# Trading 1Min Bar E-Mini NASDAQ 100 Futures Using The Nth Order Fixed Memory Polynomial Velocity Strategy

## January 3, 2014 –January 6, 2017

**Working Paper January 2017**



## Disclaimer

*The strategies, methods and indicators presented here are given for educational purposes only and should not be construed as investment advice. Be aware that the profitable performance presented here is based upon hypothetical trading with the benefit of hindsight and can in no way be assumed nor can it be claimed that the strategy and methods presented here will be profitable in the future or that they will not result in losses.*

In previous working papers at http://www.meyersanalytics.com/papers.php we showed how the application of a price curve generated by the Nth Order Fixed Memory Polynomial Velocity could be used to develop a strategy to buy and sell futures intraday. The reasoning behind this type of strategy was to only trade when the price trend velocity was above a certain threshold. Many times prices meander around without any notable trend and this is considered noise. During these times we do not wish to trade because of the cost of whipsaw losses that would occur from this type of price action. When a price trend finally starts, the velocity of that price trend moves above a minimum threshold noise value. Thus, the velocity strategy would only issue a trade when certain velocity thresholds above "noise" levels are crossed.

The velocity strategy that we will use here to trade the E-Mini NASDAQ 100 futures(NQ)contract is called the nth Order Adaptive Polynomial Velocity Strategy. The word "Adaptive" is used because the polynomial inputs change over time, adapting to the changing trading patterns of the NQ futures contract. The nth Order Adaptive Polynomial Velocity Strategy has several unknown inputs that we must determine before we can use this strategy to trade. These unknown inputs are the polynomial order or degree, the optimum number of lookback prices we need to determine the co-efficients of the polynomial and finally the velocity thresholds. Here we will use Walk Forward Optimization and out-of-sample testing to determine the "best" polynomial inputs as well as how these inputs change over time. We will use the nth Order Fixed Memory Polynomial Velocity Strategy to trade the NQ futures contract on an intraday basis using one minute bar price data from January 3, 2014 to January 6, 2017 .

## The n$^{th}$ Order Fixed Memory Velocity Strategy Defined

The least squares forecast n$^{th}$ order fixed memory polynomial velocity is constructed by solving for the coefficients $\beta_0, \beta_1, \beta_2, \beta_3 \ldots \beta_n$ **for** the discrete orthogonal Legendre polynomials each day using the last **N bars** of closing prices and the equation for $\beta_j$ shown in the **"Math"** appendix at the end of this working paper. Then n$^{th}$ Order Fixed Memory Polynomial **Velocity(T+1)** is constructed from the equation shown in the "Math" appendix.

Due to polynomial mathematics, the Velocity of the 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ order degree polynomial curve changes faster than it's corresponding first order degree polynomial velocity. Whether higher order polynomial velocities are an advantage or not, will be determined by the computer when we use a walk forward optimization technique described below.

At each bar we calculate the nth order degree (1$^{st}$ through 4$^{th}$) fixed memory polynomial velocity from the formulas in the "Math" appendix. As will be shown below, walk forward optimization will determine the **degree** for the nth order polynomial velocity, the number of lookback prices, **N**, needed to compute the polynomial coefficients and the threshold amounts **vup** and **vdn**. When the nth order degree velocity is greater than the threshold amount ***vup*** we will go long. When the velocity is less than the threshold amount ***-vdn*** we will go short.

***Buy Rule:***

**IF Velocity** is greater than the threshold amount ***vup*** then buy at the market.

***Sell Rule:***

**IF Velocity** is less than the threshold amount ***-vdn*** then sell at the market.

**Intraday Bars Exit Rule:**
Close the position at 1500 CST when the U.S stock market trading stops. (no trades will be carried overnight).

**Intraday Bars First Trade of Day Entry Rule:**
All trade signals before 30 minutes after the U.S. stock market opens are ignored. We've included this rule because with overnight trading there are often gaps in the open creating immediate strategy buys and sells. Many times these gaps are closed creating a losing whipsaw trade. To avoid the opening gap whipsaw trade problem, we've delayed the first trade of the day for 30 minutes after the opening until 9:00am CST

## Testing The Polynomial Velocity Strategy Using Walk Forward Optimization

There will be four strategy parameters to determine:

1. **degree**, degree=1 for straight line velocity, degree=2 for 2$^{nd}$ order velocity, etc.
2. ***N***, is the number of lookback bars of prices to calculate the **velocity.**
3. ***vup***, the threshold amount that velocity must be greater than to issue a buy signal
4. ***vdn***, the threshold amount that velocity must be less than to issue a sell signal

To test this strategy, we will use one minute bar prices of the NQ futures contract traded on the CME/Globex and known by the symbol NQ from January 3, 2014 to January 6, 2017.

We will test this strategy with the above NQ 1 min bars on a walk forward basis, as will be described below. To create our walk forward files we will use the ***add-in*** software product called the Power Walk Forward Optimizer (PWFO). In TradeStation (TS), we will run the PWFO strategy ***add-in*** along with the n$^{th}$ Order Polynomial Velocity Strategy on the NQ 1min data from January 3, 2014 to January 6, 2017. The PWFO will breakup and create 30 calendar day in-sample sections along with their corresponding one calendar week out-of-sample sections from the 162 weeks of NQ (see Walk forward Testing below) creating 158 out-of-sample weeks.

## What Is An In-Sample Section and Out-Of-Sample Section?

Whenever we do a TS optimization on many different strategy inputs, TS generates a report of performance metrics (total net profits, number of losing trades, etc) vs these different inputs. If the report is sorted on say the total net profits(***tnp***) performance metric column, then the highest ***tnp*** would correspond to a certain set of inputs. This is called an ***in-sample*** or ***test section***. If we choose a set of strategy inputs from this report based upon some performance metric we have no idea whether these strategy inputs will produce the same results on future price data or data they have not been tested on. Price data that is not in the ***in-sample*** section is defined as ***out-of-sample data***. Since the good performance metrics generated in the in-sample section are mostly due to "curve fitting" (see Walk Forward Out-of-Sample Testing section below) it is important to see how the strategy inputs chosen from the in-sample section perform on out-of-sample data.

## What Does The Power Walk Forward Optimizer (PWFO) Do?

The PWFO is a TS ***add-in*** that breaks up the TS optimization run into many user selectable in-sample and out-of-sample sections. The PWFO prints out the in-sample sample performance metrics **and the out-of-sample performance results**, on one line, for each case or input variable combination that is run by the TradeStation(TS) optimization module to a user selected spreadsheet comma delimited file. The PWFO can generate up to 500 different in-sample and out-of-sample date optimization files in one TS run, saving the user from having to generate optimization runs one at a time. The PWFO output allows you to quickly determine whether your procedure for selecting input parameters for your strategy just curve fits the price and noise, or produces statistically valid out-of-sample results. In addition to the out-of-sample performance results presented for each case, 30+ superior and robust performance metrics (many are new and never presented before) are added to each case line in the in-sample section and printed out to the comma delimited file. These 30+ performance metrics allow for a superior and robust selection of input variables from the in-sample section that have a higher probability of performing well on out-of-sample data (Please see **http://meyersanalytics.com/Walk-Forward-Optimization.html** for a listing of these performance metrics).

For our computer run we will have the PWFO breakup the 162 weeks of NQ one minute bar price data into 158 in-sample and out-of-sample files. The in-sample sections will be 30 calendar days and the out-of-sample(OOS) section will be the one week following the in-sample section. The OOS week will always end on a Friday as will the 30 calendar day in-sample section. As an example the first in-sample section would be from 11/28/20131 to 12/27/2013 and the out-of-sample section would be the week following from 12/30/2013 to 1/3/2014.(our in-sample and out-of-sample sections always end on a Friday). We would then move everything ahead a week and the 2nd in-sample section would be from 12/5/2013 to 1/3/2014 and the week following out-of-sample section would be from 1/6/2014 to 1/10/2014. Etc. Note: The In-Sample sections also end on a Friday and the OOS sections run from Monday to Friday.

The PWFO 158 in-sample/out-of-sample section dates are shown in **Table 1** below. We will then use another software product called the Walk Forward Performance Metric Explorer (WFME) on each of the 158 in-sample and out-of-sample sections generated by the PWFO to find the best in-sample section performance ***filter*** that determines the strategy input parameters ***(degree, N, vup, vdn)*** that will be used on the out-of-sample data. Detailed information about the WFME can be found at **http://meyersanalytics.com/wfme.html**

For the in-sample data we will run the TradeStation optimization engine on the 158 weeks of NQ 1 min bars with the following ranges for the nth order fading memory polynomial velocity strategy input variables.

1. **pw=degree from 1 to 4**
2. **N from 20 to 70 in steps of 10.**
3. **vup from 0.25 to 3.5 steps of 0.25**
4. **vdn from 0.25 to 3.5 in steps of 0.25**
5. **Mult = 3.87, iNorm=1 (See Appendix 3, the Normalization Multiplier)**

This will produce 4704 different cases or combinations of the input parameters for each of the 158 PWFO output files.

## Walk Forward Out-of-Sample Testing

Walk forward analysis attempts to minimize the curve fitting of price noise by using the law of averages from the Central Limit Theorem on the out-of-sample performance. In walk forward analysis the data is broken up into many in-sample and out-of-sample sections. Usually for any strategy, one has some performance metric selection procedure, which we will call a filter**,** used to select the input parameters from the in-sample optimization run. For instance, a ***filter*** might be all cases that have a profit factor (PF) greater than 1 and less than 3. For the number of cases left, we might select the cases that had the best percent profit. This procedure would leave you with one case in the in-sample section output and its associated strategy input parameters. Now suppose we ran our optimization on each of our many in-sample sections and applied our ***filte***r to each in-sample section. We would then use the strategy input parameters found by the ***filter*** in each in-sample section on the out-of-sample section immediately following that in-sample section. The strategy inputs found by the ***filter*** in each in-sample section and applied to each out-of-sample section would produce independent net profits and losses for each of the out-of-sample sections. Using this method over “x” in-sample sections, we now have "x" number of independent out-of-sample section profits and losses from the strategy inputs found by the ***filter*** in the in-sample sections. If we take the average of these out-of-sample section net profits and losses, then we will have an estimate of how our strategy will perform on average. Due to the Central Limit Theorem, as our sample size increases, the spurious noise results in the out-of-sample section performance tend to average out to zero in the limit leaving us with what to expect from our strategy and filter. ***Mathematical note:*** *This assumption assumes that the out-of-sample returns are from probability distributions that have a finite variance.*

Why use the walk forward technique? Why not just perform an optimization on the whole price series and choose the input parameters that give the best total net profits or profit factor or some other performance metrics? Surely the price noise cancels itself out with such a large number of in-sample prices and trades. Unfortunately, nothing could be farther from the truth! Optimization is a misnomer and should really be called combinatorial search. As stated above, whenever we run a combinatorial search over many different combinations of strategy input parameters on noisy data on a fixed number of prices, ***no matter how many***, the best performance parameters found are guaranteed to be due to ***“curve fitting”*** the noise and signal. What do we mean by ***“curve fitting”***? The price series that we trade consists of random spurious price movements, which we call noise, and repeatable price patterns (*if they exist*). When we run, for example, 5000 different input parameter combinations, the best performance parameters will be from those strategy input variables that are able to produce profits from the price pattern ***and*** the random spurious movements. While the price patterns will repeat, the same spurious price movements will not. If the spurious movements that were captured by a certain set of input parameters were a large part of the total net profits, then choosing these input parameters will produce losses when traded on future data. These losses occur because the spurious movements will not be repeated in the same way. This is why strategy optimization, neural net optimizations or combinatorial searches with no out-of-sample testing cause loses when traded in real time by mistaking chance fluctuations for genuine effects. Unfortunately, it is human nature to extrapolate past performance to project future trading results and thus results from the chance fluctuations of curve fitting give the illusion, a modern "siren call" so to speak, of future trading profits.

