Cybernetic Analysis for Stocks and Futures

Cutting-Edge DSP Technology to Improve Your Trading

JOHN F. EHLERS

WILEY

John Wiley & Sons, Inc.

Cybernetic Analysis for Stocks and Futures

Founded in 1807, John Wiley & Sons is the oldest independent publishing company in the United States. With offices in North America, Europe, Australia, and Asia, Wiley is globally committed to developing and marketing print and electronic products and services for our customers' professional and personal knowledge and understanding.

The Wiley Trading series features books by traders who have survived the market's ever changing temperament and have prospered—some by reinventing systems, others by getting back to basics. Whether a novice trader, professional, or somewhere in between, these books will provide the advice and strategies needed to prosper today and well into the future.

For a list of available titles, visit our Web site at www.WileyFinance.com.

Cybernetic Analysis for Stocks and Futures

Cutting-Edge DSP Technology to Improve Your Trading

JOHN F. EHLERS

WILEY

John Wiley & Sons, Inc.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
Published simultaneously in Canada.

Library of Congress Cataloging-in-Publication Data:

Ehlers, John F., 1933-
Cybernetic analysis for stocks and futures : cutting-edge DSP technology to improve your trading / John F. Ehlers.
p. cm.
Includes bibliographical references.
ISBN 0-471-46307-8
1. Corporations—Valuation. 2. Chief executive officers—Rating of. 3. Investment analysis. I. Title.
HG4028.V3 E365 2004
332.63'2042—dc22 2003021212

Printed in the United States of America.

10 9 8 7 6 5 4 3 2 1

To Elizabeth—my friend,
my companion, my wife

Acknowledgments

I would like to thank Mike Burgess, Rod Hare, and Mitchell Duncan, who took time out of their busy schedules to read and critique the early manuscripts of this book. Their efforts transformed the original terse descriptions of computer code and the often rambling musings and thought processes of an engineer into a readable document having a rational flow for you, the reader.

Tools are very important in our technological age. I would like to thank TradeStation Technologies for their platform, which made the development of trading systems possible. I would also like to thank eSignal for making their platform available for indicator development and Chris Kryza for converting my code to eSignal Formula Script. Additionally, I would like to thank Steve Ward, who made the resources of NeuroShell Trader available, thus enabling readers to extend the usefulness of my indicators by using neural networks and genetic algorithms.

I would also like to thank Mike Barna for showing me how to apply the coin toss methodology to trading strategy evaluation.

J. F. E.

Contents

Introduction

"This is a synopsis of my book," Tom said abstractly.

As Sir Arthur C. Clarke has noted, any significantly advanced technology is indistinguishable from magic. The advances made in computer technology in the past two decades have been dramatic and can qualify as nearly magical. The computer on my desk today is far more powerful than that which was available to the entire national defense system just 30 years ago. Software for traders, however, has not kept pace. Most of the trading tools available today are neither different from nor more complex than the simple pencil-and-paper calculations that can be achieved through the use of mechanical adding machines. True, these calculations are now made with blinding speed and presented in colorful and eye-grabbing displays, but the power and usefulness of the underlying procedures have not changed. If anything, the relative power of the calculations has diminished because the increased speed of information exchange and increased market capitalization have caused fundamental shifts in the technical character of the market. These shifts include increased volatility and shorter periods for the market swings.

Cybernetic Analysis for Stocks and Futures promises to bring magic to the art of trading by introducing wholly new digital signal-processing techniques. The application of digital signal processing offers the advantage of viewing old problems from a new perspective. The new perspective gained by digital signal processing has led me to develop some profoundly effective new trading tools. The advances in trading tools, along with the continuing advancements in hardware capabilities, virtually ensure the continued application of digital signal processing in the future. Traders who master the new concepts, therefore, will find themselves at a great advantage when approaching the volatile market of the twenty-first century. If you like code, you will love this book. Every new technique, indicator, and automatic trading system is defined in exquisite detail in both EasyLanguage code for use in TradeStation and in eSignal Formula Script (EFS) code. They are also available as compiled DLLs to be run in NeuroShell trader.

