner of the ribbon. There are four ribbon tab buttons in Builder.

^ button	Minimizes or maximizes the ribbon menu to hide or show the contents of each menu.
Theme	Allows you to choose from among nine different user interface themes.
About Builder	Displays information about this application.
Help Topics	Offers you an index to topics on which you can get help.

Theme
Use this command to change the style of the menus, toolbars, and other visual elements of the user interface of the Builder program. To change the program style, select a theme from the popup menu. Once the theme has been changed, it will be stored locally, and the program will continue to use that theme until a new theme is selected.

About Builder
Use this command to display information about Adaptrade Builder, including the copyright notice, version number, recognized number of computer cores, and recognized amount of installed memory.

Help Topics
Use this command to display the table of contents for Help. From the table of contents, you can open various topics for using Adaptrade Builder, look up topics in the index, and perform word searches using Find. Press F1 at any time to open a help topic related to the selected command or active window. The help system contains the complete contents of this user's guide.

Appendix: Performance Metrics

The different performance metrics calculated by Builder are described below. These metrics are used on the Build Metrics window and are reported in the Build Results table and in the detailed Performance Report. The first name shown below for each metric is the label displayed in the detailed Performance Report, followed by the abbreviation in parentheses, which is used on the Build Metrics window and in the results table. Unless otherwise noted, metrics are calculated from the closed trades only.

Closed Trade Net Profit (Net Profit). The total net profit is the total profit (gross profit minus gross loss) for all closed trades, both wins and losses, in the trading period.

Gross Profit. The sum of the winning trades.

Gross Loss. The sum of the losing trades.

Profit Factor (Prof Fact). Gross profit divided by the absolute value of gross loss. Profit factors of 1.5 or more suggest a strong system.

Ratio L/S Net Profit (Ratio L/S Profit). Ratio of net profit for long trades to net profit for short trades.

Open Trade Profit/Loss (Open Profit). Net profit or loss for all trades that are open at the end of the trading period. There can be at most one open trade per market-system.

Total Net Profit (Total Net Profit). The total net profit is the total profit for all trades, both wins and losses, open and closed, in the trading period. This is the sum of the closed trade net profit and the open trade profit/loss.

Trading Period. Time span of trading, as selected on the Build/Eval Process window.

Starting Account Equity. Value of account equity at the start of trading.

Highest Equity (Equity High). The highest value of account equity on an intra-bar basis over the trading period.

Lowest Equity (Equity Low). The lowest value of account equity on an intra-bar basis over the trading period.

Final Account Equity (Final Equity). Value of account equity at the end of the trading period.

Return on Starting Equity (Account Return). Percentage change in account equity from the starting account equity to the final account equity.

Total Number of Trades (No. Trades). Total number of trades in the trading period.

Number of Winning Trades (No. Wins). Total number of trades with a profit/loss greater than zero.

Number of Losing Trades (No. Losses). Total number of trades with a profit/loss less than or equal to zero.

Trades Not Taken (No. Skipped). Total number of trades with a position size of zero.

Percent Profitable (Pct Wins). The number of winning trades expressed as a percentage of the number of trades with non-zero position size (i.e., excluding trades not taken).

Ratio L/S Number of Trades (Ratio L/S Trades). Ratio of the number of long trades to the number of short trades, excluding trades not taken.

Trades Per Year. Average number of trades per year, including open trades.

Trades Per Month. Average number of trades per month, including open trades.

Trades Per Week. Average number of trades per week, including open trades.

Trades Per Day. Average number of trades per day, including open trades.

Max Position Size (Max Shares). Largest number of shares or contracts for any one trade.

Minimum Position Size (Min Shares). Smallest number of shares or contracts of any trade, excluding trades with zero shares or contracts.

Average Position Size (Ave Shares). Average number of shares or contracts per trade, excluding trades with zero shares or contracts.

Largest Winning Trade (Max Win). Largest winning trade, where the winners are expressed in currency units (e.g., dollars).

Largest Winning Trade (%) (Max Win (%)). Largest winning trade, where each winner is expressed as a percentage of account equity at the time the trade was taken.