To gain confidence that our input parameter selection method using the optimization output of the in-sample data will produce profits, we must test the input parameters we found in the in-sample section on out-of-sample data. In addition, we must perform the in-sample/out-of-sample analysis many times. Why not just do the out-of-sample analysis once or just three times? Well just as in Poker or any card game, where there is considerable variation in luck from hand to hand, walk forward out-of-sample analysis give considerable variation in week to week out-of-sample profit "luck". That is, by pure chance we may have chosen some input parameter set that did well in the in-sample section data ***and*** the out-of-sample section data. To minimize this type of "luck", statistically, we must repeat the walk forward out-of-sample (OOS) analysis over many in-sample/OOS sections and take an average of our weekly results over all out-of-sample sections. This average gives us an expected weekly return and a standard deviation of weekly returns which allows us to statistically estimate the expected equity and its path ranges for N weeks in the future.

## Finding The Strategy Input Parameters in The Walk Forward Test Sections

The PWFO generates a number of performance metrics in the in-sample section. (Please see **http://meyersanalytics.com/Walk-Forward-Optimization.html** for a listing of these performance metrics). The question we are attempting to answer statistically, is which performance metric or combination of performance metrics (which we will call a ***filter***) in the in-sample section will produce strategy inputs that produce statistically valid profits in the out-of-sample section. In other words, we wish to find a performance metric ***filter*** that we can apply to the in-sample section that can give us strategy inputs that will produce, ***on average***, good trading results in the out-of-sample sections. The PWFO produces a total of 32 different performance metrics in the in-sample section. If we have 4704 different input variations or cases, then the in-sample section consists of 32 columns of performance metrics for each of the 4704 different strategy inputs or rows.

An example of a simple filter would be to choose the row in the in-sample section that had the highest net profit or perhaps a row that had one the best performance metric from one of the other 32 PWFO metrics. Unfortunately, it was found that this type of simple filter very rarely produces good out-of-sample results. More complicated metric filters can produce good out-of-sample results minimizing spurious price movement biases in the selection of strategy inputs.

Here is a combination filter, found by the Walk Forward Performance Metric Explorer (WFME) (**figure 3**) that is used in this paper with good out-of-sample results. High profit factors (**PF**) in the in-sample section usually mean poor performance in the out-of-sample-section. This is a kind of reversion to the mean. So in the in-sample section we eliminate all strategy input rows that have a **PF>1.5.** In addition, we would like the strategy to trade a minimum 10 times a month to eliminate those strategy inputs that very rarely trade (**nt>10**). The PWFO generates the metric **eq2V.** This metric is the **Velocity Of A Least Squares 2nd Order Polynomial Line Fitted To The Equity Curve.** This is a measure of how fast the equity curve is moving on the last trade. Let us choose the 10 rows in the in-sample section that contain the highest(top) number of **eq2V** from the rows that are left after the **PF** and **nt** row elimination. This partial filter will now leave 10 cases or rows in the in-sample section that satisfy the above filter conditions. Suppose for this filter, within the 10 in-sample rows that are left, we want the row that has the maximum metric **mTrd** in the in-sample section**.** **mTrd** is the median of all trades in the In-Sample section for a given set of strategy inputs**.** This would produce a filter named **t10eq2V|p<1.5|nt>10|-mTrd.** This in-sample filter leaves only one row in the PWFO in-sample section with its associated strategy inputs and out-of-sample net profit in the out-of-sample section. This particular **t10eq2V|p<1.5|nt>10|-mTrd** filter finds the strategy inputs parameters in each of the 158 in-sample sections and applies these inputs to each of the 158 out-of-sample sections. Using the filter in-sample strategy inputs on the 158 out-of-sample sections, the average out-of-sample performance is calculated. In addition, many other important out-of-sample performance statistics for this filter are calculated and summarized. **Figure 3** shows such a filter computer run along with a small sample of other filter combinations that are constructed in a similar manner. **Row 5** of the sample output in **Figure 3** shows the results of the filter discussed above. A total of 57600 different metric filters were examined. We chose **Row 5** because it had a lower **Dev^2** and a higher **eqR2** along with better statistics than the rows above and below it. More on this below and on how that number of filters combinations effect the probability that the filter chosen was or was not due to chance

**Bootstrap Probability of Filter Results:** Using modern "Bootstrap" techniques, we can calculate the probability of obtaining each filter's total out-of-sample ***net*** profits by chance. By ***net*** we mean subtracting the cost and slippage of all round trip trades from the total out-of-sample profits. Here is how the bootstrap technique is applied. Suppose as an example, we calculate the total out-of-sample net profits(tOnpNet) over all out-of-sample weeks for a given filter like above. A mirror filter is created. However, instead of picking an out-of-sample net profit(OSNP) from a row that the filter picks, the mirror filter picks a ***random*** row's OSNP in each of the 158 PWFO files. Suppose we repeat this random row section 5000 times. Each of the 5000 mirror filters will choose a random row's OSNP of their own in each of the 158 PWFO files. At the end, each of the 5000 mirror filters will have 158 ***random*** OSNP's picked from the rows of the 158 PWFO files. The sum of the 158 random OSNP picks for each of the 5000 mirror filters will generate a random total out-of-sample net profit(tOnpNet). The average and standard deviation of the 5000 mirror filter's different random tOnpNets will allow us to calculate the chance probability for each of ***our*** filter's tOnpNet. Thus given the mirror filter's bootstrap random tOnpNet average and standard deviation, we can calculate the probability of obtaining our filter's tOnpNet by pure chance alone. Since for this run we examined 57600(shown in Figure 3) different filters, we can calculate the expected number of cases that we could obtain by pure chance that would match or exceed the tOnpNet of the filter we have chosen or 1-(1-tOnpNet Probability)$^{57600}$ ~ 57600* tOnpNet Probability. For our filter in row 5 in Figure 3 the expected number of cases that we could obtain by pure chance that would match or exceed the tOnpNet of $34,335 of Row 5 is 57660 x 3.2 $10^{-6}$ = 0.184. This is much less than one case so it is improbable that our result was due to pure chance.

## Results

**Table 1** below presents a table of the 158 in-sample and out-of-sample windows, the selected optimum parameters and the weekly out-of-sample results using the filter described above.

**Figure 1** presents a graph of the equity and net equity curves generated by using the filter on the 158 weeks ending 1/3/14 to 1/6/17. The equity curves are plotted from the Equity and Net Equity columns in Table 1. Plotted on the equity curves are 2$^{nd}$ Order Polynomial fits. The blue line is the equity curve without commissions and the red dots on the blue line are new highs in equity. The brown line is the net equity curve with commissions and the green dots are the new highs in net equity. The grey line is the weekly NQ prices superimposed on the equity chart.

**Figure 2** Walk Forward Out-Of-Sample Performance for NQ n$^{th}$ Order Fixed Memory Polynomial Velocity Strategy **1** minute bar chart of NQ from 3/10/2016

**Figure 3** Partial output of the Walk Forward Metric Performance Explorer (WFME)
Run on the 158 PWFO files of the NQ 1min bars Nth Order Fixed Memory Polynomial Velocity

## Discussion of Strategy Performance

In Figure 3 Row 5 of the spreadsheet filter output are some statistics that are of interest for our filter. **BE** is the break even weeks. Assuming the trade average and standard deviation for this filter are from a normal distribution, this is how many weeks we need to trade this strategy so that we have a 98% probability that the equity paths after that number of weeks will be greater than zero. BE is 36.8 weeks for this filter. This means we would have to trade this strategy for at least 36.8 weeks to have a 98% probability that our equity would be positive. Another interesting statistic is **Blw**. Blw is the maximum number of weeks the OSNP equity curve failed to make a new high. Blw is 12 weeks for this filter. This means that 12 weeks was the longest time that the equity for this strategy failed to make a new equity high.

To see the effect of walk forward analysis, look at **Table 1**. Notice how the input parameters ***pw, N, vup and vdn*** take sudden jumps from high to low and back. This is the walk forward process quickly adapting to changing volatility conditions in the in-sample sample. In addition, notice how often ***degree*** changes from a straight line velocity with ***degree=1*** to a 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ order velocity with ***degree= 2, 3 and 4***. The 3$^{rd}$ and 4$^{th}$ order velocities, due to the higher order components, change much faster than the straight line velocity. When the data gets very noisy with a lot of spurious price movements, it's better to have the velocity change slower filtering out the noisy data. During other times when the noise level is not as much it is better to have the velocity break its ***vup*** and ***vdn*** barriers faster to get onboard a trend faster. This is what the filter is doing. When there is a lot of noise in the in-sample section it switches to the 1$^{st}$ or 2$^{nd}$ order curve velocity. When the noise level is lower in the in-sample section, it switches to the faster changing 3$^{rd}$ or 4$^{th}$ order curve velocity.

Using this filter, the strategy was able to generate $34,335 net equity after commissions and slippage trading one NQ contract for 158 weeks. Note $20 roundtrip commission and slippage was subtracted from each trade and no positions were carried overnight. The largest trade loss was -$2000, the largest losing week was -$3030 and the largest drawdown was -$4490. The longest time between new equity highs was 12 weeks.

