

Smart Alarm Monitoring



Iman Izadi, Research Fellow

Department of Chemical and Materials Engineering
University of Alberta

- Motivation
- False alarms, causes and remedies
- Model base performance monitoring
- Multivariate vs. univariate
- Error processing
- Case studies
- Concluding remarks

Why Monitoring?

- Improving efficiency and reliability
 - Reducing unplanned downtime
 - Avoiding production loss
 - Preventing equipment damage
- } MORE
PROFIT
- Environment protection
 - Safety

History

- Traditionally, a limited number of variables are monitored.
- If a variables exceeds a certain limit, an alarm is raised.
- After an alarm is raised, the operator must understand and acknowledge the alarm, detect the event, and react accordingly.
- SPC (Statistical Process Control) and SQC (Statistical Quality Control) charts are used for performance monitoring (e.g., Shewhart chart).
- For overall performance of the process, a few “quality variables” or “key performance indicators (KPI)” are monitored.

Old Control Room

- Historically, alarms were expensive and difficult to implement
- Each alarm had to be hardwired
- Limited space in control panels
- Resulting in careful design and review before implementation



Modern Control Room

- Today, hardware and software advances has made it easy to add alarms at minimal cost
- Large increase in the quantity of alarms
- Reducing the quality and efficiency of alarms



Why False Alarms?

- Thousands of alarms configured and continuously added
- Bad design, bad tuning
- Different operating states
- Processes change over time
- Equipments change and degrade
- Seasonal changes
- Noise

Standards and Regulations

- 1999 EEMUA 191 v1
 - World-wide standard
- 2007 EEMUA 191 v2
- 2008 ISA S18.02 - Management of Alarm Systems for the Process Industries
- 2008 ANSI Adoption of ISA

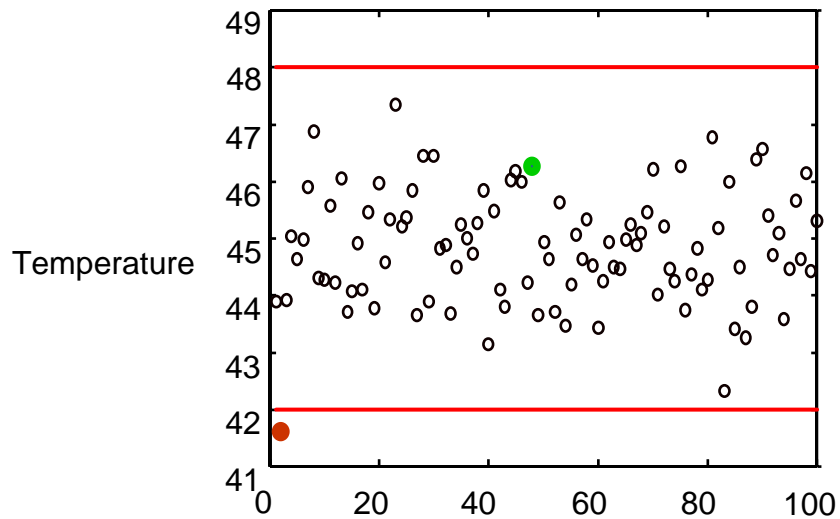
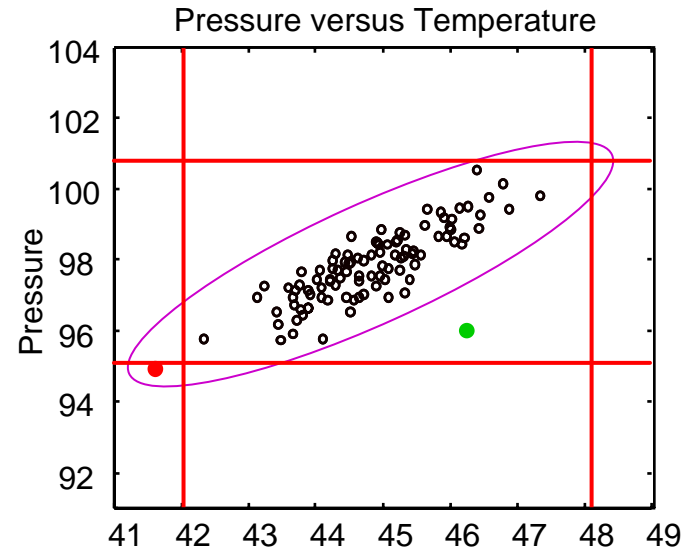
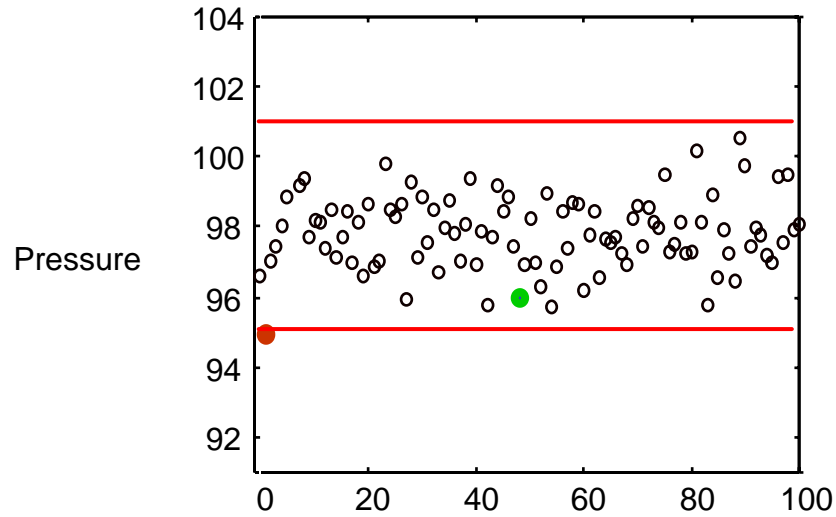
EEMUA Benchmarks

	EEMUA	Oil & Gas	PetroChem	Power	Other
Average Alarms per hour	<6	36	54	48	30
Average Standing Alarms	9	50	100	65	35
Peak Alarms/hour (10 Minutes)	60	1320	1080	2100	1080
Distribution % (Low/Med/High)	80/15/5	25/40/35	25/40/35	25/40/35	25/40/35

How to Reduce False Alarms

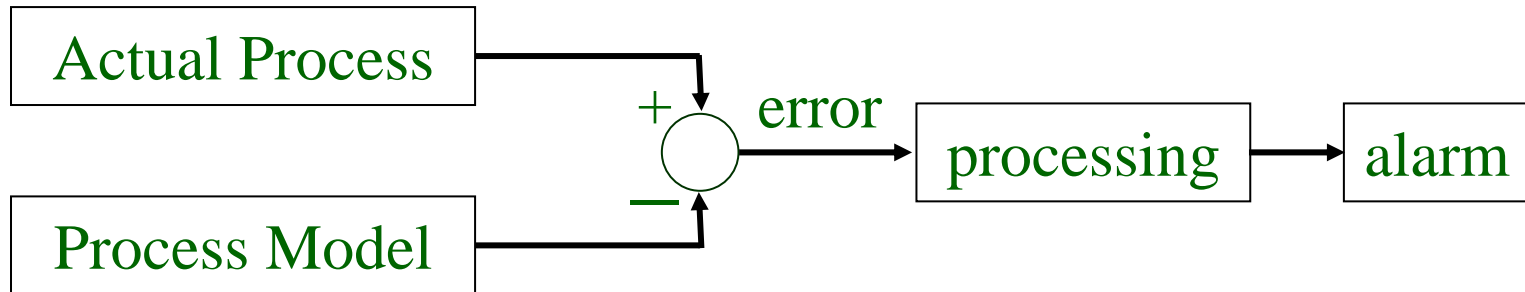
- Can be addressed in different levels in the plant (design, operation, management)
- Improve the design
 - Multivariate instead of univariate
 - More accurate models
 - Better configuration (tuning)
 - Processing of data
- Alarm Management