Average Winning Trade (Ave Win). Average of the winning trades, where the winners are expressed in currency units (e.g., dollars).

Average Winning Trade (%) (Ave Win (%)). Average of the winning trades, where each winner is expressed as a percentage of account equity at the time the trade was taken.

Average Bars in Wins (Ave Bars Wins). Average number of bars in winning trades.

Average Length of Wins (Ave Length, Wins). Average duration of winning trades in days, hours, minutes, seconds.

Max Number Consecutive Wins (Max Consec Wins). Largest number of winning trades in a row.

Average R-Multiple, Wins (Ave R-Mult, Wins). The R-multiple is the trade profit/loss divided by the risk of the trade, including trading costs. See Tharp, Van K. "Trade Your Way to Financial Freedom," 2nd ed., McGraw-Hill, New York, 2007. This metric is the average of the R-multiples for winning trades.

Largest Losing Trade (Max Loss). Largest losing trade, where the losses are expressed in currency units (e.g. dollars).

Largest Losing Trade (%) (Max Loss (%)). Largest losing trade, where each loss is expressed as a percentage of account equity at the time the trade was taken.

Average Losing Trade (Ave Loss). Average of the losing trades, where the losses are expressed in currency units (e.g. dollars).

Average Losing Trade (%) (Ave Loss (%)). Average of the losing trades, where each loss is expressed as a percentage of account equity at the time the trade was taken.

Average Bars in Losses (Ave Bars Loss). Average number of bars in losing trades.

Average Length of Losses (Ave Length, Losses). Average duration of losing trades in days, hours, minutes, seconds.

Max Number Consecutive Losses (Max Consec Losses). Largest number of losing trades in a row.

Average R-Multiple, Losses (Ave R-Mult, Losses). The R-multiple is the trade profit/loss divided by the risk of the trade, including trading costs. See Tharp, Van K. "Trade Your Way to Financial Freedom," 2nd ed., McGraw-Hill, New York, 2007. This metric is the average of the R-multiples for losing trades.

Average Trade (Expectation, Ave Trade). Sum of all trades, wins and losses, divided by the total number of trades, excluding trades with zero position size. When choosing the build metrics, keep in mind that the average trade is related to the number of trades. Setting a weight value for this metric will tend to result in strategies with a higher average trade and fewer trades.

Average Trade (%) (Ave Trade (%)). Average of all trades, where each trade is expressed as a percentage of account equity at the time the trade was taken.

Trade Standard Deviation (Trade Std Dev). Standard deviation of the trades, where the trades are expressed in currency units (e.g. dollars). The standard deviation is a measure of variability or dispersion. 68% of normally distributed values are within one standard deviation of the average. 99.7% are within three standard deviations of the average.

Trade Standard Deviation (%) (Trade Std Dev (%)). Standard deviation of the trades, where each trade is expressed as a percentage of account equity at the time the trade was taken.

Average Bars in Trades (Ave Bars). Average number of bars in all trades, both wins and losses. Consider setting a target and/or weight value for this metric if you want to limit the length of trades in the generated strategies.

Average MAE (Ave MAE). Average maximum adverse excursion. The maximum adverse excursion (MAE) is the worst-case intra-trade drawdown; i.e., the largest loss on an open trade. The Ave MAE is the average of the MAE's over all trades. Consider setting a target and/or weight value for this metric if you want to limit intra-trade drawdown in the generated strategies.

Average MAE (%) (Ave MAE (%)). Average maximum adverse excursion (MAE), where the adverse excursion is expressed as a percentage of equity. The Ave MAE (%) is the

average of the percentage MAE's over all trades. Consider setting a target and/or weight value for this metric if you want to limit intra-trade drawdown in the generated strategies.

Maximum MAE (Max MAE). Maximum value of the maximum adverse excursion (MAE). The Max MAE is the largest of the MAE's over all trades. Consider setting a target and/or weight value for this metric if you want to limit intra-trade drawdown in the generated strategies.

Maximum MAE (%) (Max MAE (%)). Maximum value of the maximum adverse excursion (MAE) in percent of equity. The Max MAE (%) is the largest of the percentage MAE's over all trades. Consider setting a target and/or weight value for this metric if you want to limit intra-trade drawdown in the generated strategies.