In observing Table 1 we can see that this strategy and filter made trades from a low of no trades/week to a high of 7 trades/week with an average of 2 trades/week on the weeks it did trade. The strategy seemed to wait for really strong trends and then initiate a buy or sell. There were many weeks that had no trades. Out of the 158 out-of-sample weeks the filter only traded 140 of those weeks or 89% of the time with 52% of all trades profitable. In observing the Equity Curve plot in Figure 1 we can see that the equity did quite well in both big up and down moves of the NQ. In observing the chart from 12/4/15 to 2/12/16 where NQ declined from 4684 to 3983 we can see the strategy did well on this unusually large NQ decline. After the Brexit vote on 6/23/2016, the strategy did well in the volatile market from Friday 6/24 to Friday 7/1 making $2035 on 5 trades that week.

**References**


1. Efron, B., Tibshirani, R.J., (1993), "An Introduction to the Bootstrap", New York, Chapman & Hall/CRC.
2. Morrison, Norman "Introduction to Sequential Smoothing and Prediction", McGraw-Hill Book Company, New York, 1969.

## Figure 1 Graph of Net Equity Curve Applying the Walk Forward Filter Each Week On NQ 1min Bar Prices 01/03/14 – 01/06/17

**Note: The blue line is the equity curve without commissions and the red dots on the blue line are new highs in equity. The brown line is the equity curve with commissions and the green dots are the new highs in net equity The grey line is the NQ Weekly Closing prices superimposed on the Equity Chart.**

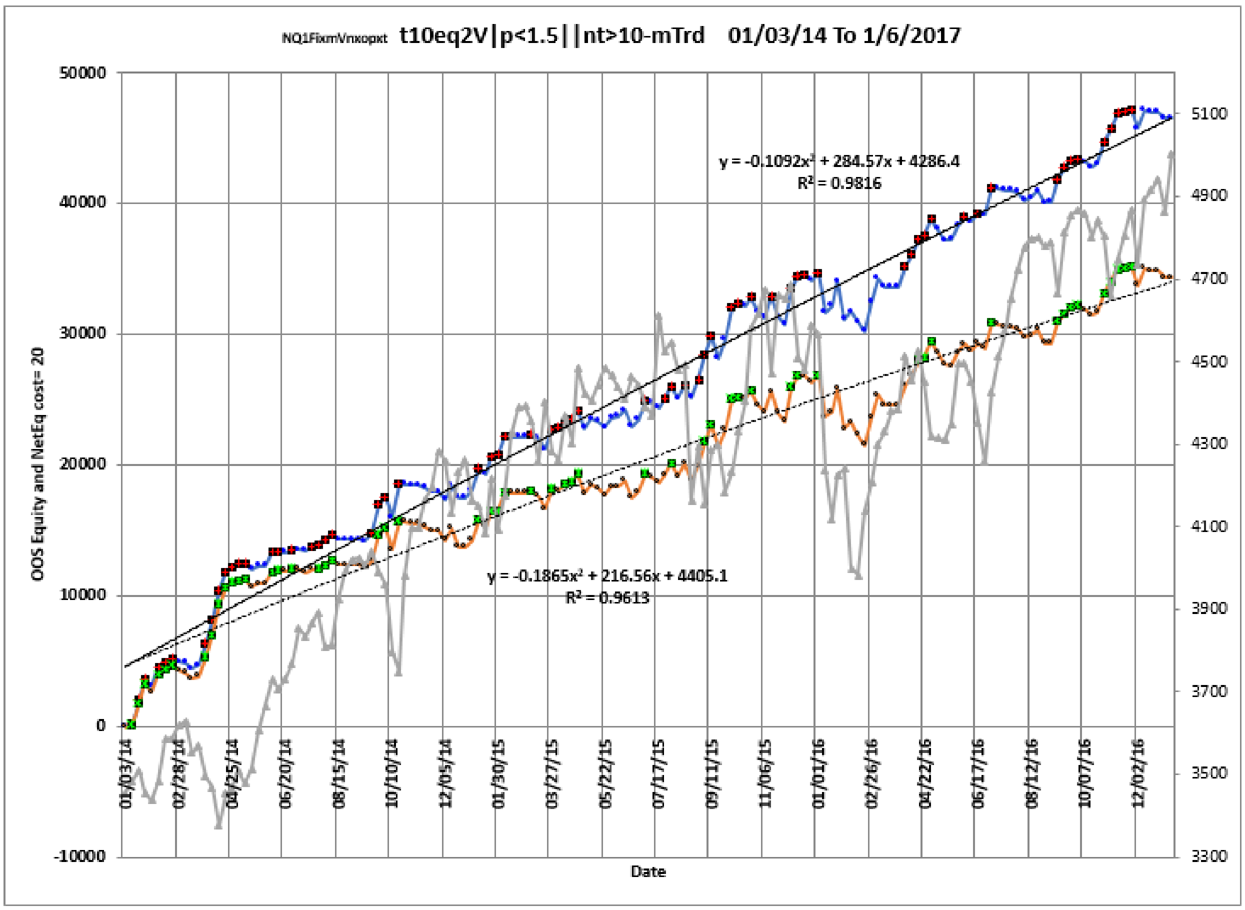

**Figure 2 Walk Forward Out-Of-Sample Performance Summary for Nth Order Fixed Memory Polynomial Velocity Strategy NQ 1 minute bar chart from 10/28/16**

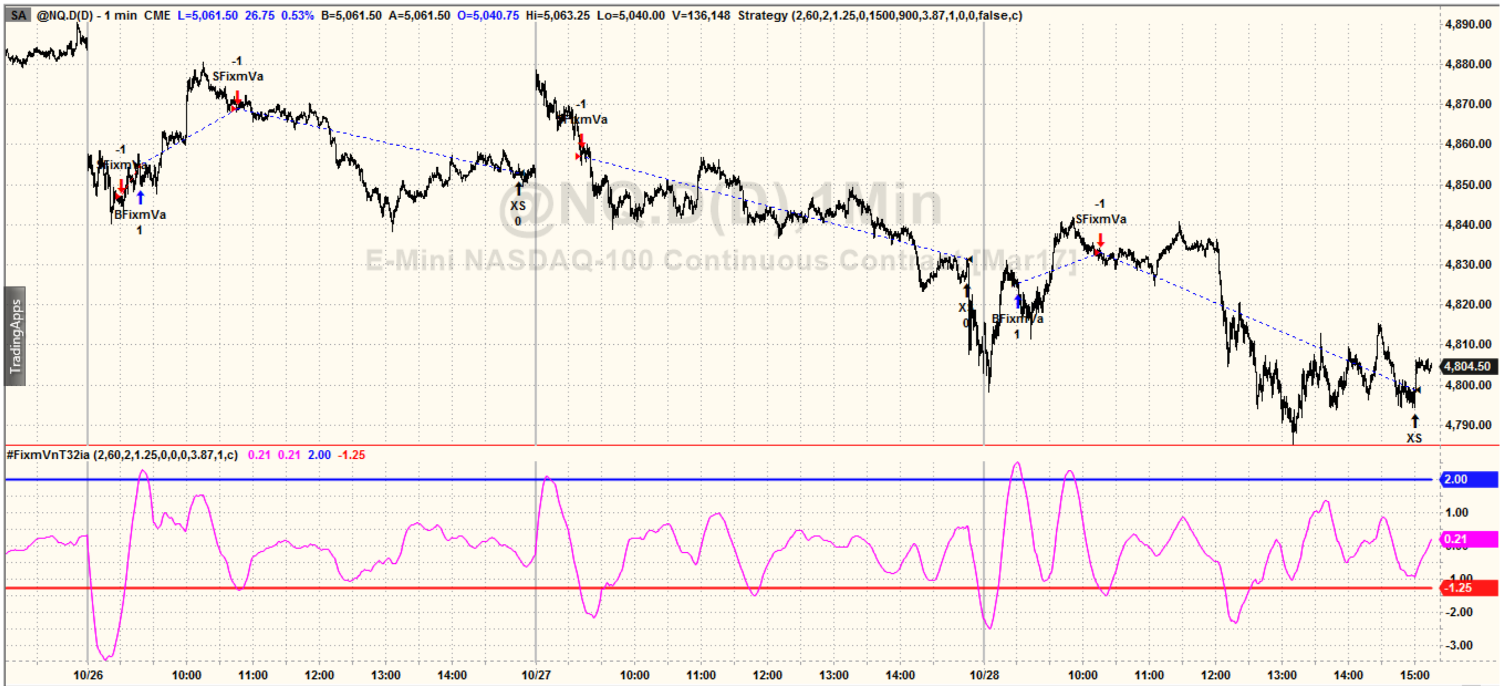

**Figure 3  Partial output of the Walk Forward Metric Performance Explorer (WFME)**
**NQ1 min bars Nth Order Fixed Memory Velocity Strategy**