Multivariate vs. Univariate



Why Multivariate Analysis

- Hundreds to thousands of variables are measured
- Variables are highly correlated with one another
 - It is not easy to understand the correlation between variables
 - Statistical rank of data is very low
 - Rank is independent of the number of variables measured
 - The behavior of the process can be expressed by a few independent variables (sources of variation in the process)
- Low signal-to-noise ratio
 - Little information in any one variable



- The actual behavior of the process is compared with the behavior predicted by the model.
- (perfect model) and (no abnormalities)
→ (error is white noise)
- The prediction error is processed.
- The result is compared with a threshold.

- First principles model
- Data-driven modeling
 - Dynamical modeling (system identification)
 - Statistical modeling (PCA, PLS, CCA, ...)
 - A new set of independent variables are created (from a combination of the original variables) that capture the variability of the process
 - Neural networks
 - ...

Error Processing

- After the error is generated, it should be processed to facilitate
 - Threshold design
 - Noise reduction
 - detection delay and false alarm rate trade-off
 - false alarm rate and missed alarm rate trade-off

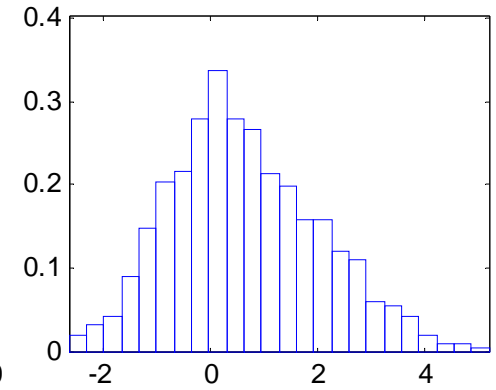
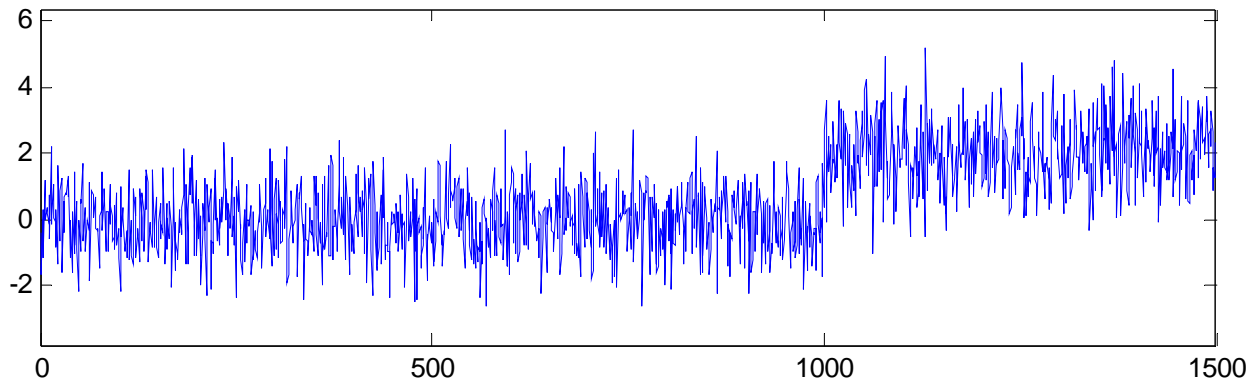
Reducing False Alarm Rate

- False alarm rate can be reduced using simple processing techniques
 - Filtering
 - Reduces noise
 - Removes spikes
 - Modifies distribution
 - Time delay
 - Dead-band
 - Reduces alarm chattering

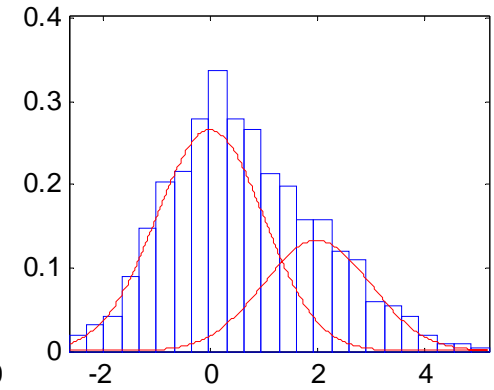
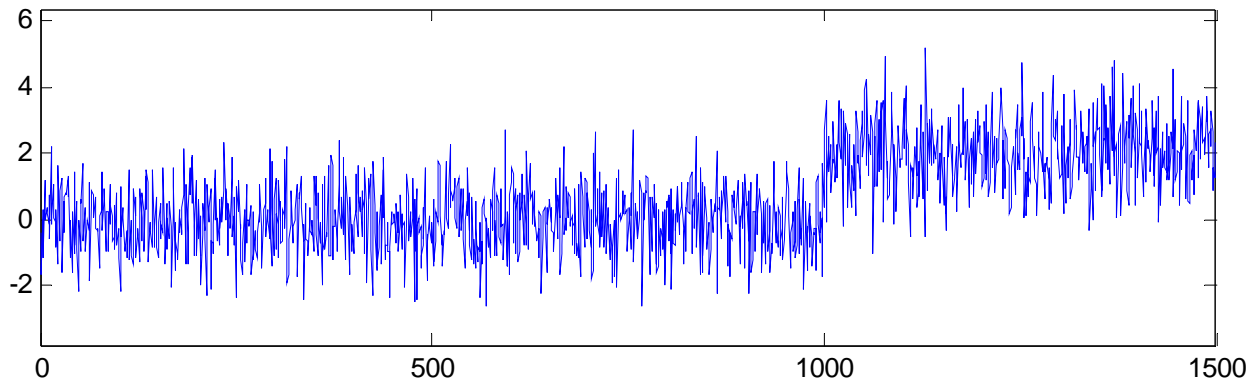
Filtering

- Filters are applied to variables to:
 - reduce noise
 - remove bad or unwanted data
 - extract features
 - modify statistical distributions
 - separate frequency components
- Common filters
 - Moving average
 - Moving variance
 - Moving range
 - EWMA
 - Finite Impulse Response (FIR)