Chapter 1 starts the wizardry off with a bang by challenging the conventional wisdom that market prices have a Gaussian probability density function (PDF). Just think about it. Do prices really have several events separated by a standard deviation from the mean across the screen as you would expect with a Gaussian PDF? Absolutely not! If the PDF is not Gaussian, then attaching significance to the one-sigma points in trading systems is, at best, just plain wrong. I show you how to establish an approximate Gaussian PDF through the application of the Fisher transform.

I derive a new zero-lag Instantaneous Trendline in Chapter 2. By dividing the market into a trend component and a cycle component, I create a zero-lag cycle oscillator from the derivation. These results are put to work by designing an automatic trend-following trading strategy in Chapter 3 and an automatic cycle-trading strategy in Chapter 4.

Several new oscillators are then derived. These include the CG Oscillator in Chapter 5 and the Relative Vigor Index (RVI) in Chapter 6. The performance of the Cyber Cycle Oscillator, the CG Oscillator, and the RVI are compared in Chapter 7. Noting that a favorite technical analysis tool is the Stochastic Relative Strength Index (RSI), where the RSI curve is sharpened by taking the Stochastic of it, I then show you in Chapter 8 how to enhance the oscillators by taking the Stochastic of them and also applying the Fisher transform.

In Chapter 9 I give an all-new exciting method of measuring market cycles. Using the Hilbert transform, a fast-reacting method of measuring cycles is derived. The validity and accuracy of these measurements are then demonstrated using several stressing theoretical waveforms. In Chapter 10 I then show you how to use the measured Dominant Cycle length to make standard indicators automatically adaptive to the measured Dominant Cycle. This adaptation makes good indicators stand out and sparkle as outstanding indicators. In Chapter 11, the cycle component of the Dominant Cycle is synthesized from the cycle measurement and displayed as the Sinewave Indicator. The advantages of the Sinewave Indicator are that it can anticipate cyclic turning points and that it is not subject to whipsaw trades when the market is in a trend. I continue the theme of adapting to the measured Dominant Cycle in Chapter 12 by showing you how to use the measurement to design an automatic trend-following trading strategy. The performance of the strategies I disclose is on par with or exceeds that of commercially available strategies.

Chapter 13 provides you with several types of filters that give vastly superior smoothing with a minimum penalty in lag. Computer code is provided for these filters, as well as tables of coefficient values. Another way to obtain superior smoothing is through the use of Laguerre polynomials. Laguerre polynomials enable smoothing to be done using a very short amount of data, as I explain in Chapter 14.

One of the problems with using backtests of automatic trading strategies is that they don't necessarily predict future performance. I describe a technique in Chapter 15 that will enable you to use the theory of probability to visualize how your trading strategy could perform. It also illustrates what historical parameters are important to make this assessment. In Chapter 16 I show you how to generate leading indicators, along with the penalty in increased noise that you must accept when these indicators are used. I conclude in Chapter 17 by showing you how to simplify the coding of simple moving averages (SMAs).

Many of the digital signal-processing techniques described in this book have been known and used in the physical sciences for many years. For example, Maximum Entropy Spectral Analysis (MESA) algorithm was originally developed by geophysicists in their exploration for oil. The small amount of data obtainable from seismic exploration demanded a solution using a short amount of data. I successfully adapted this approach and popularized it for the measurement of market cycles. More recently, the use of digital signal processing has exploded in consumer electronics, making devices such as CDs and DVDs possible. Today, complete radio receivers are constructed without the use of analog components. As we expand DSP use by introducing it to the field of trading, we will see that digital signal processing is an exciting new field, perfect for technically oriented traders. It allows us to generalize and expand the use of many traditionally used indicators as well as achieve more precise computations.

I begin each chapter with a Tom Swifty. Perhaps this is a testament to my adolescent sense of humor, but the idea is to anchor the concept of the chapter in your mind. A Tom Swifty is a play on words that follows an unvarying pattern and relies for its humor on a punning relationship between the way an adverb describes the speaker and at the same time refers significantly to the import of the speaker's statement, as in, "*I like fuzzy bunnies*," *said Tom acutely.* The combinations are endless. Since this book contains magic, perhaps I should have selected Harry Potter as a hero rather than Tom Swift.