<table>
<tr><td>1</td><td>NQ1FixmVnxopxt</td><td>s01/03/14</td><td>e01/06/17</td><td>#158</td><td>AnyTnp</td><td></td><td></td><td></td><td></td><td>a(193.9)</td><td>s97.3</td><td>f57660</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>c=$20</td><td></td></tr>
<tr><td>2</td><td>Filter-Metric</td><td>toGP</td><td>aoGP</td><td>aoTr</td><td>ao#T</td><td>oW|oL</td><td>%Wtr</td><td>t</td><td>std</td><td>LLtr</td><td>LLp</td><td>eqDD</td><td>LRp</td><td>#</td><td>eqTrn</td><td>eqV^2</td><td>eqR2</td><td>Dev^2</td><td>Blw</td><td>BE</td><td>tOnpNet</td><td>Prob</td></tr>
<tr><td>3</td><td>t10PF|p<1.5||nt>10-mTrd</td><td>55935</td><td>361</td><td>63.9</td><td>5.7</td><td>1.32</td><td>52</td><td>3.59</td><td>1251</td><td>-1475</td><td>-3475</td><td>-5130</td><td>7</td><td>155</td><td>386</td><td>529</td><td>97</td><td>2863</td><td>22</td><td>48.1</td><td>38415</td><td>2.82E-06</td></tr>
<tr><td>4</td><td>t20eq10|p<2|l3|nt>10-eq2A</td><td>46855</td><td>358</td><td>97.0</td><td>3.7</td><td>1.48</td><td>52</td><td>4.34</td><td>943</td><td>-1600</td><td>-1825</td><td>-2820</td><td>4</td><td>131</td><td>308</td><td>253</td><td>96</td><td>2915</td><td>10</td><td>27.8</td><td>37195</td><td>4.54E-07</td></tr>
<tr><td>5</td><td>t10eq2V|p<1.5||nt>10-mTrd</td><td>46555</td><td>333</td><td>76.2</td><td>4.4</td><td>1.38</td><td>52</td><td>3.9</td><td>1009</td><td>-2000</td><td>-3030</td><td>-4490</td><td>4</td><td>140</td><td>267</td><td>250</td><td>98</td><td>1682</td><td>12</td><td>36.8</td><td>34335</td><td>3.20E-06</td></tr>
<tr><td>6</td><td>t10eq2V|p<1.5|l5|nt>10-mTrd</td><td>46420</td><td>334</td><td>76.0</td><td>4.4</td><td>1.36</td><td>52</td><td>3.96</td><td>993</td><td>-2000</td><td>-3030</td><td>-4490</td><td>4</td><td>139</td><td>280</td><td>211</td><td>98</td><td>1649</td><td>12</td><td>35.4</td><td>34200</td><td>3.08E-06</td></tr>
<tr><td>7</td><td>t20mWb|mLb|p<1.5|l3|nt>10-m(p-rd)</td><td>49875</td><td>378</td><td>63.3</td><td>6</td><td>1.41</td><td>51</td><td>3.77</td><td>1152</td><td>-1560</td><td>-3755</td><td>-4040</td><td>4</td><td>132</td><td>328</td><td>335</td><td>98</td><td>1998</td><td>11</td><td>37.2</td><td>34115</td><td>1.67E-06</td></tr>
<tr><td>8</td><td>t20eq2V|p<2|l3|nt>10-eq2A</td><td>43355</td><td>331</td><td>90.5</td><td>3.7</td><td>1.46</td><td>52</td><td>4.1</td><td>924</td><td>-1600</td><td>-1825</td><td>-2820</td><td>4</td><td>131</td><td>282</td><td>234</td><td>95</td><td>2811</td><td>14</td><td>31.2</td><td>33775</td><td>1.72E-06</td></tr>
<tr><td>9</td><td>t20%P|p<1.5|l5|nt>10-PF</td><td>49965</td><td>329</td><td>60.7</td><td>5.4</td><td>1.42</td><td>50</td><td>4.14</td><td>979</td><td>-1665</td><td>-2235</td><td>-3010</td><td>4</td><td>152</td><td>298</td><td>400</td><td>97</td><td>2292</td><td>12</td><td>35.5</td><td>33505</td><td>1.03E-05</td></tr>
</table>

**The WFME Filter Output Columns are defined as follows:**

**Row 1** NQ1FixmVnxopxt is the strategy abbreviation, First OOS Week End Date(1/3/14), Last OOS Week End Date(1/6/17), **Number of weeks**(#158) **a**=weekly net average of bootstrap random picks. **s**= weekly standard deviation of bootstrap random picks. **f**=number of different filters examined. **c**= slippage and round trip trade cost(c=$20).

**Filter** = The filter that was run. Row10 filter **t10eq2V|p<1.5|nt>10|-mTrd**

**The t10eq2V|p<1.5|nt>10|-mTrd filter produced the following average 158 week statistics on Row 7.**

**toGP** = Total out-of-sample(OOS) gross profit for these 158 weeks.

**aoGP** = Average OOS gross profit for the 158 weeks

**aoTr** = Average OOS profit per trade

**ao#T** = Average number of OOS trades per week

**oW|oL** = The average OOS winning trade divided by the average OOS losing trade

**%Wtr** = percent of all OOS trades that were winning trades

**t** = The student t statistic for the 158 weekly OOS profits. The higher the t statistic the higher the probability that this result was not due to pure chance

**std** = The standard deviation of the 158 weekly OOS profits

**LLtr** = The largest losing OOS trade in all OOS periods,

**LLp** = The largest losing OOS period(week)

**eqDD** = The OOS equity drawdown

**LRp** = The largest number of losing OOS weeks in a row

**#** = The number of weeks this filter produced a weekly result. Note for some weeks there can be no strategy inputs that satisfy a given filter's criteria.

**eqTrn** = The straight line trend of the OOS gross profit equity curve in $/week.

**eqV^2** = The ending velocity of 2$^{nd}$ order polynomial that is fit to the OOS equity curve

 

**eqR2 =** The correlation coefficient($r^2$) of a straight line fit to the OOS equity curve

**Dev^2** = A measure of equity curve smoothness. The square root of the average [(equity curve minus a straight line)$^2$]

**Blw** = The maximum number of weeks the OOS equity curve failed to make a new high.

**BE** = Break even weeks. Assuming the average and standard deviation are from a normal distribution, this is the number of weeks you would have to trade to have a 98% probability that your OOS equity is above zero.

**tOnpNet** = Total out-of-sample net profit(tOnpNet) minus the total trade cost.
tOnpNet=tOnp – (Number of trade weeks)*aOnT*Cost.

**Prob** = the probability that the filter's tOnpNet was due to pure chance.

## Table 1   Walk Forward Out-Of-Sample Performance Summary for NQ1min Nth Order Fixed Memory Polynomial Velocity Strategy

**NQ-1 min bars 1/3/2014 - 1/6/2017. The input values *degree(pw), N, vup, vdn* are the values found from applying the filter to the in-sample section optimization runs.**

**Filter = t10eq2V|p<1.5|nt>10|-mTrd, PF<=1.5, nt>=10 then top 10 eq2V and then maximum mTrd**

**osnp** = Weekly Out-of-sample gross profit in $
**Equity** = Running Sum of weekly out-of-sample gross profits $
**NOnp$20** = Weekly Out-Of-Sample Net Profit in $ = **osnp-ont*20**.
**NetEq** = running sum of the weekly out-of-sample net profits in $
**ollt** = The largest losing trade in the out-of-sample section in $.
**odd** = The drawdown in the out-of-sample section in $.
**ont** = The number of trades in the out-of-sample week.
**pw= degree**, degree=1 for straight line velocity, degree=2 for 2nd order velocity, etc.
**N** = N the lookback period
***vup***, the threshold amount that velocity has to be greater than to issue a buy signal
***vdn***, the threshold amount that velocity has to be less than to issue a sell signal
**Note:** Blank rows indicate that no out-of-sample trades were made that week

| In-Sample Dates | | | Out-Of-Sample Dates | | | osnp | Eq | NOnp$20 | NetEq | ont | ollt | odd | pw | N | vup | vdn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/28/13 | To | 12/27/13 | 12/30/13 | To | 01/03/14 | -45 | -45 | -85 | -85 | 2 | -75 | -75 | 1 | 70 | 1.25 | 1 |
| 12/05/13 | To | 01/03/14 | 01/06/14 | To | 01/10/14 | 260 | 215 | 180 | 95 | 4 | -220 | -260 | 4 | 30 | 1 | 2.5 |
| 12/12/13 | To | 01/10/14 | 01/13/14 | To | 01/17/14 | 1820 | 2035 | 1720 | 1815 | 5 | -95 | -95 | 2 | 20 | 1 | 1.5 |
| 12/19/13 | To | 01/17/14 | 01/20/14 | To | 01/24/14 | 1505 | 3540 | 1405 | 3220 | 5 | -180 | -180 | 3 | 40 | 1.5 | 1 |
| 12/26/13 | To | 01/24/14 | 01/27/14 | To | 01/31/14 | -505 | 3035 | -605 | 2615 | 5 | -690 | -925 | 3 | 30 | 1 | 2.75 |
| 01/02/14 | To | 01/31/14 | 02/03/14 | To | 02/07/14 | 1480 | 4515 | 1360 | 3975 | 6 | -750 | -750 | 4 | 20 | 2.5 | 1.25 |
| 01/09/14 | To | 02/07/14 | 02/10/14 | To | 02/14/14 | 430 | 4945 | 410 | 4385 | 1 | 0 | 0 | 2 | 70 | 1.75 | 2.25 |
| 01/16/14 | To | 02/14/14 | 02/17/14 | To | 02/21/14 | 270 | 5215 | 230 | 4615 | 2 | -15 | -15 | 2 | 60 | 1.25 | 3 |
| 01/23/14 | To | 02/21/14 | 02/24/14 | To | 02/28/14 | -275 | 4940 | -355 | 4260 | 4 | -370 | -475 | 2 | 60 | 1.25 | 3 |
| 01/30/14 | To | 02/28/14 | 03/03/14 | To | 03/07/14 | -95 | 4845 | -155 | 4105 | 3 | -115 | -115 | 4 | 40 | 1.75 | 3 |
| 02/06/14 | To | 03/07/14 | 03/10/14 | To | 03/14/14 | -420 | 4425 | -500 | 3605 | 4 | -545 | -585 | 4 | 50 | 1.5 | 2.5 |
| 02/13/14 | To | 03/14/14 | 03/17/14 | To | 03/21/14 | 275 | 4700 | 195 | 3800 | 4 | -115 | -115 | 4 | 50 | 2.75 | 1.5 |
| 02/20/14 | To | 03/21/14 | 03/24/14 | To | 03/28/14 | 1590 | 6290 | 1470 | 5270 | 6 | -220 | -220 | 4 | 50 | 3 | 1.5 |
| 02/27/14 | To | 03/28/14 | 03/31/14 | To | 04/04/14 | 1795 | 8085 | 1735 | 7005 | 3 | -245 | -245 | 2 | 70 | 2.75 | 1.5 |
| 03/06/14 | To | 04/04/14 | 04/07/14 | To | 04/11/14 | 2330 | 10415 | 2290 | 9295 | 2 | 0 | 0 | 1 | 70 | 3 | 1.75 |
| 03/13/14 | To | 04/11/14 | 04/14/14 | To | 04/18/14 | 1380 | 11795 | 1320 | 10615 | 3 | 0 | 0 | 3 | 20 | 2.25 | 2.75 |
| 03/20/14 | To | 04/18/14 | 04/21/14 | To | 04/25/14 | 405 | 12200 | 385 | 11000 | 1 | 0 | 0 | 3 | 20 | 2.25 | 3 |
| 03/27/14 | To | 04/25/14 | 04/28/14 | To | 05/02/14 | 220 | 12420 | 160 | 11160 | 3 | -305 | -305 | 4 | 30 | 2.25 | 3.5 |
| 04/03/14 | To | 05/02/14 | 05/05/14 | To | 05/09/14 | 75 | 12495 | 55 | 11215 | 1 | 0 | 0 | 4 | 30 | 2.25 | 3.5 |
| 04/10/14 | To | 05/09/14 | 05/12/14 | To | 05/16/14 | -500 | 11995 | -560 | 10655 | 3 | -330 | -545 | 3 | 40 | 1.5 | 2.5 |
| 04/17/14 | To | 05/16/14 | 05/19/14 | To | 05/23/14 | 265 | 12260 | 245 | 10900 | 1 | 0 | 0 | 1 | 40 | 1.75 | 1.75 |
| 04/24/14 | To | 05/23/14 | 05/26/14 | To | 05/30/14 | | 12260 | | 10900 | | | | 2 | 70 | 1.75 | 2 |
| 05/01/14 | To | 05/30/14 | 06/02/14 | To | 06/06/14 | 1025 | 13285 | 945 | 11845 | 4 | -20 | -20 | 2 | 60 | 0.5 | 3.25 |
| 05/08/14 | To | 06/06/14 | 06/09/14 | To | 06/13/14 | 60 | 13345 | 20 | 11865 | 2 | 0 | 0 | 3 | 60 | 1.25 | 1.75 |
| 05/15/14 | To | 06/13/14 | 06/16/14 | To | 06/20/14 | | 13345 | | 11865 | | | | 2 | 30 | 1.25 | 1.75 |
| 05/22/14 | To | 06/20/14 | 06/23/14 | To | 06/27/14 | 195 | 13540 | 135 | 12000 | 3 | -530 | -530 | 3 | 50 | 1.5 | 1.25 |
| 05/29/14 | To | 06/27/14 | 06/30/14 | To | 07/04/14 | | 13540 | | 12000 | | | | 3 | 70 | 1.5 | 1.25 |
| 06/05/14 | To | 07/04/14 | 07/07/14 | To | 07/11/14 | -115 | 13425 | -275 | 11725 | 8 | -480 | -795 | 4 | 50 | 1.75 | 1.25 |
| 06/12/14 | To | 07/11/14 | 07/14/14 | To | 07/18/14 | 345 | 13770 | 265 | 11990 | 4 | -255 | -255 | 2 | 70 | 1 | 2.5 |
| 06/19/14 | To | 07/18/14 | 07/21/14 | To | 07/25/14 | 120 | 13890 | 80 | 12070 | 2 | 0 | 0 | 1 | 60 | 1.25 | 1.25 |
| 06/26/14 | To | 07/25/14 | 07/28/14 | To | 08/01/14 | 395 | 14285 | 295 | 12365 | 5 | -390 | -390 | 1 | 50 | 1.75 | 1.25 |
| 07/03/14 | To | 08/01/14 | 08/04/14 | To | 08/08/14 | 395 | 14680 | 355 | 12720 | 2 | -60 | -60 | 4 | 70 | 3 | 1.75 |
| 07/10/14 | To | 08/08/14 | 08/11/14 | To | 08/15/14 | -365 | 14315 | -385 | 12335 | 1 | -365 | -365 | 1 | 50 | 2.5 | 1.25 |