Win/Loss Ratio. Ratio of the average win to the absolute value of the average loss.

Win/Loss Ratio (%). Ratio of average winning trade to average losing trade, where each trade is expressed as a percentage of account equity at the time the trade was taken.

Return/Drawdown Ratio (Ret/DD Ratio). Ratio of the percentage account return to the worst-case percentage drawdown.

Sharpe Ratio. Average monthly return minus the risk-free interest rate, all divided by the standard deviation of the monthly returns. The risk-free interest rate is assumed to be zero. This is a classic measure of risk-adjusted return. Higher values are better.

Sortino Ratio Average monthly return minus the target return, all divided by the so-called downside deviation. The downside deviation is similar to the standard deviation except that positive deviations are set to zero, whereas in the standard deviation, both positive and negative deviations are included. The Sortino ratio is an alternative to the Sharpe ratio and is sometimes preferred because it doesn't penalize positive returns that exceed the target value. In Builder, the target rate of return is set to zero. The Sortino ratio is generally higher than the Sharpe ratio.

MAR Ratio Average annual compounded rate of return divided by the maximum historical percentage drawdown. The MAR ratio is often used to evaluate and compare hedge funds and commodity trading advisors (CTAs). MAR ratios between 0.5 and 1.0 over long histories are generally considered excellent.

Correlation Coefficient (Corr Coeff). Correlation coefficient of the equity curve. The correlation coefficient varies from -1 to +1, with values close to +1 indicating a straight, upward sloping curve. Values above 0.9 indicate a fairly straight equity curve and therefore less variation in returns over different periods. If position sizing is applied such that larger positions are taken as the account equity grows (antimartingale position sizing), then the correlation coefficient is applied to the logarithm of the equity curve.

Statistical Significance (Significance). Student's t-test applied to the average trade. This can be used as a measure of strategy quality. It takes into account the statistical properties of the distribution of trades and the number of degrees-of-freedom of the trading strategy. The number of degrees-of-freedom is the number of trades minus the number of inputs to the strategy. The more degrees-of-freedom, the better. A significance level of 95% or greater is generally desirable. Please refer to Evaluation Options in the Build Settings chapter for a discussion of the difference between this metric and the statistical significance test available on the Evaluation menu.

Complexity. In Builder, strategy complexity is defined as the number of strategy inputs. Builder includes an input for each adjustable parameter used in an entry rule, entry order, or exit order. The complexity is incremented by 2 to account for position sizing (1 for the method and 1 for the parameter value). The total number of inputs is a measure of the complexity of the system. Lower complexity implies a greater number of degrees-of-freedom and a lower likelihood of over-fitting.

In many cases, after some number of generations, the top results will tend to converge so that several strategies with different number of inputs will produce the same performance results. Setting the weight for complexity to a small value can be a way to "break ties" among these otherwise similar strategies based on the number of inputs. For example, you may find that the top 10 strategies have the same performance results but several of them have extra inputs. If the complexity is part of the fitness function, the strategies with the fewest inputs will be ranked higher.

Average Risk (Ave Risk). Average risk for all trades. The risk is the amount per contract or share that would be lost if the money management (protective) stop were hit, including trading costs.

Average Risk (%) (Ave Risk (%)). Average risk where the risk (see Ave Risk, above) is expressed as a percentage of account equity at the time the trade is taken.

Average R-Multiple (Ave R-Mult, Expectancy). The R-multiple is the trade profit/loss divided by the risk of the trade, including trading costs. See Tharp, Van K. "Trade Your Way to Financial Freedom," 2nd ed., McGraw-Hill, New York, 2007. This metric is the average of the R-multiples for all trades, both wins and losses. Tharp refers to this as the expectancy.

R-Mulitple Standard Deviation (R-Mult Std Dev). Standard deviation of R-multiples over all trades, both wins and losses.

Average Leverage (Ave Leverage). Average value of leverage over all positions. Leverage is defined as the position value divided by the account equity.

Maximum Leverage (Max Leverage). Largest value of leverage over all positions. Leverage is defined as the position value divided by the account equity.