Throughout this book my objective is to not only describe new techniques and tools but also to provide you the means to make your trading more profitable and therefore more pleasurable.

Cybernetic Analysis for Stocks and Futures

CHAPTER 1

The Fisher Transform

"I don't see any chance of a market recovery,"
said Tom improbably.

The focus of my research for more than two decades has been directed toward applying my background in engineering and signal processing to the art of trading. The goal of this book is to share the results of this research with you. Throughout the book I will demonstrate new methods for technical analysis of stocks and commodities and ways to code them for maximum efficiency and effectiveness. I will discuss methods for modeling the market to help categorize market activity. In addition to new indicators and automatic trading systems, I will explain how to turn good-performing traditional indicators into outstanding adaptive indicators. The trading systems that subsequently evolve from this analysis will seriously challenge, and often exceed, the consistent performance and profit-making capabilities of most commercially available trading systems. While much of what is covered in this book breaks new ground, it is not simply innovation for innovation's sake. Rather, it is intended to challenge conventional wisdom and illuminate the shortcomings of many prevailing approaches to systems development.

In this chapter we plunge right into an excellent example of challenging conventional wisdom. I know at least a dozen statistically based indicators that reference "the one-sigma point," "the three-sigma point," and so on. Sigma is the standard deviation from the mean. In order to have a standard deviation from the mean, one must know the probability density function (PDF). A Gaussian, or Normal, PDF is almost universally assumed. A Gaussian PDF is the familiar bell-shaped curve used to describe IQ distribution in the population and a host of other statistical descriptions. The Gaussian PDF has long "tails" that describe events that have a wide deviation from the mean with relatively low probability. With a Gaussian PDF, 68.26 percent of all occurrences fall within plus or minus one standard deviation from the mean, 95.44 percent of occurrences fall within plus or minus two standard deviations, and 99.73 percent of all occurrences fall within plus or minus three deviations. In other words, the majority of all cases fall within the one-sigma "boundary" with a Gaussian PDF. If an event falls outside the one-sigma level, then certain inferences have been drawn about what can happen in the future.

The real question here is whether the Gaussian PDF can be used to reliably describe market activity. You can easily answer that question yourself. Just think about the way prices look on a bar chart. Do you see only 68 percent of the prices clustered near the mean price? That is, do you see 32 percent of the prices separated by more than one deviation from the mean? And, do you see prices spike away from the mean nearly 5 percent of the time by two standard deviations? How often do you even see price spikes at all? If you don't see these deviations, a Gaussian PDF is not a good assumption.

The Fisher transform is a simple mathematical process used to convert any data set to a modified data set whose PDF is approximately Gaussian. Once the Fisher transform is computed, we can then analyze the transformed data set in terms of its deviation from the mean.

The Commodity Channel Index (CCI), developed by Donald Lambert, is an example of reliance on the Gaussian PDF assumption. The equation to compute the CCI is

$$\text{CCI} = \frac{\text{Price} - \text{Moving Average}}{0.015 * \text{Deviation}} \tag{1.1}$$

Deviation is computed from the difference of prices and moving average values over a period. The period of the moving average over which the computation is done is selectable by the user. The CCI can be viewed as the current deviation normalized to the standard deviation. But what gives with the 0.015 term? Well, conveniently enough, the reciprocal of 0.015 is 66.7, which is close enough to one standard deviation of a Gaussian PDF for most technical analysis work. The premise is that if prices exceed a standard deviation, they will revert to the mean. Therefore, the common rules are to sell if the CCI exceeds +100 and buy if the CCI is less than –100. Needless to say, the CCI can be improved substantially through the use of the Fisher transform.

Suppose prices behave as a square wave. If you tried to use the price crossing a moving average as a trading system, you would be destined for failure because the price has already switched to the opposite value by the time the movement is detected. There are only two price values. Therefore,

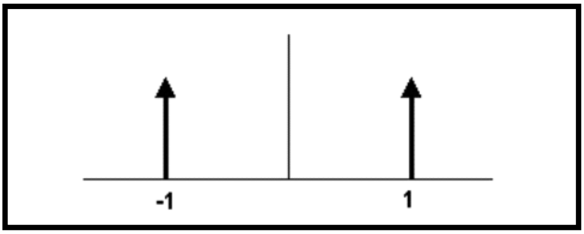

FIGURE 1.1 The Probability Distribution of a Square Wave Has Only Two Values

the probability distribution is 50 percent that the price will be at one value or the other. There are no other possibilities. The probability distribution of the square wave is shown in Figure 1.1. Clearly, this probability function does not remotely resemble a Gaussian probability distribution.