| In-Sample Dates | | | Out-Of-Sample Dates | | | osnp | Eq | NOnp$20 | NetEq | ont | ollt | odd | pw | N | vup | vdn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 07/17/14 | To | 08/15/14 | 08/18/14 | To | 08/22/14 | | 14315 | | 12335 | | | | 3 | 70 | 1.5 | 3 |
| 07/24/14 | To | 08/22/14 | 08/25/14 | To | 08/29/14 | | 14315 | | 12335 | | | | 4 | 50 | 2 | 3 |
| 07/31/14 | To | 08/29/14 | 09/01/14 | To | 09/05/14 | | 14315 | | 12335 | | | | 4 | 50 | 2 | 3 |
| 08/07/14 | To | 09/05/14 | 09/08/14 | To | 09/12/14 | -135 | 14180 | -215 | 12120 | 4 | -615 | -615 | 4 | 50 | 1.25 | 2.5 |
| 08/14/14 | To | 09/12/14 | 09/15/14 | To | 09/19/14 | 660 | 14840 | 560 | 12680 | 5 | -200 | -200 | 4 | 50 | 1 | 2.5 |
| 08/21/14 | To | 09/19/14 | 09/22/14 | To | 09/26/14 | 2105 | 16945 | 1985 | 14665 | 6 | -240 | -240 | 1 | 30 | 1 | 1.75 |
| 08/28/14 | To | 09/26/14 | 09/29/14 | To | 10/03/14 | 575 | 17520 | 475 | 15140 | 5 | -650 | -650 | 2 | 60 | 1.25 | 3.25 |
| 09/04/14 | To | 10/03/14 | 10/06/14 | To | 10/10/14 | -1505 | 16015 | -1645 | 13495 | 7 | -1080 | -2485 | 2 | 60 | 1.5 | 3.25 |
| 09/11/14 | To | 10/10/14 | 10/13/14 | To | 10/17/14 | 2525 | 18540 | 2165 | 15660 | 18 | -545 | -785 | 1 | 30 | 2 | 1 |
| 09/18/14 | To | 10/17/14 | 10/20/14 | To | 10/24/14 | | 18540 | | 15660 | | | | 4 | 40 | 3 | 3.25 |
| 09/25/14 | To | 10/24/14 | 10/27/14 | To | 10/31/14 | -115 | 18425 | -155 | 15505 | 2 | -105 | -115 | 4 | 40 | 3 | 3.25 |
| 10/02/14 | To | 10/31/14 | 11/03/14 | To | 11/07/14 | | 18425 | | 15505 | | | | 4 | 40 | 3 | 3.25 |
| 10/09/14 | To | 11/07/14 | 11/10/14 | To | 11/14/14 | -185 | 18240 | -205 | 15300 | 1 | -185 | -185 | 1 | 50 | 1.75 | 3.5 |
| 10/16/14 | To | 11/14/14 | 11/17/14 | To | 11/21/14 | -290 | 17950 | -350 | 14950 | 3 | -215 | -290 | 2 | 20 | 1.25 | 2.5 |
| 10/23/14 | To | 11/21/14 | 11/24/14 | To | 11/28/14 | | 17950 | | 14950 | | | | 2 | 40 | 1.5 | 2 |
| 10/30/14 | To | 11/28/14 | 12/01/14 | To | 12/05/14 | -590 | 17360 | -690 | 14260 | 5 | -355 | -715 | 2 | 60 | 1.25 | 2.25 |
| 11/06/14 | To | 12/05/14 | 12/08/14 | To | 12/12/14 | 1005 | 18365 | 885 | 15145 | 6 | -1355 | -1615 | 2 | 40 | 2.5 | 1 |
| 11/13/14 | To | 12/12/14 | 12/15/14 | To | 12/19/14 | -870 | 17495 | -1470 | 13675 | 30 | -810 | -1740 | 4 | 20 | 2.75 | 1.75 |
| 11/20/14 | To | 12/19/14 | 12/22/14 | To | 12/26/14 | | 17495 | | 13675 | | | | 1 | 60 | 3.25 | 1.25 |
| 11/27/14 | To | 12/26/14 | 12/29/14 | To | 01/02/15 | 570 | 18065 | 530 | 14205 | 2 | 0 | 0 | 2 | 60 | 3.5 | 1.75 |
| 12/04/14 | To | 01/02/15 | 01/05/15 | To | 01/09/15 | 1685 | 19750 | 1585 | 15790 | 5 | -145 | -145 | 1 | 40 | 3.25 | 2.25 |
| 12/11/14 | To | 01/09/15 | 01/12/15 | To | 01/16/15 | -460 | 19290 | -540 | 15250 | 4 | -1315 | -1315 | 1 | 60 | 2.5 | 2.25 |
| 12/18/14 | To | 01/16/15 | 01/19/15 | To | 01/23/15 | 1310 | 20600 | 1210 | 16460 | 5 | -570 | -570 | 3 | 40 | 2.75 | 2.25 |
| 12/25/14 | To | 01/23/15 | 01/26/15 | To | 01/30/15 | 125 | 20725 | 45 | 16505 | 4 | -735 | -1020 | 3 | 30 | 2.25 | 3.25 |
| 01/01/15 | To | 01/30/15 | 02/02/15 | To | 02/06/15 | 1410 | 22135 | 1370 | 17875 | 2 | -65 | -65 | 2 | 30 | 2.5 | 3.25 |
| 01/08/15 | To | 02/06/15 | 02/09/15 | To | 02/13/15 | | 22135 | | 17875 | | | | 4 | 60 | 2.5 | 3.5 |
| 01/15/15 | To | 02/13/15 | 02/16/15 | To | 02/20/15 | | 22135 | | 17875 | | | | 4 | 70 | 3 | 3.25 |
| 01/22/15 | To | 02/20/15 | 02/23/15 | To | 02/27/15 | | 22135 | | 17875 | | | | 1 | 50 | 2 | 3.5 |
| 01/29/15 | To | 02/27/15 | 03/02/15 | To | 03/06/15 | 200 | 22335 | 140 | 18015 | 3 | -340 | -380 | 1 | 50 | 2 | 1.75 |
| 02/05/15 | To | 03/06/15 | 03/09/15 | To | 03/13/15 | -295 | 22040 | -395 | 17620 | 5 | -400 | -650 | 3 | 70 | 1.5 | 1.75 |
| 02/12/15 | To | 03/13/15 | 03/16/15 | To | 03/20/15 | -850 | 21190 | -1010 | 16610 | 8 | -435 | -960 | 4 | 40 | 2.5 | 1.25 |
| 02/19/15 | To | 03/20/15 | 03/23/15 | To | 03/27/15 | 1585 | 22775 | 1505 | 18115 | 4 | -375 | -375 | 4 | 60 | 3.25 | 2 |
| 02/26/15 | To | 03/27/15 | 03/30/15 | To | 04/03/15 | 10 | 22785 | -70 | 18045 | 4 | -220 | -220 | 4 | 60 | 2.25 | 2 |
| 03/05/15 | To | 04/03/15 | 04/06/15 | To | 04/10/15 | 510 | 23295 | 470 | 18515 | 2 | 0 | 0 | 3 | 50 | 2 | 3 |
| 03/12/15 | To | 04/10/15 | 04/13/15 | To | 04/17/15 | 215 | 23510 | 175 | 18690 | 2 | -90 | -90 | 4 | 30 | 1.5 | 3.25 |
| 03/19/15 | To | 04/17/15 | 04/20/15 | To | 04/24/15 | 650 | 24160 | 590 | 19280 | 3 | 0 | 0 | 4 | 50 | 1.75 | 3 |
| 03/26/15 | To | 04/24/15 | 04/27/15 | To | 05/01/15 | -1370 | 22790 | -1490 | 17790 | 6 | -825 | -2060 | 1 | 70 | 0.25 | 2.5 |
| 04/02/15 | To | 05/01/15 | 05/04/15 | To | 05/08/15 | 720 | 23510 | 640 | 18430 | 4 | -50 | -70 | 2 | 70 | 2.25 | 1.75 |
| 04/09/15 | To | 05/08/15 | 05/11/15 | To | 05/15/15 | -160 | 23350 | -240 | 18190 | 4 | -515 | -910 | 1 | 50 | 2 | 2 |
| 04/16/15 | To | 05/15/15 | 05/18/15 | To | 05/22/15 | -500 | 22850 | -520 | 17670 | 1 | -500 | -500 | 2 | 40 | 1.75 | 2.75 |
| 04/23/15 | To | 05/22/15 | 05/25/15 | To | 05/29/15 | 730 | 23580 | 650 | 18320 | 4 | -65 | -65 | 2 | 40 | 1 | 2.75 |
| 04/30/15 | To | 05/29/15 | 06/01/15 | To | 06/05/15 | 110 | 23690 | 30 | 18350 | 4 | -115 | -120 | 2 | 70 | 1.5 | 3.25 |
| 05/07/15 | To | 06/05/15 | 06/08/15 | To | 06/12/15 | 470 | 24160 | 410 | 18760 | 3 | -420 | -420 | 1 | 70 | 1.75 | 2 |
| 05/14/15 | To | 06/12/15 | 06/15/15 | To | 06/19/15 | -1220 | 22940 | -1300 | 17460 | 4 | -530 | -1220 | 3 | 70 | 2.75 | 1.5 |
| 05/21/15 | To | 06/19/15 | 06/22/15 | To | 06/26/15 | 545 | 23485 | 485 | 17945 | 3 | -45 | -45 | 4 | 60 | 2.75 | 2.25 |
| 05/28/15 | To | 06/26/15 | 06/29/15 | To | 07/03/15 | 1430 | 24915 | 1370 | 19315 | 3 | -100 | -100 | 2 | 70 | 2 | 1.5 |
| 06/04/15 | To | 07/03/15 | 07/06/15 | To | 07/10/15 | -155 | 24760 | -295 | 19020 | 7 | -1070 | -1955 | 1 | 50 | 1 | 2.75 |
| 06/11/15 | To | 07/10/15 | 07/13/15 | To | 07/17/15 | -360 | 24400 | -380 | 18640 | 1 | -360 | -360 | 2 | 50 | 2.25 | 2 |
| 06/18/15 | To | 07/17/15 | 07/20/15 | To | 07/24/15 | 600 | 25000 | 540 | 19180 | 3 | -260 | -260 | 2 | 50 | 2 | 1.75 |
| 06/25/15 | To | 07/24/15 | 07/27/15 | To | 07/31/15 | 1015 | 26015 | 935 | 20115 | 4 | -135 | -250 | 4 | 20 | 2 | 2.25 |
| 07/02/15 | To | 07/31/15 | 08/03/15 | To | 08/07/15 | -945 | 25070 | -985 | 19130 | 2 | -600 | -945 | 1 | 50 | 2.75 | 2.75 |
| 07/09/15 | To | 08/07/15 | 08/10/15 | To | 08/14/15 | 1015 | 26085 | 935 | 20065 | 4 | -415 | -415 | 2 | 70 | 1.75 | 3.5 |
| 07/16/15 | To | 08/14/15 | 08/17/15 | To | 08/21/15 | -930 | 25155 | -1290 | 18775 | 18 | -925 | -2720 | 4 | 50 | 2.5 | 2.5 |
| 07/23/15 | To | 08/21/15 | 08/24/15 | To | 08/28/15 | 1355 | 26510 | 1135 | 19910 | 11 | -1275 | -1835 | 1 | 70 | 1.25 | 3 |