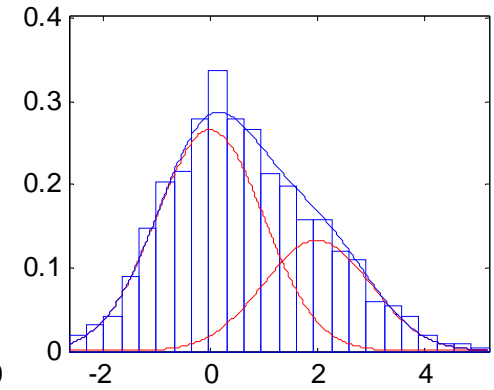
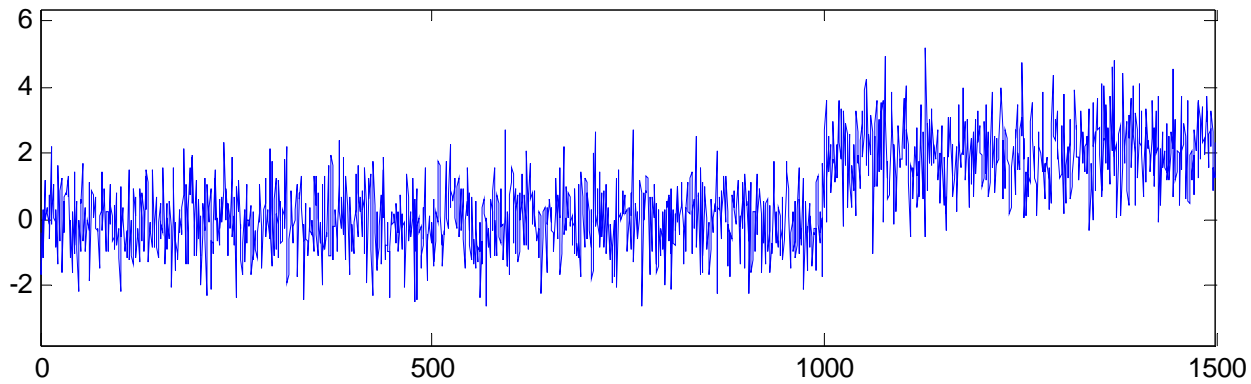
Filter: Moving Average



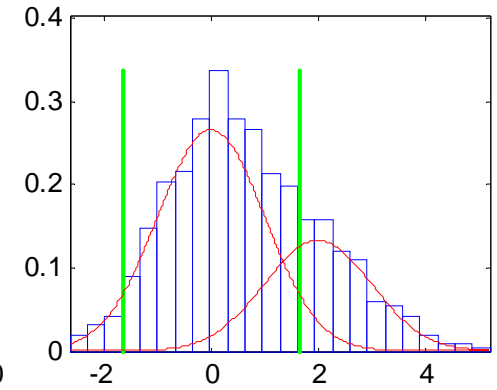
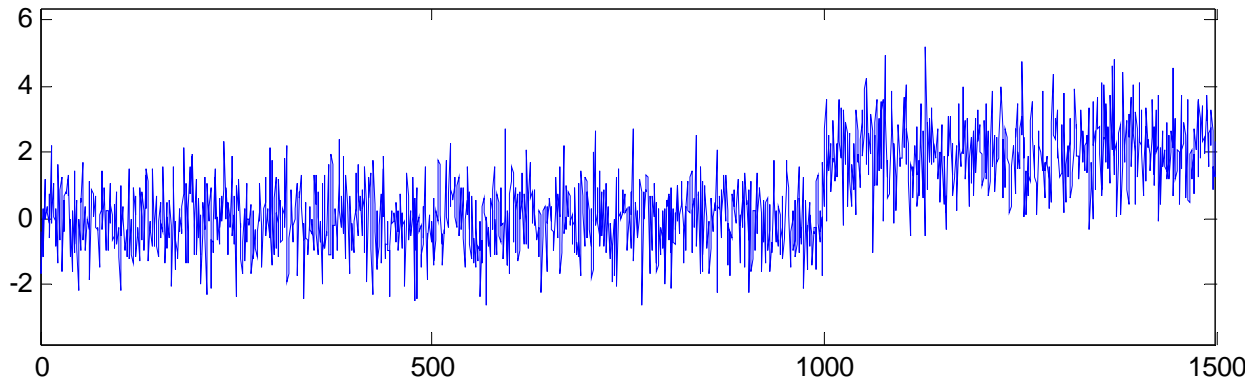
Filter: Moving Average



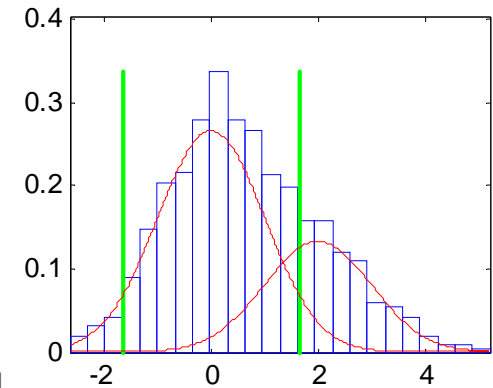
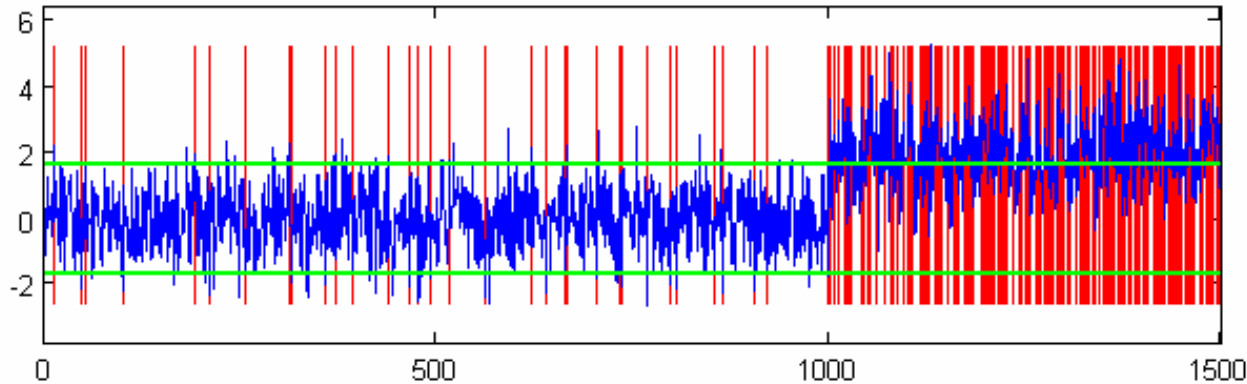
Filter: Moving Average