There is no great mystery about the meaning of a probability density or how it is computed. It is simply the likelihood the price will assume a given value. Think of it this way: Construct any waveform you choose by arranging beads strung on a series of parallel horizontal wires. After the waveform is created, turn the frame so the wires are vertical. All the beads will fall to the bottom, and the number of beads on each wire will stack up to demonstrate the probability of the value represented by each wire.

I used a slightly more sophisticated computer code, but nonetheless the same idea, to create the probability distribution of a sinewave in Figure 1.2. In this case, I used a total of 10,000 "beads." This PDF may be surprising, but if you stop and think about it, you will realize that most of the sampled data points of a sinewave occur near the maximum and minimum extremes. The PDF of a simple sinewave cycle is not at all similar to a Gaussian PDF. In fact, cycle PDFs are more closely related to those of a square wave. The high probability of a cycle being near the extreme values is one of the reasons why cycles are difficult to trade. About the only way to successfully trade a cycle is to take advantage of the short-term coherency and predict the cyclic turning point.

The Fisher transform changes the PDF of any waveform so that the transformed output has an approximately Gaussian PDF. The Fisher transform equation is

$$y = 0.5 * \ln\left[\frac{1+x}{1-x}\right] \tag{1.2}$$

Where x is the input
y is the output
ln is the natural logarithm

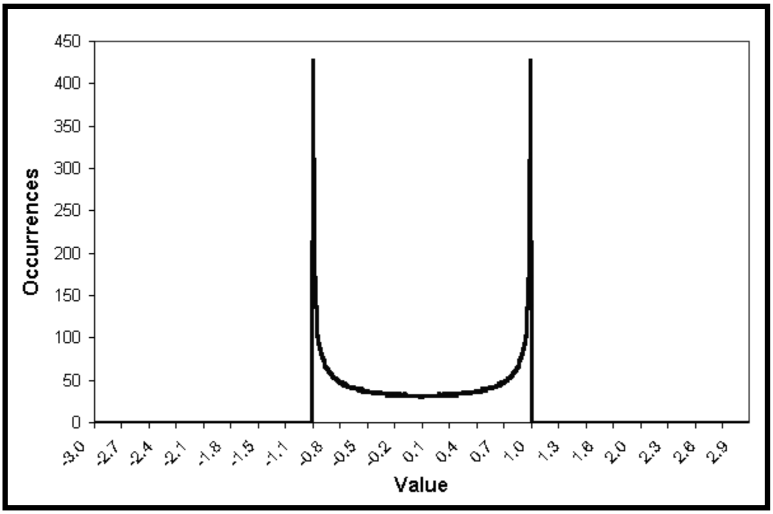

FIGURE 1.2 Sinewave Cycle PDF Does Not Resemble a Gaussian PDF

The transfer function of the Fisher transform is shown in Figure 1.3.

The input values are constrained to be within the range $-1 < X < 1$. When the input data is near the mean, the gain is approximately unity. For example, go to $x = 0.5$ in Figure 1.3. There, the Y value is only slightly larger than 0.5. By contrast, when the input approaches either limit within the