| In-Sample Dates | | | Out-Of-Sample Dates | | | osnp | Eq | NOnp$20 | NetEq | ont | ollt | odd | pw | N | vup | vdn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 07/30/15 | To | 08/28/15 | 08/31/15 | To | 09/04/15 | 1970 | 28480 | 1870 | 21780 | 5 | -690 | -690 | 1 | 60 | 2.25 | 2.5 |
| 08/06/15 | To | 09/04/15 | 09/07/15 | To | 09/11/15 | 1325 | 29805 | 1265 | 23045 | 3 | -475 | -475 | 2 | 40 | 3.5 | 3.25 |
| 08/13/15 | To | 09/11/15 | 09/14/15 | To | 09/18/15 | -1640 | 28165 | -1720 | 21325 | 4 | -575 | -1640 | 4 | 40 | 3.5 | 3.5 |
| 08/20/15 | To | 09/18/15 | 09/21/15 | To | 09/25/15 | 1440 | 29605 | 1340 | 22665 | 5 | -205 | -295 | 4 | 40 | 3.5 | 3.5 |
| 08/27/15 | To | 09/25/15 | 09/28/15 | To | 10/02/15 | 2445 | 32050 | 2325 | 24990 | 6 | -800 | -1110 | 1 | 30 | 1.75 | 3.5 |
| 09/03/15 | To | 10/02/15 | 10/05/15 | To | 10/09/15 | 260 | 32310 | 220 | 25210 | 2 | 0 | 0 | 3 | 40 | 2.25 | 3 |
| 09/10/15 | To | 10/09/15 | 10/12/15 | To | 10/16/15 | -110 | 32200 | -130 | 25080 | 1 | -110 | -110 | 1 | 30 | 2.5 | 2.25 |
| 09/17/15 | To | 10/16/15 | 10/19/15 | To | 10/23/15 | 610 | 32810 | 570 | 25650 | 2 | 0 | 0 | 1 | 70 | 1.75 | 3.25 |
| 09/24/15 | To | 10/23/15 | 10/26/15 | To | 10/30/15 | -1070 | 31740 | -1090 | 24560 | 1 | -1070 | -1070 | 1 | 40 | 3 | 3.5 |
| 10/01/15 | To | 10/30/15 | 11/02/15 | To | 11/06/15 | -465 | 31275 | -525 | 24035 | 3 | -465 | -480 | 1 | 20 | 2.25 | 2.25 |
| 10/08/15 | To | 11/06/15 | 11/09/15 | To | 11/13/15 | 1585 | 32860 | 1545 | 25580 | 2 | 0 | 0 | 4 | 40 | 2.75 | 2.5 |
| 10/15/15 | To | 11/13/15 | 11/16/15 | To | 11/20/15 | -1540 | 31320 | -1620 | 23960 | 4 | -1095 | -1635 | 4 | 60 | 2.75 | 2 |
| 10/22/15 | To | 11/20/15 | 11/23/15 | To | 11/27/15 | -580 | 30740 | -660 | 23300 | 4 | -540 | -625 | 1 | 20 | 2 | 1.75 |
| 10/29/15 | To | 11/27/15 | 11/30/15 | To | 12/04/15 | 2725 | 33465 | 2645 | 25945 | 4 | 0 | 0 | 1 | 70 | 2.25 | 1.5 |
| 11/05/15 | To | 12/04/15 | 12/07/15 | To | 12/11/15 | 975 | 34440 | 895 | 26840 | 4 | -590 | -590 | 1 | 40 | 2.75 | 2.25 |
| 11/12/15 | To | 12/11/15 | 12/14/15 | To | 12/18/15 | 105 | 34545 | -55 | 26785 | 8 | -815 | -1600 | 3 | 20 | 2.25 | 3.5 |
| 11/19/15 | To | 12/18/15 | 12/21/15 | To | 12/25/15 | -415 | 34130 | -435 | 26350 | 1 | -415 | -415 | 2 | 40 | 3 | 2.25 |
| 11/26/15 | To | 12/25/15 | 12/28/15 | To | 01/01/16 | 555 | 34685 | 535 | 26885 | 1 | 0 | 0 | 1 | 60 | 1.5 | 3.25 |
| 12/03/15 | To | 01/01/16 | 01/04/16 | To | 01/08/16 | -3030 | 31655 | -3230 | 23655 | 10 | -1355 | -3030 | 3 | 60 | 3 | 3 |
| 12/10/15 | To | 01/08/16 | 01/11/16 | To | 01/15/16 | 535 | 32190 | 375 | 24030 | 8 | -2000 | -2000 | 1 | 70 | 3.25 | 2 |
| 12/17/15 | To | 01/15/16 | 01/18/16 | To | 01/22/16 | 1840 | 34030 | 1760 | 25790 | 4 | -330 | -330 | 1 | 30 | 2.5 | 3.5 |
| 12/24/15 | To | 01/22/16 | 01/25/16 | To | 01/29/16 | -2900 | 31130 | -3060 | 22730 | 8 | -1795 | -4490 | 1 | 60 | 2.5 | 3.5 |
| 12/31/15 | To | 01/29/16 | 02/01/16 | To | 02/05/16 | 595 | 31725 | 535 | 23265 | 3 | 0 | 0 | 1 | 20 | 2.5 | 3.5 |
| 01/07/16 | To | 02/05/16 | 02/08/16 | To | 02/12/16 | -785 | 30940 | -945 | 22320 | 8 | -1015 | -2420 | 1 | 40 | 1.5 | 3.5 |
| 01/14/16 | To | 02/12/16 | 02/15/16 | To | 02/19/16 | -700 | 30240 | -780 | 21540 | 4 | -590 | -1065 | 1 | 20 | 3.5 | 0.5 |
| 01/21/16 | To | 02/19/16 | 02/22/16 | To | 02/26/16 | 2190 | 32430 | 2070 | 23610 | 6 | -500 | -500 | 1 | 70 | 0.5 | 3.5 |
| 01/28/16 | To | 02/26/16 | 02/29/16 | To | 03/04/16 | 1800 | 34230 | 1760 | 25370 | 2 | -25 | -25 | 1 | 60 | 2 | 1.75 |
| 02/04/16 | To | 03/04/16 | 03/07/16 | To | 03/11/16 | -605 | 33625 | -785 | 24585 | 9 | -900 | -1375 | 2 | 30 | 0.75 | 3.5 |
| 02/11/16 | To | 03/11/16 | 03/14/16 | To | 03/18/16 | | 33625 | | 24585 | | | | 2 | 60 | 2.5 | 3 |
| 02/18/16 | To | 03/18/16 | 03/21/16 | To | 03/25/16 | | 33625 | | 24585 | | | | 1 | 60 | 3 | 1.75 |
| 02/25/16 | To | 03/25/16 | 03/28/16 | To | 04/01/16 | 1525 | 35150 | 1465 | 26050 | 3 | -185 | -185 | 2 | 50 | 2 | 2.25 |
| 03/03/16 | To | 04/01/16 | 04/04/16 | To | 04/08/16 | 895 | 36045 | 815 | 26865 | 4 | -700 | -700 | 1 | 50 | 1.75 | 2.25 |
| 03/10/16 | To | 04/08/16 | 04/11/16 | To | 04/15/16 | 1185 | 37230 | 1125 | 27990 | 3 | -210 | -210 | 2 | 40 | 2.5 | 2 |
| 03/17/16 | To | 04/15/16 | 04/18/16 | To | 04/22/16 | 295 | 37525 | 235 | 28225 | 3 | -115 | -115 | 4 | 60 | 3 | 1.75 |
| 03/24/16 | To | 04/22/16 | 04/25/16 | To | 04/29/16 | 1300 | 38825 | 1220 | 29445 | 4 | -380 | -380 | 4 | 60 | 3.25 | 1.75 |
| 03/31/16 | To | 04/29/16 | 05/02/16 | To | 05/06/16 | -785 | 38040 | -865 | 28580 | 4 | -945 | -1080 | 1 | 70 | 2.75 | 1.25 |
| 04/07/16 | To | 05/06/16 | 05/09/16 | To | 05/13/16 | -830 | 37210 | -870 | 27710 | 2 | -560 | -830 | 3 | 30 | 1.75 | 3.5 |
| 04/14/16 | To | 05/13/16 | 05/16/16 | To | 05/20/16 | 5 | 37215 | -135 | 27575 | 7 | -305 | -700 | 1 | 50 | 1.5 | 2 |
| 04/21/16 | To | 05/20/16 | 05/23/16 | To | 05/27/16 | 1055 | 38270 | 995 | 28570 | 3 | 0 | 0 | 1 | 30 | 1 | 3 |
| 04/28/16 | To | 05/27/16 | 05/30/16 | To | 06/03/16 | 740 | 39010 | 660 | 29230 | 4 | -40 | -40 | 1 | 30 | 1 | 3.25 |
| 05/05/16 | To | 06/03/16 | 06/06/16 | To | 06/10/16 | -405 | 38605 | -485 | 28745 | 4 | -250 | -525 | 4 | 70 | 2 | 2.5 |
| 05/12/16 | To | 06/10/16 | 06/13/16 | To | 06/17/16 | 660 | 39265 | 540 | 29285 | 6 | -500 | -715 | 4 | 60 | 1.5 | 3.25 |
| 05/19/16 | To | 06/17/16 | 06/20/16 | To | 06/24/16 | -110 | 39155 | -330 | 28955 | 11 | -735 | -770 | 3 | 60 | 2.25 | 1.5 |
| 05/26/16 | To | 06/24/16 | 06/27/16 | To | 07/01/16 | 2035 | 41190 | 1935 | 30890 | 5 | -55 | -55 | 1 | 60 | 1.75 | 1.75 |
| 06/02/16 | To | 07/01/16 | 07/04/16 | To | 07/08/16 | -35 | 41155 | -135 | 30755 | 5 | -715 | -810 | 1 | 70 | 1.5 | 1.75 |
| 06/09/16 | To | 07/08/16 | 07/11/16 | To | 07/15/16 | -140 | 41015 | -180 | 30575 | 2 | -80 | -140 | 1 | 40 | 2 | 3.5 |
| 06/16/16 | To | 07/15/16 | 07/18/16 | To | 07/22/16 | | 41015 | | 30575 | | | | 1 | 50 | 2.5 | 3.5 |
| 06/23/16 | To | 07/22/16 | 07/25/16 | To | 07/29/16 | -130 | 40885 | -150 | 30425 | 1 | -130 | -130 | 1 | 40 | 2.25 | 3.5 |
| 06/30/16 | To | 07/29/16 | 08/01/16 | To | 08/05/16 | -625 | 40260 | -665 | 29760 | 2 | -330 | -625 | 3 | 60 | 2 | 1.5 |
| 07/07/16 | To | 08/05/16 | 08/08/16 | To | 08/12/16 | 190 | 40450 | 170 | 29930 | 1 | 0 | 0 | 4 | 70 | 1.75 | 2.75 |
| 07/14/16 | To | 08/12/16 | 08/15/16 | To | 08/19/16 | 525 | 40975 | 425 | 30355 | 5 | -160 | -210 | 3 | 60 | 0.75 | 2.75 |
| 07/21/16 | To | 08/19/16 | 08/22/16 | To | 08/26/16 | -940 | 40035 | -1040 | 29315 | 5 | -335 | -940 | 1 | 50 | 1.25 | 1.75 |
| 07/28/16 | To | 08/26/16 | 08/29/16 | To | 09/02/16 | 80 | 40115 | 0 | 29315 | 4 | -340 | -465 | 4 | 40 | 2.5 | 1 |
| 08/04/16 | To | 09/02/16 | 09/05/16 | To | 09/09/16 | 1735 | 41850 | 1695 | 31010 | 2 | 0 | 0 | 4 | 40 | 2.5 | 1.25 |