Risk of Ruin. Probability of account depletion. See Vince, Ralph. "Portfolio Management Formulas," John Wiley & Sons, New York, 1990, p. 136, equation R3. The equation for risk of ruin assumes (1) unequal wins and losses, (2) a fixed number of contracts or shares per trade, and (3) ruin is defined as 100% account depletion.

Kelly f. The Kelly fraction (f) is typically used to calculate position size. However, here it's used as a measure of strategy quality. Expressed as a percentage, Kelly fractions greater than roughly 20% can be considered higher quality strategies.

Average Annual Profit/loss (Ave Annual P/L). Average of all yearly profits (losses), including partial years.

Ave Annual Compounded Return (Ave Annual Return). Average annual rate of return assuming annual compounding.

Average Monthly Profit/loss (Ave Monthly P/L). Average of all monthly profits (losses), including partial months.

Ave Monthly Compounded Return (Ave Monthly Return). Average monthly rate of return assuming monthly compounding.

Average Weekly Profit/loss (Ave Weekly P/L). Average of all weekly profits (losses), including partial weeks.

Ave Weekly Compounded Return (Ave Weekly Return). Average weekly rate of return assuming weekly compounding.

Average Daily Profit/loss (Ave Daily P/L). Average of all daily profits (losses).

Ave Daily Compounded Return (Ave Daily Return). Average daily rate of return assuming daily compounding.

In Builder, **drawdown** is defined as a decline from the highest prior peak in intra-bar equity. The drawdown is measured from the highest prior peak to the lowest intra-bar equity value. Because Builder does not have access to intra-bar price points other than the open, high, low, and close, the order of the high and low prices is assumed based on the bar shape. This assumption can affect the intra-bar equity and drawdown calculations, which are therefore approximate on an intra-bar basis.

Number of Drawdowns (No. Drawdowns). This is the total number of drawdowns over the trading period.

Average Drawdown (Ave Drawdown). Average value of the drawdowns expressed in currency units (e.g., dollars).

Average Drawdown (%) (Ave Drawdown (%)). Average value of the drawdowns expressed as percentage declines from the prior highest peak in equity.
Average Length of Drawdowns (Ave Length, Drawdowns). Average duration of drawdowns in days, hours, minutes, and/or seconds.

Average Trades in Drawdowns (Ave Trades, Drawdowns). Average number of trades from the start of a drawdown until the first trade that makes a new equity high.

Worst Case Drawdown (Drawdown). Largest drawdown, where the drawdowns are expressed in currency units (e.g., dollars).

Date at Trough (Date, Max Drawdown). The date at the lowest equity point during the worst-case drawdown.

Length of Drawdown (Length, Max Drawdown). Duration of worst-case drawdown, from the start of the drawdown to the trade that makes a new equity high.

Trades in Drawdown (Trades, Max Drawdown). The number of trades from the start of the worst-case drawdown until the trade the makes a new equity high.

Worst Case Drawdown (%) (Max Drawdown (%)). Largest value of the drawdowns expressed as percentage declines from the prior highest peak in equity.

Date at Trough (Date, Max % Drawdown). The date of the trade at the lowest equity point during the worst-case percentage drawdown.

Length of Drawdown (Length, Max % Drawdown). Duration of worst-case percentage drawdown, from the start of the drawdown to the trade that makes a new equity high.

Trades in Drawdown (Trades, Max % Drawdown). The number of trades from the start of the worst-case percentage drawdown until the trade that makes a new equity high.

Longest Drawdown. Duration of longest drawdown, from the first trade in the drawdown to the trade that makes a new equity high.

Start of Drawdown (Start, Longest Drawdown). Date at the start of the longest drawdown.

End of Drawdown (End, Longest Drawdown). Date at the end of the longest drawdown.

Percent of Equity (% of Equity, Longest Drawdown). Depth of longest drawdown, expressed as a percentage decline from the prior equity peak.

Longest Flat Period (Max Flat Period). Duration of longest period with no change in equity.