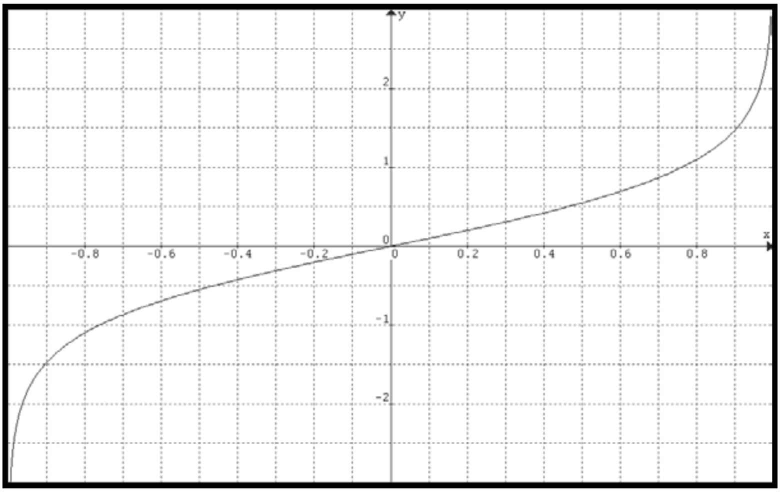

FIGURE 1.3 The Nonlinear Transfer of the Fisher Transform Converts Inputs (*x* Axis) to Outputs (*y* Axis) Having a Nearly Gaussian PDF

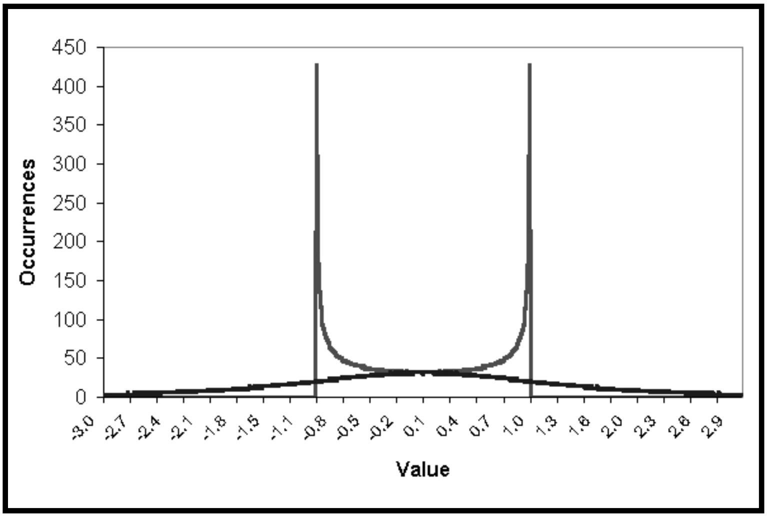

FIGURE 1.4 The Fisher-Transformed Sinewave Has a Nearly Gaussian PDF Shape

range, the output is greatly amplified. This amplification accentuates the largest deviations from the mean, providing the "tail" of the Gaussian PDF. Figure 1.4 shows the PDF of the Fisher-transformed output as the familiar bell-shaped curve, compared to the input sinewave PDF. Both have the same probability at the mean value. The transformed output PDF is nearly Gaussian, a radical change from the sinewave PDF.

I measured the probability distribution of U.S. Treasury Bond futures over a 15-year span from 1988 to 2003. To make the measurement, I created a normalized channel 10 bars long. The normalized channel is basically the same as a 10-bar Stochastic Indicator. I then measured the price location within that channel in 100 bins and counted up the number of times the price was in each bin. The results of this probability distribution measurement are shown in Figure 1.5. This actual probability distribution more closely resembles the PDF of a sinewave rather than a Gaussian PDF. I then increased the length of the normalized channel to 30 bars to test the hypothesis that the sinewave-like probability distribution is only a short-term phenomenon. The resulting probability distribution is shown in Figure 1.6. The probability distributions of Figures 1.5 and 1.6 are very similar. I will leave it to you to extend the probability analysis to any market of your choice. I predict you will get substantially similar results.

So what does this mean for trading? If the prices are normalized to fall within the range from −1 to +1 and subjected to the Fisher transform, extreme price movements are relatively rare events. This means the turning points can be clearly and unambiguously identified. The EasyLanguage