| In-Sample Dates | | | Out-Of-Sample Dates | | | osnp | Eq | NOnp$20 | NetEq | ont | ollt | odd | pw | N | vup | vdn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 08/11/16 | To | 09/09/16 | 09/12/16 | To | 09/16/16 | 830 | 42680 | 510 | 31520 | 16 | -295 | -725 | 2 | 30 | 1.5 | 1.5 |
| 08/18/16 | To | 09/16/16 | 09/19/16 | To | 09/23/16 | 600 | 43280 | 580 | 32100 | 1 | 0 | 0 | 2 | 20 | 2 | 2.5 |
| 08/25/16 | To | 09/23/16 | 09/26/16 | To | 09/30/16 | 110 | 43390 | 50 | 32150 | 3 | -160 | -165 | 1 | 20 | 2 | 2.5 |
| 09/01/16 | To | 09/30/16 | 10/03/16 | To | 10/07/16 | -240 | 43150 | -300 | 31850 | 3 | -365 | -470 | 1 | 20 | 2.25 | 2 |
| 09/08/16 | To | 10/07/16 | 10/10/16 | To | 10/14/16 | -355 | 42795 | -395 | 31455 | 2 | -530 | -530 | 3 | 20 | 3 | 2 |
| 09/15/16 | To | 10/14/16 | 10/17/16 | To | 10/21/16 | 260 | 43055 | 200 | 31655 | 3 | -85 | -85 | 3 | 20 | 3.25 | 1.75 |
| 09/22/16 | To | 10/21/16 | 10/24/16 | To | 10/28/16 | 1585 | 44640 | 1425 | 33080 | 8 | -245 | -400 | 2 | 60 | 2 | 1.25 |
| 09/29/16 | To | 10/28/16 | 10/31/16 | To | 11/04/16 | 1050 | 45690 | 990 | 34070 | 3 | 0 | 0 | 2 | 40 | 2.75 | 1.75 |
| 10/06/16 | To | 11/04/16 | 11/07/16 | To | 11/11/16 | 1170 | 46860 | 930 | 35000 | 12 | -510 | -780 | 1 | 30 | 2 | 1.5 |
| 10/13/16 | To | 11/11/16 | 11/14/16 | To | 11/18/16 | 155 | 47015 | 95 | 35095 | 3 | -140 | -140 | 1 | 40 | 1.75 | 3 |
| 10/20/16 | To | 11/18/16 | 11/21/16 | To | 11/25/16 | 155 | 47170 | 135 | 35230 | 1 | 0 | 0 | 2 | 50 | 2.25 | 3.25 |
| 10/27/16 | To | 11/25/16 | 11/28/16 | To | 12/02/16 | -1390 | 45780 | -1490 | 33740 | 5 | -825 | -1390 | 2 | 70 | 0.75 | 3.5 |
| 11/03/16 | To | 12/02/16 | 12/05/16 | To | 12/09/16 | 1330 | 47110 | 1290 | 35030 | 2 | 0 | 0 | 2 | 50 | 2.25 | 3.25 |
| 11/10/16 | To | 12/09/16 | 12/12/16 | To | 12/16/16 | -105 | 47005 | -205 | 34825 | 5 | -230 | -310 | 1 | 60 | 2 | 1.25 |
| 11/17/16 | To | 12/16/16 | 12/19/16 | To | 12/23/16 | | 47005 | | 34825 | | | | 4 | 50 | 1.75 | 3.5 |
| 11/24/16 | To | 12/23/16 | 12/26/16 | To | 12/30/16 | -450 | 46555 | -490 | 34335 | 2 | -375 | -450 | 3 | 40 | 2 | 2.5 |
| 12/01/16 | To | 12/30/16 | 01/02/17 | To | 01/06/17 | | 46555 | | 34335 | | | | 4 | 20 | 2.5 | 2.5 |

## What is the $n^{th}$ Order Polynomial ?

The $n^{th}$ Order Polynomial, also called the $n^{th}$ Order Fixed Memory Polynomial, is simply the least square fit of a polynomial of the form $\mathbf{b_0+b_1*t+b_2*t^2+b_3*t^3+\ldots b_n*t^n}$ to a ***fixed*** number of past data points. Where **t** is discrete time bars. Time could be daily bars or one minute bars. We use the term "Fixed Memory" to designate that only a fixed number of data points are used to calculate the polynomial coefficients. It is assumed that the time bars occur at fixed intervals of time so tic bars would not be appropriate for this analysis. Least squares is a mathematical technique where the squared vertical distance between the data and the curve that is being fit to the data is minimized. When the net squared distance (also called the sum of the squared errors) is minimized, a unique set of coefficients $\mathbf{b_0,b_1,b_2,\ldots,b_n}$ for the polynomial is determined. This type of error minimization is mathematically solvable and is widely used in science and mathematics.