Filter: Moving Average



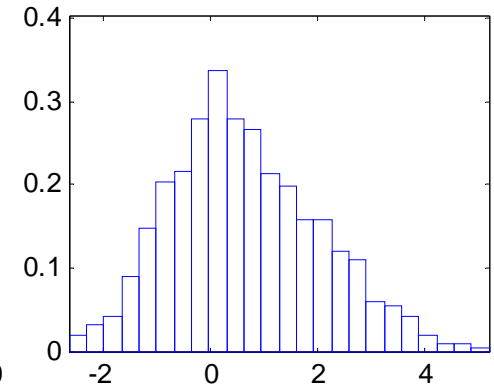
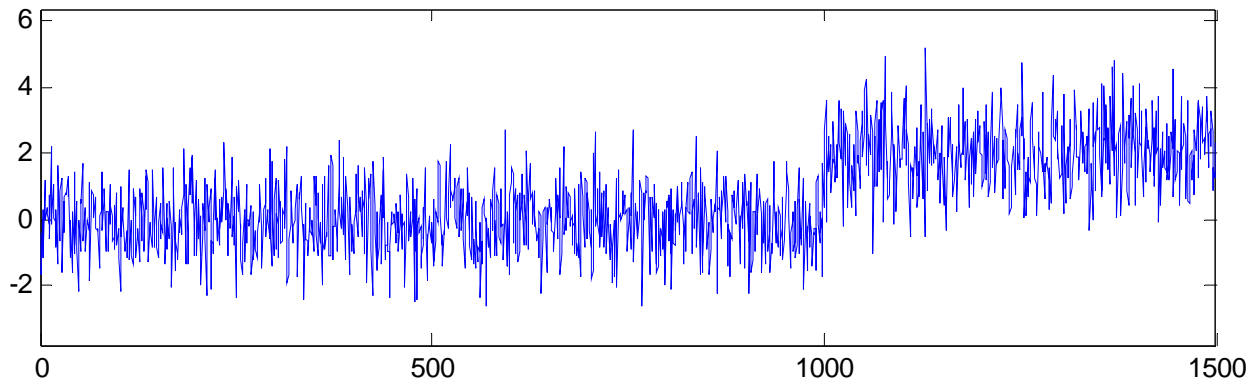
Filter: Moving Average



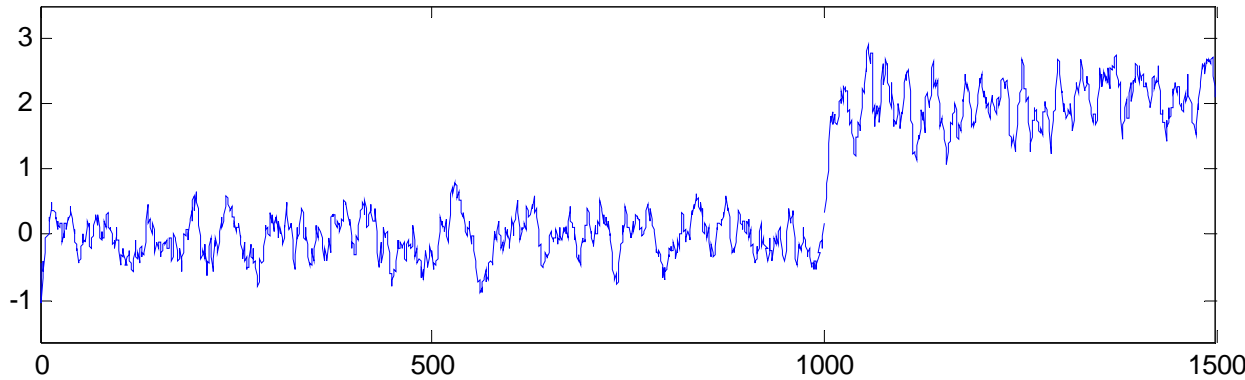
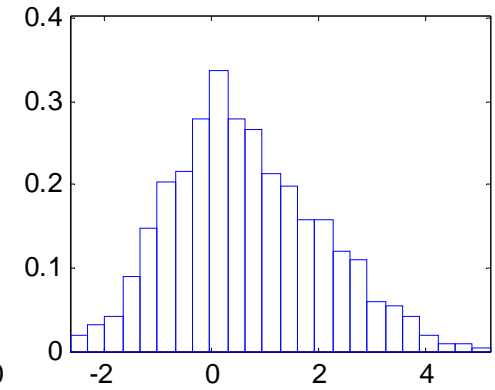
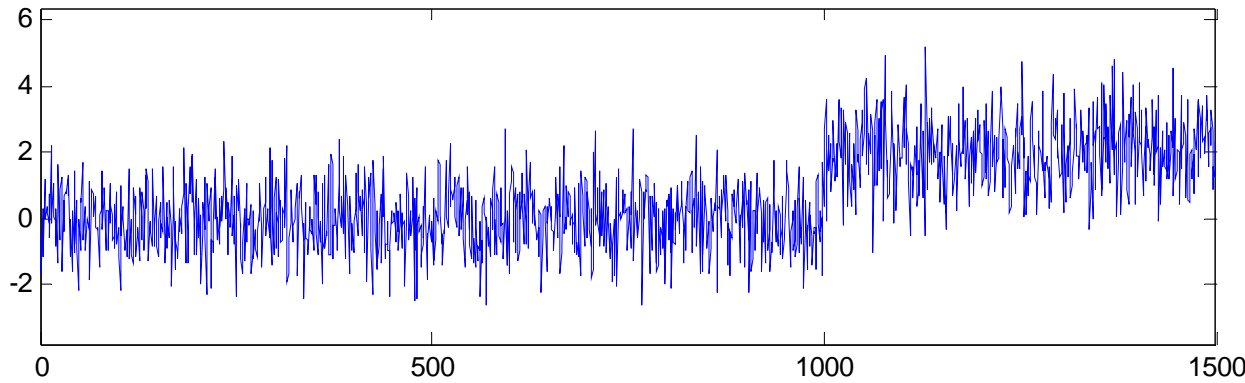
false alarm = 102