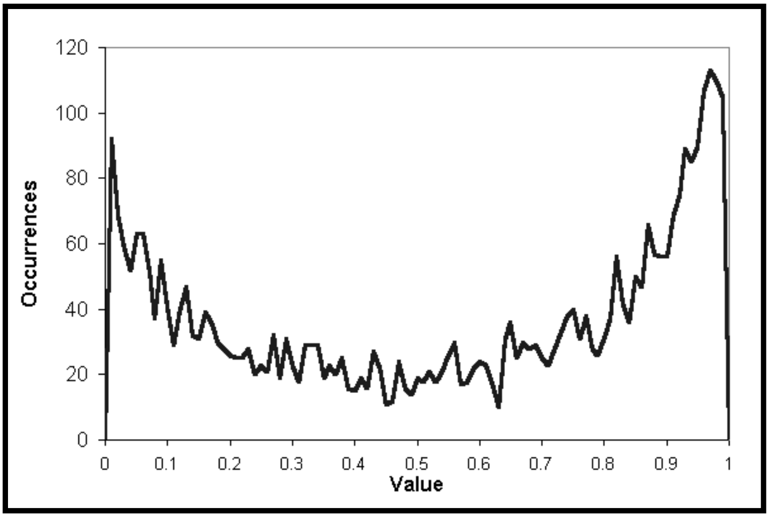

FIGURE 1.5 Probability Distribution of Treasury Bond Futures in a 10-Bar Channel over 15 Years

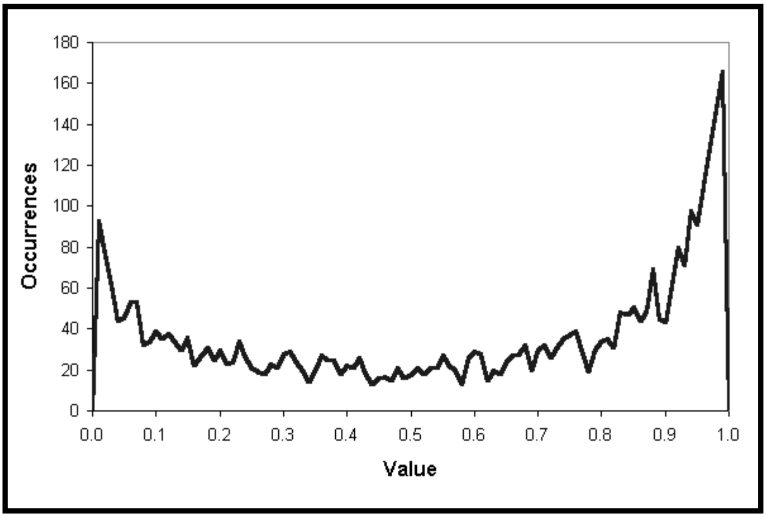

FIGURE 1.6 Probability Distribution of Treasury Bond Futures in a 30-Bar Channel over 15 Years

```
Inputs:     Price((H+L)/2),
            Len(10);

Vars:       MaxH(0),
            MinL(0),
            Fish(0);

MaxH = Highest(Price, Len);
MinL = Lowest(Price, Len);

Value1 = .5*2*((Price - MinL)/(MaxH - MinL) - .5)
   + .5*Value1[1];
If Value1 > .9999 then Value1 = .9999;
If Value1 < -.9999 then Value1 = -.9999;

Fish = 0.25*Log((1 + Value1)/(1 - Value1)) + .5*Fish[1];

Plot1(Fish, "Fisher");
Plot2(Fish[1], "Trigger");
```

FIGURE 1.7 EasyLanguage Code to Normalize Price to a 10-Day Channel and Compute Its Fisher Transform