Appendix: Technical Indicators

Adaptrade Builder currently includes the indicators described below, which are also listed in Table 1 in Chapter 1. Subsequent versions of Builder may include other indictors as well. Most indicators include one or more inputs, such as the averaging length for a moving average. The values of these inputs are chosen by Builder during the build process from the range of values specified on the Parameter Ranges window.

Simple moving average

Simple moving average of price over past the most recent N bars, where N is an input. The simple moving average adds up the price over the past N bars and divides by N.

Exponential moving average

Exponential moving average (XMA) of price. The XMA is an exponentially weighted average of price. As additional prices are added, their contribution decreases exponentially as (1 - alpha)^N, where alpha = 2/(1 + N). Because more recent prices are weighted more heavily, the XMA is considered to be more responsive to price changes than the simple moving average.

Weighted moving average

Weighted moving average of price. The weighted average assigns more weight to recent prices. The weight value decreases by 1 starting with the current bar. Because more recent prices are weighted more heavily, the weighted average is considered to be more responsive to price changes than the simple moving average.

Triangular moving average[1,2]

Triangular moving average of price. The triangular moving average is the simple moving average of the simple moving average of price, where the length of the simple moving averages is one-half the specified length of the triangular moving average. Because the triangular moving average is a double-smoothed simple moving average, it weights the middle portion of the look-back period most heavily.

Adaptive variable moving average (Adapt Variable MA)

This is an extension of Tushar Chande VIDYA indicator, which is essentially an exponential moving average in which the smoothing constant (alpha) adapts to market volatility or trend strength. In Chande's version, the effective period of the moving average decreases with the trend strength so that highly trending markets have a short moving average period and sideways or choppy markets have a long period moving average.

This version adds an extra input, TrendParam, which can be used to change the relationship between trend and moving average period. Positive values of TrendParam give the same relationship as in Chande's version, where a TrendParam of 1 is similar to VIDYA. Negative values of TrendParam reverse the relationship, so that the period increases with the trend strength and decreases with flat or trendless markets. A TrendParam of zero is a regular exponential moving average with no dependence on trend. Reasonable values of TrendParam are between roughly -5 and +5.

Zero-lag trend

Moving average of price based on John Ehlers' ITrend or InstTrend indicator in Cybernetic Analysis for Stocks and Futures, John Wiley & Sons, Inc, New Jersey, 2004, pp. 16, 24. According to Dr. Ehlers, this indicator has essentially zero lag for price frequencies within the range of interest to most traders.

Adaptive zero-lag trend (Adapt Zero-Lag Trend)

This is an extension of the zero-lag trend indicator, which is based on John Ehlers' ITrend or InstTrend indicator in Cybernetic Analysis for Stocks and Futures, John Wiley & Sons, Inc, New Jersey, 2004, pp. 16, 24.

In this version, the smoothing constant (alpha) adapts to market volatility or trend strength, depending on the input TrendParam, which defines the relationship between trend and moving average period. Positive values of TrendParam give a short moving average period during highly trending markets and a long period moving average during sideways or choppy markets. Negative values of TrendParam reverse the relationship, so that the period increases with the trend strength and decreases with flat or trendless markets. A TrendParam of zero gives a period equal to Length (i.e., independent of trend strength). The efficiency ratio is used as a measure of trend strength. Reasonable values of TrendParam are between roughly -5 and +5.

Moving average convergence divergence (MACD)

Moving average convergence divergence indicator. The MACD is calculated as the difference between two exponential moving averages of price.

Triple exponential moving average (TRIX)[1]

The triple exponential moving average (TRIX) indicator starts by taking the natural logarithm of price, which is then smoothed by applying the exponential moving average three times. The TRIX is calculated as the difference between successive values of the triply-smoothed result multiplied by a normalizing factor of 10000. The TRIX acts as an oscillator with values typically ranging from -100 to +100.

Momentum

Momentum is an oscillator calculated as the difference between the current price and the price N bars ago, where N is an input. Positive values indicate that prices are rising, whereas negative values indicator that prices are falling.

Rate of change (ROC)[1]

ROC is an oscillator calculated as the ratio of the current price to the price N bars ago, subtracted from 1 and multiplied by 100. Positive values indicate that prices are rising, whereas negative values indicator that prices are falling.