missed alarm = 157

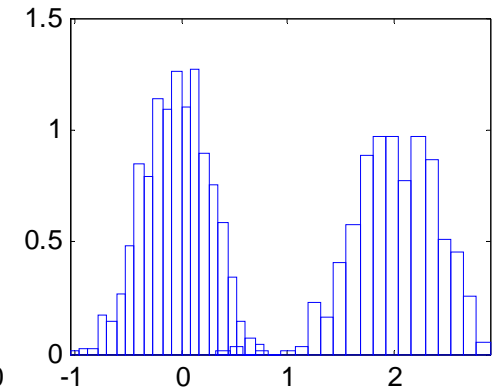
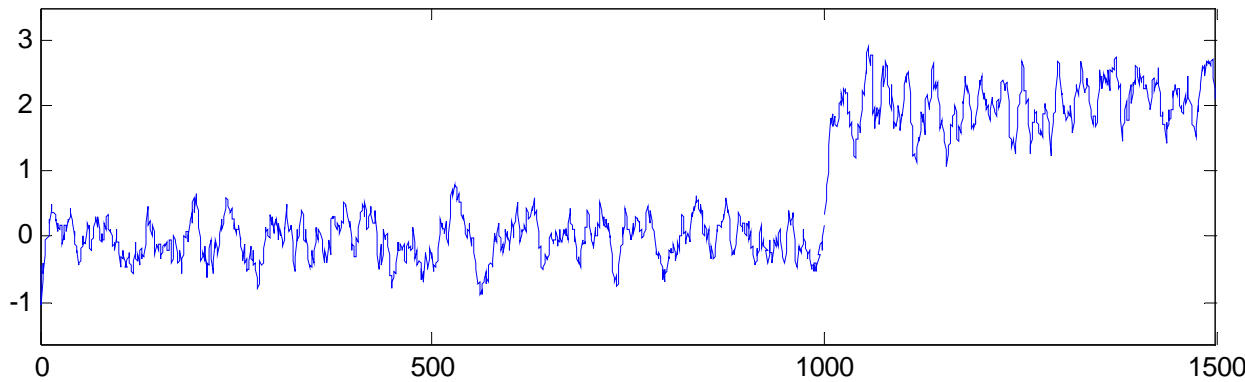
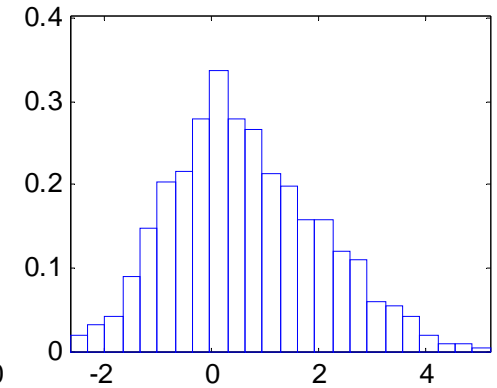
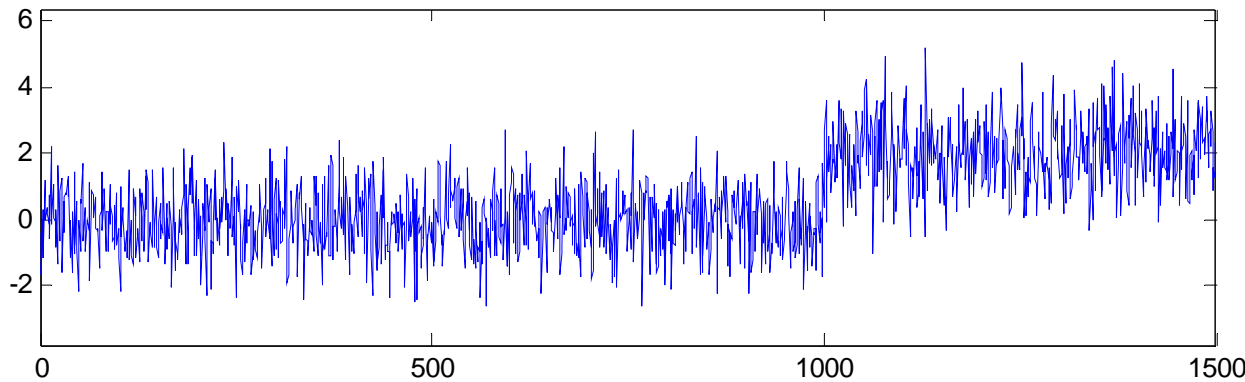
Filter: Moving Average



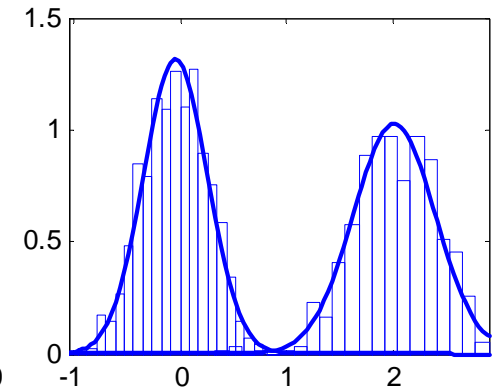
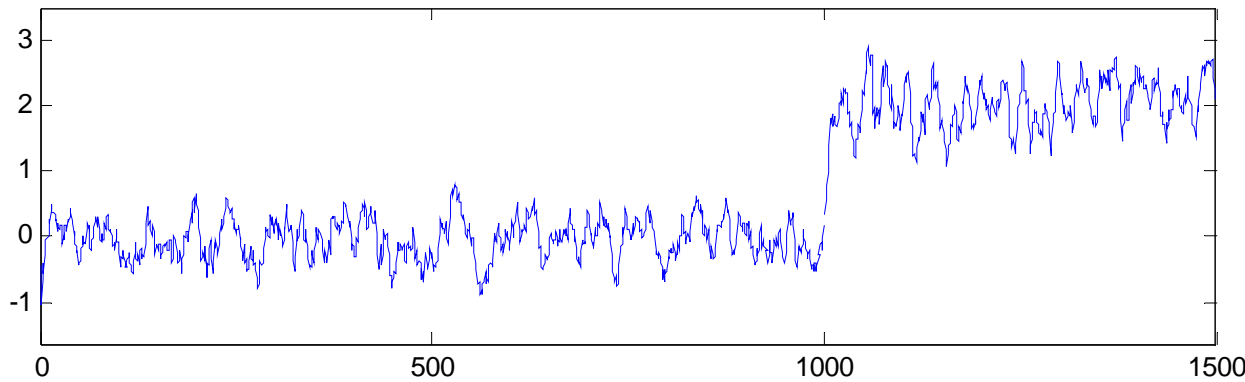
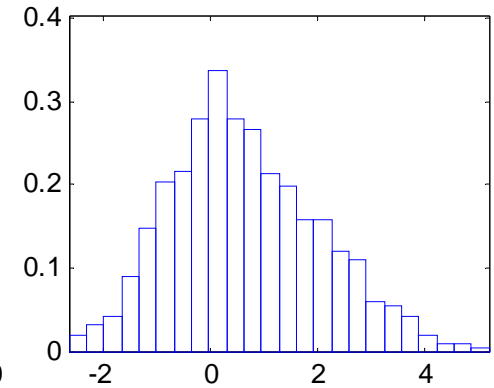
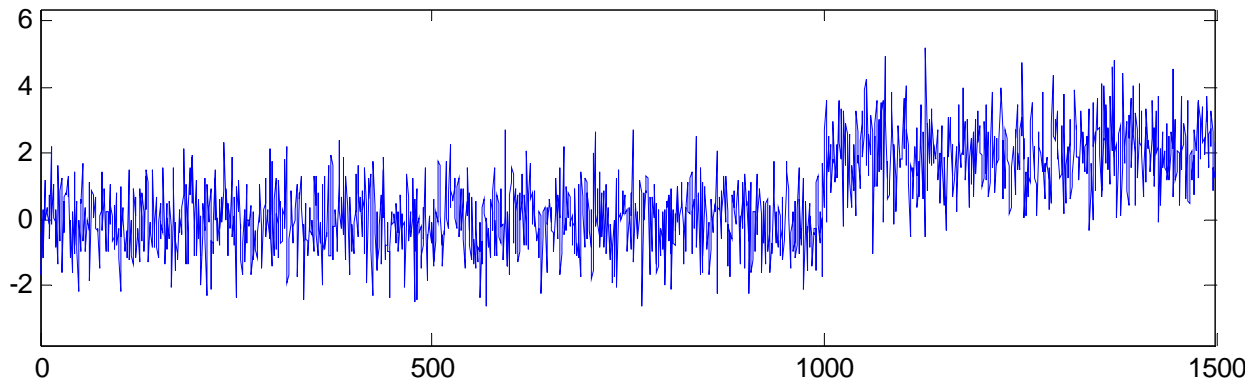
Filter: Moving Average