code to do this is shown in Figure 1.7 and the eSignal Formula Script (EFS) code is shown in Figure 1.8. Value1 is a function used to normalize price within its last 10-day range. The period for the range is adjustable as an input. Value1 is centered on its midpoint and then doubled so that Value1 will swing between the –1 and +1 limits. Value1 is also smoothed with an exponential moving average whose alpha is 0.5. The smoothing may allow Value1 to exceed the 10-day price range, so limits are introduced to preclude the Fisher transform from blowing up by having an input value larger than unity. The Fisher transform is computed to be the variable “Fish”. Both Fish and Fish delayed by one bar are plotted to provide a crossover system that identifies the cyclic turning points.

```
/*****************************************************
Title:                Fisher Transform
*****************************************************/

function preMain() {
    setStudyTitle("Fisher Transform");
    setCursorLabelName("Fisher", 0);
    setCursorLabelName("Trigger", 1);
    setDefaultBarFgColor(Color.blue, 0);
    setDefaultBarFgColor(Color.red, 1);
        setDefaultBarThickness(2, 0);
    setDefaultBarThickness(2, 1);
}

var Value1 = null;
var Value1_1 = 0;
var Fish = null;
var Fish_1 = 0;
var vPrice = null;
var aPrice = null;

function main(nLength) {
    var nState = getBarState();

        if (nLength == null) nLength = 10;
        if (aPrice == null) aPrice = new Array(nLength);

    if (nState == BARSTATE_NEWBAR && vPrice != null) {
      aPrice.pop();
      aPrice.unshift(vPrice);
      if (Value1 != null) Value1_1 = Value1;
      if (Fish != null) Fish_1 = Fish;
    }

        vPrice = (high() + low()) / 2;
        aPrice[0] = vPrice;

    if (aPrice[nLength-1] == null) return;

        var MaxH = high();
        var MinL = low();
        var temp;
```

FIGURE 1.8 EFS Code to Normalize Price to a 10-Day Channel and Compute Its Fisher Transform

```
        for(i = 0; i < nLength; ++i) {
      MaxH = Math.max(MaxH, aPrice[i]);
                MinL = Math.min(MinL, aPrice[i]);
    }

        Value1 = .5 * 2 * ((vPrice - MinL) /
      (MaxH - MinL) - .5) + .5 * Value1_1;

        if(Value1 > .9999) Value1 = .9999;
        if(Value1 < -.9999) Value1 = -.9999;

        Fish = 0.25 * Math.log((1 + Value1) /
      (1 - Value1)) + .5 * Fish_1;

        return new Array(Fish, Fish_1);
}
```

FIGURE 1.8 *(Continued)*

The Fisher transform of the prices within an eight-day channel is plotted below the price bars in Figure 1.9. Note that the turning points are not only sharp and distinct, but they also occur in a timely fashion so that profitable trades can be entered. The Fisher transform is also compared to a similarly scaled moving average convergence-divergence (MACD) indicator in Figure 1.9. The MACD is representative of conventional indicators whose turning points are rounded and indistinct in comparison to the Fisher transform. As a result of the rounded turning points, the entry and exit signals are invariably late.

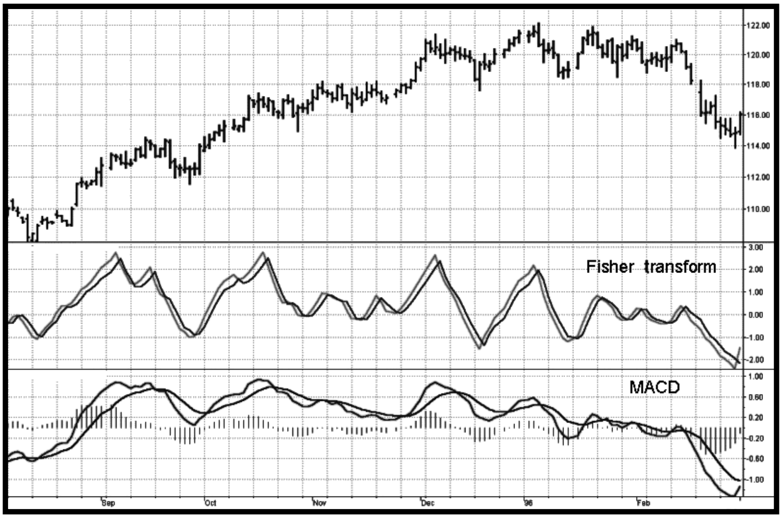

FIGURE 1.9 The Fisher Transform of Normalized Prices Has Very Sharp Turning Points When Compared to Conventional Indicators such as the MACD

KEY POINTS TO REMEMBER

- Prices almost never have a Gaussian, or Normal, probability distribution.
- Statistical measures based on Gaussian probability distributions, such as standard deviations, are in error because the probability distribution assumption underlying the calculation is in error.
- The Fisher transform converts almost any input probability distribution to be nearly a Gaussian probability distribution.
- The Fisher transform, when applied to indicators, provides razor-sharp buy and sell signals.