Fast K stochastic[1,2]

The Fast K stochastic is a price oscillator scaled to the range 0 to 100. It's calculated as the difference between the bar's close and the lowest low, all divided by the difference between the highest high and the lowest low. High values are generally considered to represent so-called over-bought conditions, whereas low values are generally considered to represent so-called over-sold conditions.

Fast D stochastic

The Fast D stochastic is a price oscillator scaled to the range 0 to 100. It's calculated as a 3-period exponential moving average of the Fast K stochastic. High values are generally considered to represent so-called over-bought conditions, whereas low values are generally considered to represent so-called over-sold conditions.

Slow D stochastic

The Slow D stochastic is a price oscillator scaled to the range 0 to 100. It's calculated as a 3-period exponential moving average of the Fast D stochastic, in which the exponential moving average uses a smoothing factor of 1/N, rather than the value 2/(1 + N) of the normal XMA. High values are generally considered to represent so-called over-bought conditions, whereas low values are generally considered to represent so-called over-sold conditions.

Relative strength indicator (RSI)
The RSI is a momentum oscillator that indicates the strength of the market within a range of 0 to 100. The calculation is based on the ratio of up price changes to down price changes. High values are generally considered to represent so-called over-bought conditions, whereas low values are generally considered to represent so-called over-sold conditions.

Inverse Fisher RSI
Inverse Fisher transform of the RSI indicator. The inverse Fisher transform provides sharper turning points for the RSI. The price values are smoothed with a 4-bar weighted moving average before applying the RSI. Indicator values lie between -1 and +1.

Inverse Fisher cycle
Inverse Fisher transform of John Ehlers' Stochastic Cyber Cycle indicator from Cybernetic Analysis for Stocks and Futures, John Wiley & Sons, Inc, New Jersey, 2004, p. 75. The Cyber Cycle is an oscillator derived from the cyclic component of price. After computing the stochastic cyber cycle and scaling it to -5 to +5, the inverse Fisher transform is taken to provide sharper turning points. Indicator values lie between -1 and +1.

Adaptive inverse Fisher RSI (Adapt Inv Fisher RSI)
This is an extension of the inverse Fisher RSI indicator, which applies the inverse Fisher transform to the RSI function in order to provide sharper turning points in the RSI. In this version, the smoothing constant (alpha) adapts to market volatility or trend strength, depending on the input TrendParam, which defines the relationship between trend and moving average period. Positive values of TrendParam give a short moving average period during highly trending markets and a long period moving average during sideways or choppy markets. Negative values of TrendParam reverse the relationship, so that the period increases with the trend strength and decreases with flat or trendless markets. A TrendParam of zero gives a period equal to Length (i.e., independent of trend strength). The efficiency ratio is used as a measure of trend strength. Reasonable values of TrendParam are between roughly -5 and +5. Indicator values lie between -1 and +1.

Adaptive inverse Fisher cycle (Adapt Inv Fisher Cycle)
This is an extension of the inverse Fisher cycle indicator, which is based on John Ehlers' Stochastic Cyber Cycle indicator from Cybernetic Analysis for Stocks and Futures, John Wiley & Sons, Inc, New Jersey, 2004, p. 75. The Cyber Cycle is an oscillator derived from the cyclic component of price. In this version, the smoothing constant (alpha) adapts to market volatility or trend strength, depending on the input TrendParam, which defines the relationship between trend and moving average period. Positive values of TrendParam give a short moving average period during highly trending markets and a long period moving average during sideways or choppy markets. Negative values of TrendParam reverse the relationship, so that the period increases with the trend strength and decreases with flat or trendless markets. A TrendParam of zero gives a period equal to Length (i.e., independent of trend strength). The efficiency ratio is used as a measure of trend strength. Reasonable values of TrendParam are between roughly -5 and +5. Indicator values lie between -1 and +1.

Commodity channel index (CCI)
The commodity channel index (CCI) is an oscillator calculated as the deviation of the average price, (H+L+C)/3, divided by the average deviation of the average price. The ratio is adjusted by a factor that helps keep most values within the range -200 to +200.