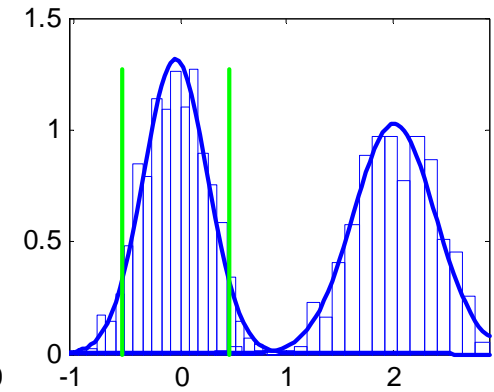
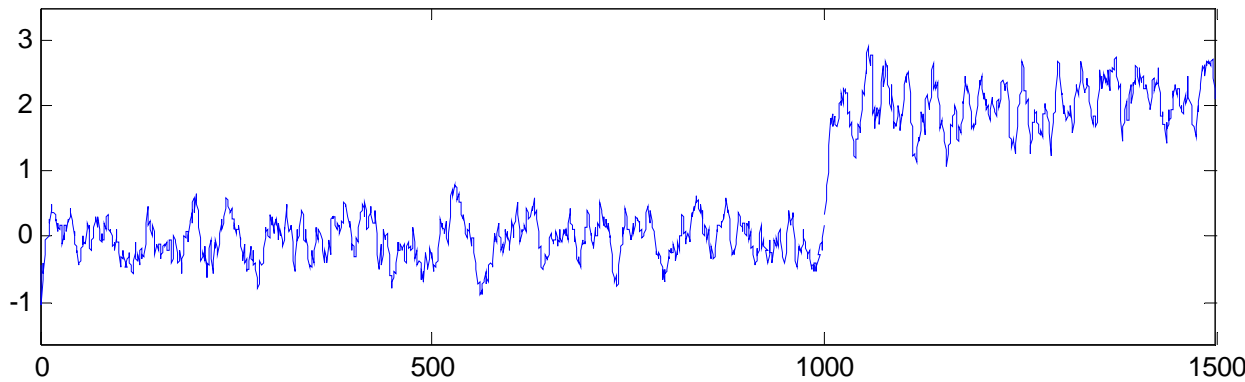
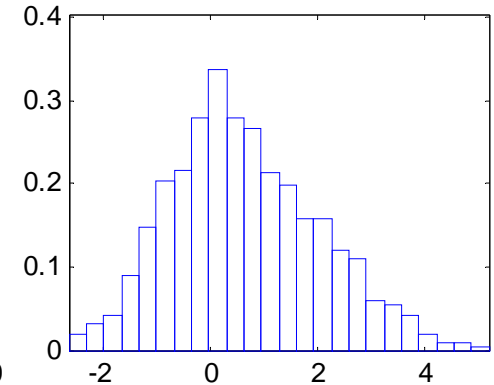
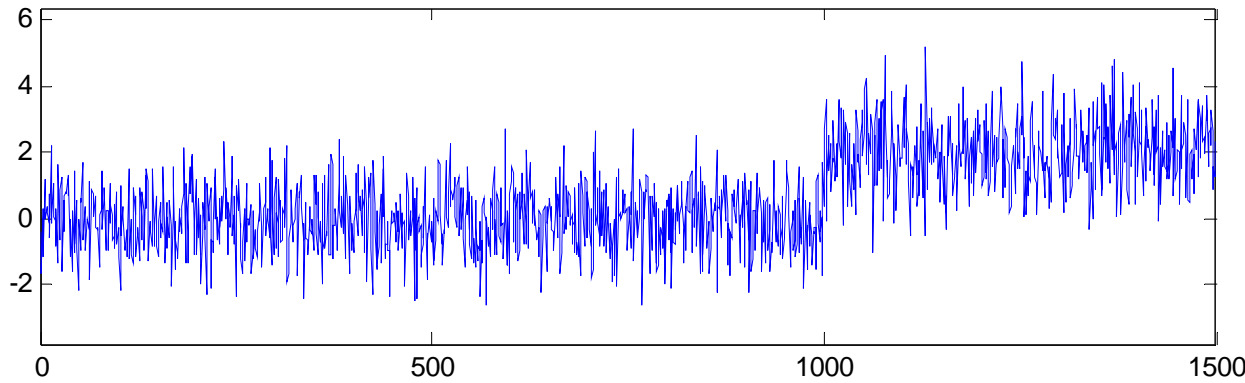
Filter: Moving Average



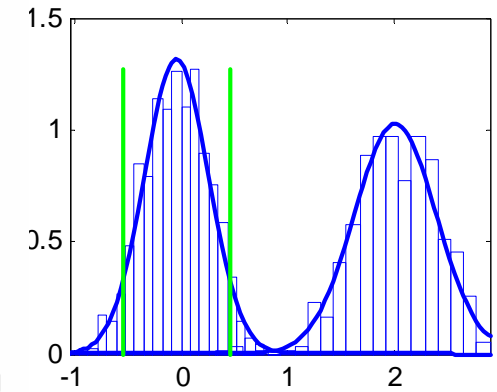
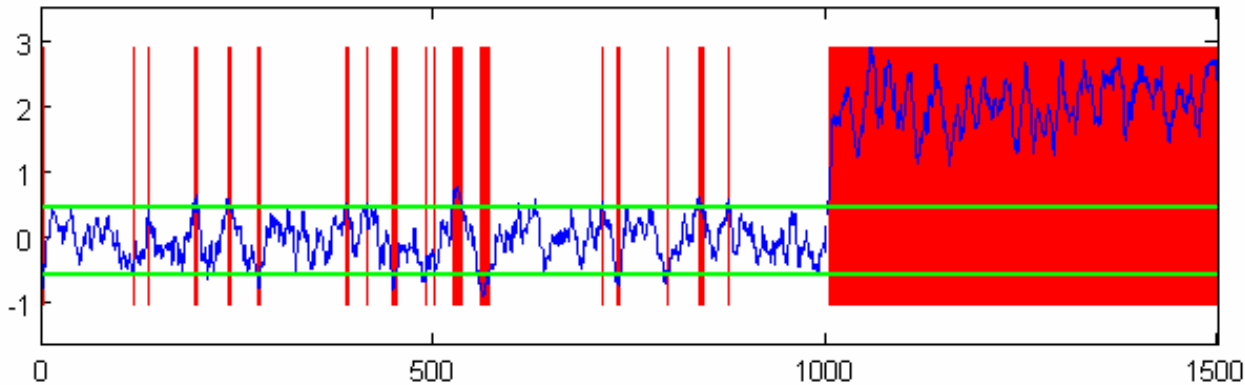
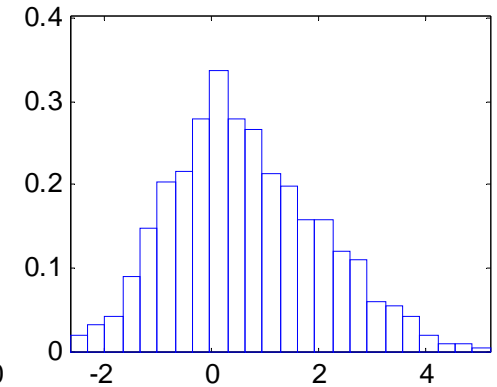
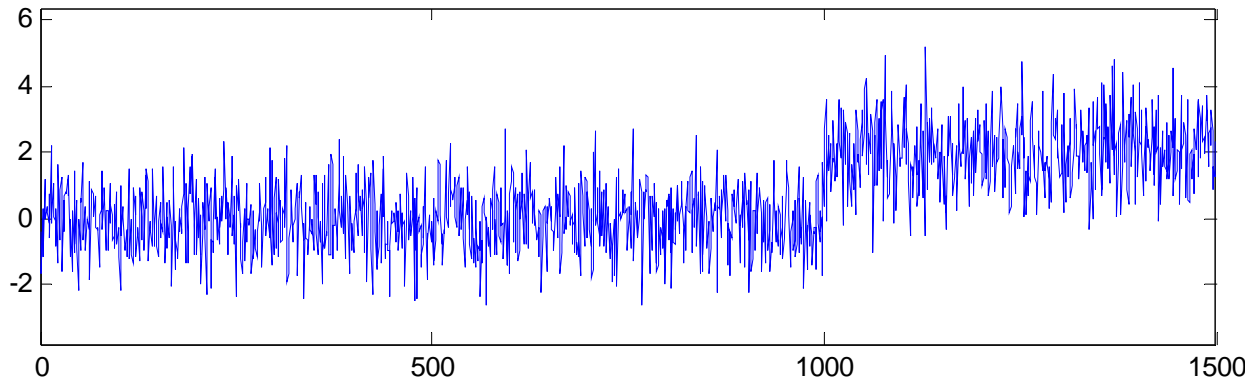
Filter: Moving Average