For a $4^{th}$ order polynomial equation, the least squares coefficients are obtained from the solution of the following matrix equation.

$$\begin{vmatrix} T & \sum t & \sum t^2 & \sum t^3 & \sum t^4 \\ \sum t & \sum t^2 & \sum t^3 & \sum t^4 & \sum t^5 \\ \sum t^2 & \sum t^3 & \sum t^4 & \sum t^5 & \sum t^6 \\ \sum t^3 & \sum t^4 & \sum t^5 & \sum t^6 & \sum t^7 \\ \sum t^4 & \sum t^5 & \sum t^6 & \sum t^7 & \sum t^8 \end{vmatrix} \begin{vmatrix} a_0 \\ b_0 \\ c_0 \\ d_0 \\ e_0 \end{vmatrix} = \begin{vmatrix} \sum p(t) \\ \sum (p(t)*t) \\ \sum (p(t)*t^2) \\ \sum (p(t)*t^3) \\ \sum (p(t)*t^4) \end{vmatrix}$$

where

**p(T)** is the current bar's price, **p(T-1)** is the previous bar's price and **p(1)** is the price **T** bars ago.
**T** is the number of Bars in the Least Squares estimation
**∑p(t)** is the summation of prices from **t=1 to T** bars
**∑p(t)*t** is the summation of prices times t from **t=1 to T** bars
**∑t** is the summation of the integer **t** from **t=1 to T** bars
$\mathbf{\sum t^2}$ is the summation of the integer **t** squared from **t=1 to T** bars
etc.

Once the coefficients to the polynomial have been solved for we generate the forecast for the next bar's price which is given for the equation by:

$$\mathbf{P_f = a_0 + b_0*(T+1) + c_0*(T+1)^2 + d_0*(T+1)^3 + e_0*(T+1)^4}$$

Where $\mathbf{P_f}$ stands for price forecast.

With these coefficients, we can also generate the forecast for the next bar's ***velocity*** and ***velocity*** by the equations:

$$\mathbf{Velocity(T+1) = dP_f /dt = b_0 + 2c_0*(T+1) + 3d_0*(T+1)^2 + 4e_0*(T+1)^3}$$

$$\mathbf{Velocity(t+1) = d^2P_f /d^2t = 2 c_0 + 6d_0*(T+1) + 12e_0*(T+1)^2}$$

We use the next bar forecast because changes in the trend are more quickly reflected in the forecast price, velocity and velocity than in the end point price, velocity and velocity.

Programs that solve for the solution to matrix equations can be found in the book "Numerical Recipes" by W. Press, et. al. However these type of matrix equation solvers are very slow and for these type of problems are unstable. They cause numerical errors and floating point overflows due to matrix inversion ill conditioning which produces false results.

Fortunately these type of problems can be solved by a fast, efficient and accurate algorithm using Discrete

## Appendix I: $n^{th}$ Order Polynomial Next Bar's Forecast Math

Orthogona1 Legendre Polynomials. This method is explained in detail in Norman Morrison' book entitled "Introduction to Sequential Smoothing and Prediction", Chapter 7 page 223., referenced at the end of this section.

Without going into detail here (see Morrison reference), the polynomial filter can now be represented by:

$$P_e(t) = \sum_{j=0}^{n} \beta_j * \phi_j(t) \quad j=0 \text{ to } n$$

Where **n** is the polynomial order, **T** is the total number of Bars of data used in the Least Squares fit and

$$\beta_j = \sum_{k=0}^{T-1} p(t-T+k) * \phi_j(k)$$

**$\phi_j(t)$ = the *normalized* discrete Legendre polynomial. t = an integer from 0 to T**

The coefficients, $\beta_0, \beta_1, \beta_2, \beta_3, , , , \beta_n$ for a **$n^{th}$** order polynomial can now be solved for by the equation above and we can generate the forecast for the next bar's close, velocity and velocity which are given by the equations

$$P_F(T+1) = \beta_0*\phi_0(T+1) + \beta_1*\phi_1(T+1) + \beta_2*\phi_2(T+1) + \beta_3*\phi_3(T+1) + \ldots + \beta_n*\phi_n(T+1)$$

$$\text{Velocity} = (dP_F/dt)_{(T+1)} = \beta_1*(d\phi_1/dt)_{(T+1)} + \beta_2*(d\phi_2/dt)_{(T+1)} + \beta_3*(d\phi_3/dt)_{(T+1)} ++ \beta_n*(d\phi_n/dt)_{(T+1)}$$

$$\text{Velocity} = (d^2P_F/d^2t)_{(T+1)} = \beta_2*(d^2\phi_2/d^2t)_{(T+1)} + \beta_3*(d^2\phi_3/d^2t)_{(T+1)} + \ldots + \beta_n*(d^2\phi_n/d^2t)_{(T+1)}$$

## The $n^{th}$ Order Fixed Memory Forecast Next Bar's Velocity Strategy Defined

The least squares forecast is constructed by solving for the least squares coefficients $\beta_1, \beta_2, , , \beta_n$ at each bar using the last **T** bars of closing prices and the Discrete Orthogonal Legendre Polynomial equations for $\beta_j$ above. Then **Velocity** = **$d^2P_F(T+1)/d^2t$** is constructed from the velocity equation above and plotted under the price chart. In general what we will be doing is following the plotted curve of **Velocity** which is calculated at each bar from the previous T bars. When the velocity is greater than a threshold amount ***vup*** we will go long. When the velocity is less than a threshold amount ***-vdn*** we will go short.

***Buy Rule:***
**IF Velocity** is greater than the threshold amount ***vup*** then buy at the market.

***Sell Rule:***
**IF Velocity** is less than the threshold amount ***-vdn*** then sell at the market.

## References


1. Morrison, Norman "Introduction to Sequential Smoothing and Prediction", McGraw-Hill Book Company, New York, 1969.

# The *Normalization Multiplier*

## What is the Multiplier ?

The $n^{th}$ Order Fixed Memory Polynomial, also called an $n^{th}$ Order Polynomial, is the least square fit of a polynomial of the form $\mathbf{b_0+b_1*t+b_2*t^2+b_3*t^3+\ldots+b_n*t^n}$ to a ***fixed*** number of past data points. Where **t** is discrete time bars. Time could be daily bars or one minute bars. We use the term “Fixed Memory” to designate that only a fixed number of data points are used to calculate the polynomial coefficients. It is assumed that the time bars occur at fixed intervals of time so tic bars would not be appropriate for this analysis. Least squares is a mathematical technique where the squared vertical distance between the data and the curve that is being fit to the data is minimized. When the net squared distance (also called the sum of the squared errors) is minimized, a unique set of coefficients $\mathbf{b_0,b_1,b_2,\ldots,b_n}$ for the polynomial is determined. This type of error minimization is mathematically solvable and is widely used in science and mathematics. Once the $\mathbf{b_n}$ coefficients are found using a lookback period of **T** bars to calculate the $\mathbf{b_n}$ coefficients, then the next bar’s estimate **(T+1)** of the $n^{th}$ order polynomial velocity and acceleration can be easily found by the equations below.

$$\textbf{Velocity(T+1)} = dP_f/dt = b_0 + 2c_0*(T+1) + 3d_0*(T+1)^2 + 4e_0*(T+1)^3 + \ldots + n*b_n*(T+1)^{n-1}$$

$$\textbf{Acceleration(t+1)} = d^2P_f/d^2t = 2c_0 + 9d_0*(T+1) + 12e_0*(T+1)^3 + \ldots + n*(n-1)*b_n*(T+1)^{n-2}$$

Please see the $\boldsymbol{n^{th}}$ **Order Fixed Memory Polynomial Next Bar’s Forecast Math** section for a more detailed explanation.

For any tradable, the inputs to the polynomial are the **polynomial degree(Order)** and the number or lookback bars **N** (denoted by T in equations above). When we plot the velocity or acceleration we notice that the amplitude, and the maximum and minimum values of the velocity or acceleration vary quite significantly with different degree and N inputs.

Below is a table of the standard deviation(SD) of the 56340 calculated Velocity values for different **degree** and **N** inputs. We used 1min bars of the E-Mini from 8/1/2014 to 2/20/2015 to generate this table. As one can see the standard deviation of the velocity for each degree and N vary greatly. For instance for degree=4, N=20 the SD is 6.8 times the SD for degree=1, N=20. This creates problems when trying to determine the correct ranges for vup/vdn and aup/adn during optimization.

**@ES.D 1 min bars Date Range 1140801 to 1150220**
**Total Number of Bars=56340 Norm=0**
**FixmVn Multiplier= 1/SD to Scale Velocity pw and N Range to One SD**

| Degree | N | SD | 1/SD |
|---|---|---|---|
| 1 | 20 | 0.1902 | 5.2565 |
| 1 | 30 | 0.1540 | 6.4916 |
| 1 | 40 | 0.1328 | 7.5279 |
| 1 | 50 | 0.1183 | 8.4502 |
| 1 | 60 | 0.1077 | 9.2880 |
| 1 | 70 | 0.0996 | 10.0440 |
| avg | | 0.1338 | 7.8430 |
| | | | |
| 2 | 20 | 0.4351 | 2.2982 |
| 2 | 30 | 0.3443 | 2.9046 |
| 2 | 40 | 0.2936 | 3.4060 |
| 2 | 50 | 0.1583 | 3.8275 |
| 2 | 60 | 0.2371 | 4.2180 |
| 2 | 70 | 0.2173 | 4.6010 |
| avg | | 0.2981 | 3.5425 |
| | | | |
| 3 | 20 | 0.7854 | 1.2732 |

| | | | |
|---|---|---|---|
| 3 | 30 | 0.5933 | 1.6855 |
| 3 | 40 | 0.4973 | 2.0111 |
| 3 | 50 | 0.4347 | 2.3005 |
| 3 | 60 | 0.3949 | 2.5324 |
| 3 | 70 | 0.3656 | 2.7352 |
| avg | | 0.5119 | 2.0897 |
| | | | |
| 4 | 20 | 1.2924 | 0.7738 |
| 4 | 30 | 0.9279 | 1.0777 |
| 4 | 40 | 0.7582 | 1.3189 |
| 4 | 5 | 0.6542 | 1.5285 |
| 4 | 60 | 0.5804 | 1.7228 |
| 4 | 70 | 0.5314 | 1.8818 |
| avg | | 0.7908 | 1.3839 |

The problem may get worse when we want to find good inputs for other tradables. Other tradables, because of their scales and tick size have much different Velocity ranges then the E-Mini for the same degree and N. Thus the NS search ranges have to be different for each different tradable.

To solve this problem and to have a standard search space for each tradable, I created a **Mult** input for each FixmXVA Velocity and Acceleration strategy and indicator. If each tradable's Velocity is multiplied by a number such that the standard deviation of that tradable's Velocity is around one, then the search space for vup and vdn for each tradable would be 0 to 3.5 SDs and we wouldn't have to change the TS search space every time we wanted to examine a new stock or future. The complicated equations that I use to normalize the ranges to one standard deviation were derived using the software TableCurve 3D, automated surface and equation discovery.

 