Directional indicator (DI+/DI-)
DI+ is the positive directional indicator, whereas DI- is the negative directional indicator. DI+ indicates the presence of an up trend, whereas DI- indicates the presence of a down trend.

Directional movement index (DMI)[1,2]
The DMI indicates the strength of the price trend. The DMI is calculated as the absolute value of the difference between DI+ and DI- divided by the sum of DI+ and DI-, multiplied by 100.

Average directional index(ADX)
The ADX indicates the strength of the price trend. The ADX is calculated as an exponential moving average of the DMI.

True range (TR)
The TR is the difference between the true high (highest of the current bar's high and the prior close) and the true low (lowest of the current bar's low and the prior close). The TR is intended to more accurately represent the bar's range than the high minus the low when the prior close is outside of the current bar's range.

Average true range (ATR)
The ATR is the simple moving average of the true range over the past N bars, where N is an input.

Standard deviation
The standard deviation is the population (as opposed to sample) standard deviation of price over the past N bars, where N is an input. The standard deviation is a type of price difference and can be compared to other price differences within Builder.

Bollinger band
The Bollinger band is the average price plus a multiple of the standard deviation of price. If the number of standard deviations is positive, the result is an upper band. If the number of standard deviations is negative, the result is a lower band. The upper and lower bands are traditionally used to indicate a range of "normal" price movement.

Keltner channel[1]
The Keltner channel is the average price plus a multiple of the average true range. As with Bollinger bands, positive and negative multiples are used to produce upper and lower bands of the Keltner channel.

Lowest
The lowest price over the past N bars, where N is an input. Because the Lowest function returns a price, it is used in Builder where a price value is required, such as in the calculation of stop and target prices.

Highest
The highest price over the past N bars, where N is an input. Because the Highest function returns a price, it is used in Builder where a price value is required, such as in the calculation of stop and target prices.

Volume
The volume is the number of shares or contracts traded. For tick data, Builder uses the sum of the up and down tick volumes. Builder uses volume in several ways: the volume on the current bar, the volume N bars ago, the moving average or exponential moving average of volume, and the highest or lowest volume over the past N bars. Any of these volume values may be compared to any other.

Accumulation/distribution
The Accumulation/distribution line is a volume oscillator, calculated by accumulating a portion of the volume of each bar. The amount of volume added at each bar is equal to the difference between the close and the open divided by the range. The use of this indicator in MetaTrader 4 strategies is not recommended because its value depends strongly on the starting bar, which cannot be controlled in MetaTrader. As a result, it's likely that different values for the indicator will be found in Builder than in MetaTrader 4.

Chaiken oscillator[1]
The Chaiken oscillator is the difference between two exponential moving averages of the accumulation distribution line.

Crosses Above/Below[1]

The crosses above indicator returns “true” if the first input is above the second input on the current bar and below it on the prior bar. If the two inputs are equal on the prior bar, the indicator looks back up to the maximum look-back length to determine if the first input was below the second. If not, the indicator returns “false”. The crosses below indicator works analogously to “crosses above” to return “true” if the first input crosses below the second input on the current bar and returns “false” otherwise. The crosses above/below indicators can be used anywhere that inequality operators (>, <, <=, >=) apply, including with moving averages, stochastics, RSI, MACD, momentum, and so on.

Price patterns

A price pattern in Builder is defined as the comparison between two prices, where the price can any of the following: simple price (O, H, L, C), look-back price (O[N], H[N], L[N], C[N]), a day price (OpenD(0), HighD(0), LowD(0), CloseD(1)), or any other selected indicator that returns price, such as highest, lowest, and moving averages. The comparison between the two prices may be <, <=, >, or >=. Builder may construct any number of price patterns, depending on the tree depth and the other indicators selected as part of the build process.

Day of week

The day-of-week indicator returns an integer value from 1 to 7 to represent the day of week.

Time of day

The time-of-day indicator returns the time of the price bar N bars ago, where N is an input. Typically, the time of a price bar is the time at which the bar closes.