Filter: Moving Average

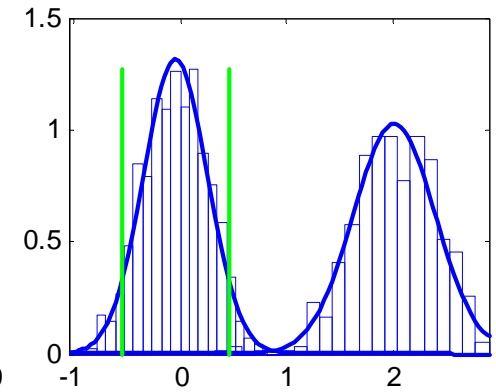
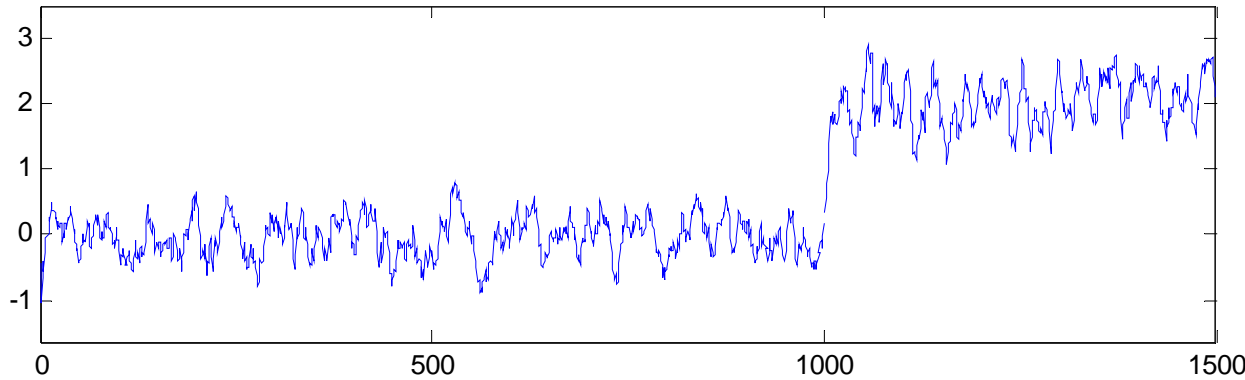
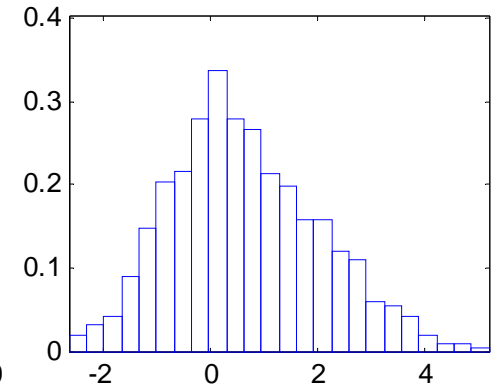
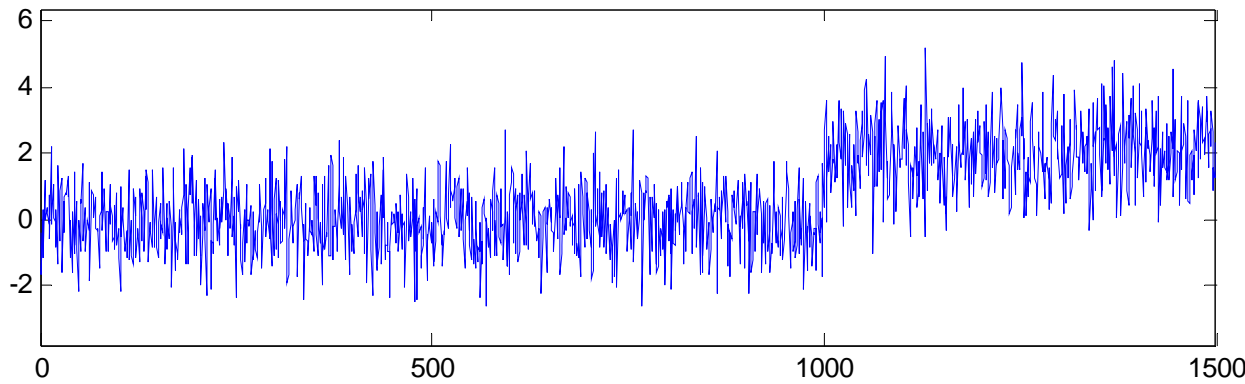