Absolute value

The absolute value function is used when computing the difference between prices. Normally, when using the price difference in a stop or target, the absolute value is applied to ensure that the price difference is a non-negative number. You can exclude this function from the build set to remove this restriction.

[1]Indicator not available for MetaTrader 4 code. [2]Indicator not available for AmiBroker code.

Appendix: Code Conventions

The strategy code generated by Builder uses various naming conventions for inputs, variables, and order type labels. Unless otherwise noted, the same naming conventions apply to all code types available in Builder.

The strategy code naming conventions for input variables are shown below.

N : integer or number, typically an indicator look-back length (e.g., N1, NATR).
X : floating point value (e.g., X1, X2, etc.).
En or Ent : entry (e.g., EntFr, ATRFrEn).
Ex : exit (e.g., TimeEx, NBarEx1).
Fr : fraction or multiple (e.g., EntFr).
Targ : target exit (e.g., TargFr).
MM : money management (protective) stop (e.g., MMFr).
StartEquity: starting equity value for position sizing calculations.
PSParam : position sizing parameter value, such a fixed fraction, delta (fixed ratio), percent of equity, etc.
RoundPS : true/false variable. True means round position size to nearest RoundTo increment.
RoundTo : value to round position size to if RoundPS is true; ignored if RoundPS is false.
SizeLimit : maximum allowable number of shares or contracts per trade.

As an example, consider the following code from the input section of a generated EasyLanguage strategy, with comments added to explain each input:

```
NBarEn1 (60),          // Number of bars, entry
NBarEn2 (14),          // Number of bars, entry
NBarEn3 (5),           // Number of bars, entry
EntFr (2.6909),        // Entry fraction of price difference or average true range (ATR)
NATR (30),             // Look-back length for ATR
TargFr (1.7681),       // Target fraction; fraction/multiple of ATR
MMFr  (1.51),          // Money management stop fraction; fraction/multiple of ATR
N1 (27),               // Indicator look-back length
N2 (59),               // Indicator look-back length
N3 (27),               // Indicator look-back length
N4 (59),               // Indicator look-back length
N5 (61),               // Indicator look-back length
X1 (10.0000),          // Indicator parameter (floating point) value
NATR (79),             // Look-back length of ATR
ATRFrEn (2.8858),      // Fraction/multiple of ATR for entry
TimeEx  (1015),        // Exit time
StartEquity (100000.00),   // Starting account equity; for position sizing calculations
PSParam (28.39),       // Position sizing parameter value; e.g., percent of equity
RoundPS (true),        // Round position size to nearest RoundTo
RoundTo (1),           // Round position sizing to nearest 1
SizeLimit (100);       // Limit position size to 100 shares or contracts
```

Strategy code generated by Builder also includes labels for the entry and exit orders. In TradeStation, these labels are listed in the Trade List and appear on the chart next to each entry and exit. The order labels added by Builder are shown below.

EnStop-L : Entry stop order
EnLimit-L : Limit entry order

EnMark-L : Market entry order
ExMark-L : Market exit order
ExTime-L : Exit-at-time order
ExNBars-L : Exit at N bars from entry order
ExStop-L : Money management (protective) stop exit order
ExTrail-L : Trailing stop exit order
ExTmRnge-L : Exit based on time range option (only for strategies built prior to version 1.3.0.0)
ExTarg-L : Target exit order

The "L" at the end of each label indicates that the order is for a long trade. Order labels for short trades end in "S".

Variables for Entry and Exit Conditions
The entry and exit conditions in Builder can be quite complex and may consist of multiple variables and multiple logical condition statements. Variables for numeric quantities, such as indicators, start with "Var" and end with "L" for long conditions or "S" for short-side conditions, followed by a number. Examples include VarL1, VarL2, VarS1, VarS2, etc.

Variables for logical conditions, which involve logical or inequality operators, follow the same convention as numeric variables except that they begin with "Cond". Examples include CondL1, CondL2, CondS1, CondS2, etc. An example showing how these variables are used is provided in Chapter 1, Entry and Exit Conditions.

The entry and exit conditions themselves are assigned to variables EntCondL, EntCondS, ExCondL, and ExCondL for, respectively, long and short entry conditions and long and short exit conditions.

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