Filter: Moving Average

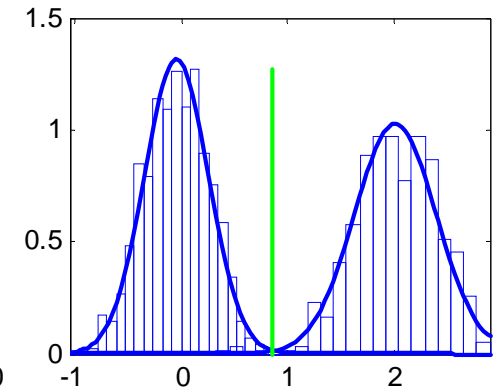
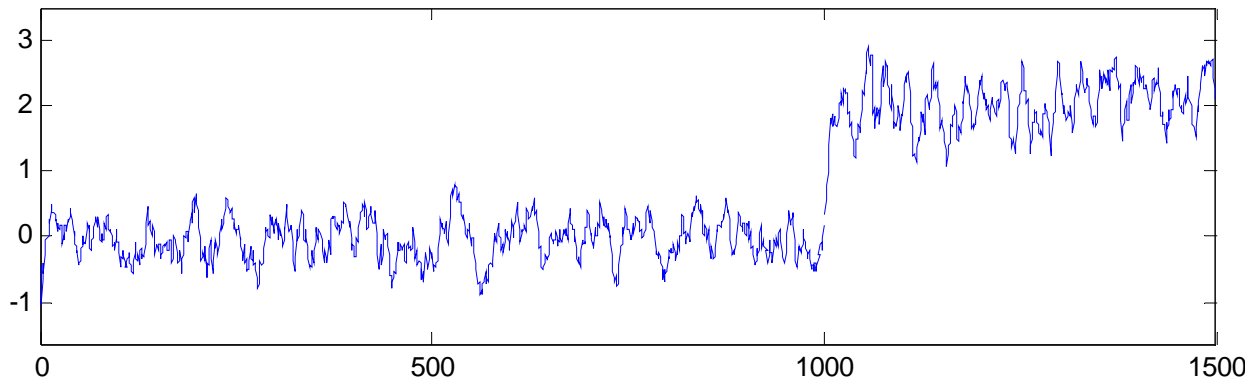
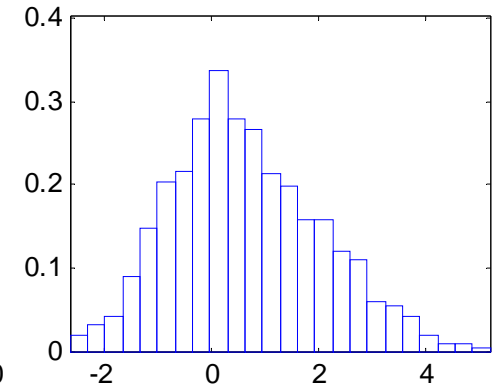
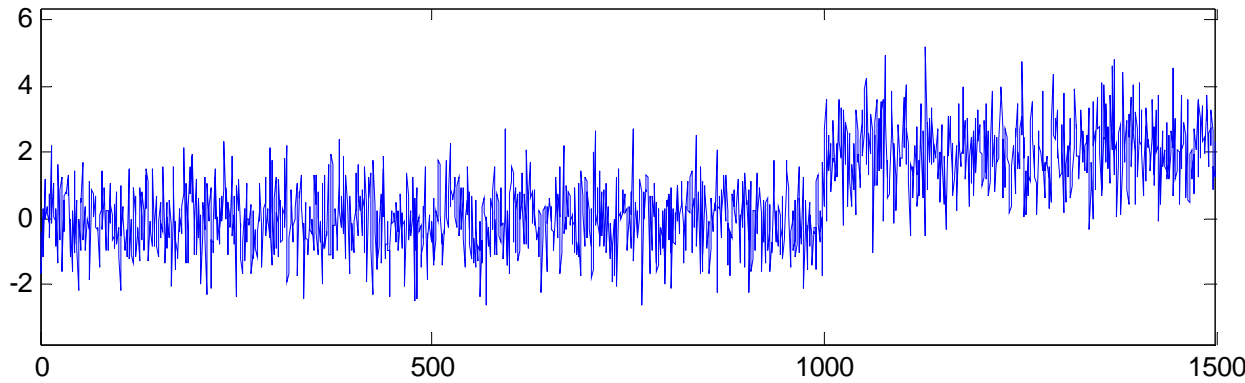


false alarm = 39, missed alarm = 1

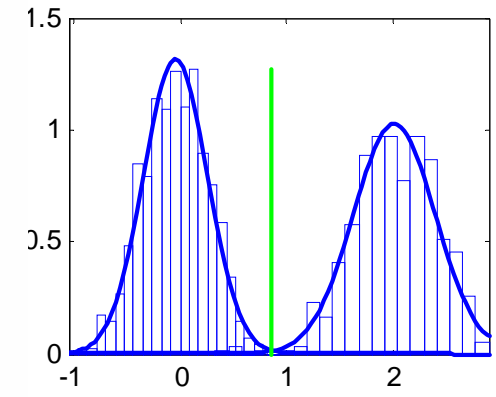
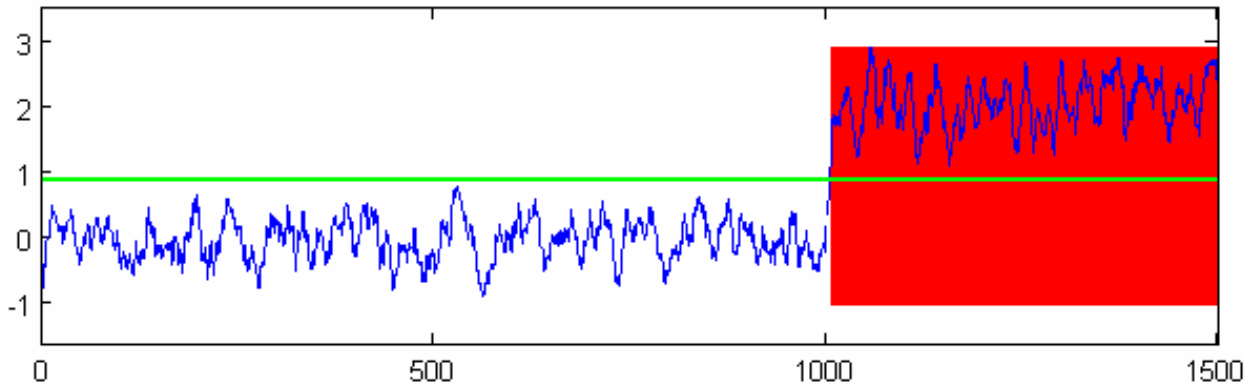
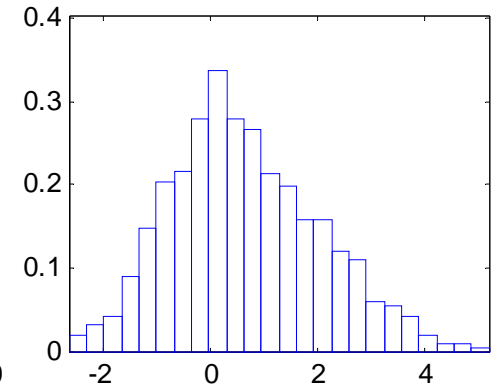
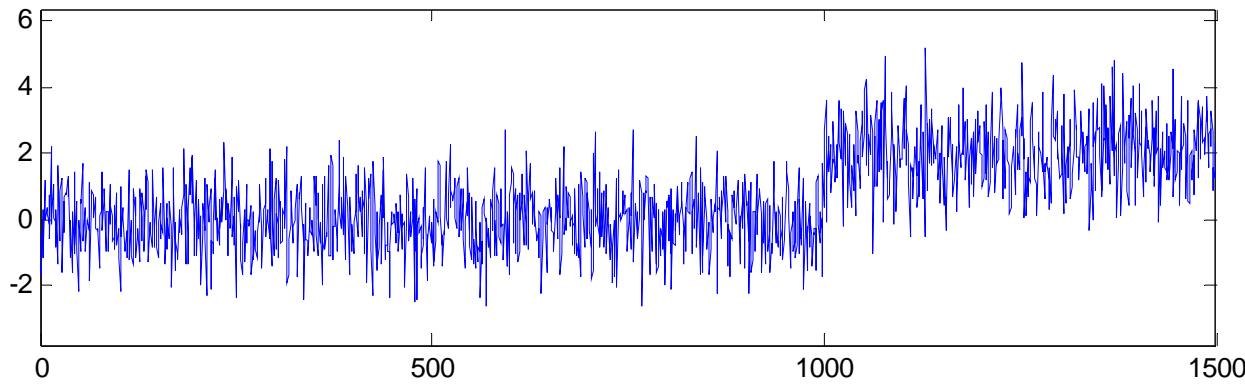
Filter: Moving Average



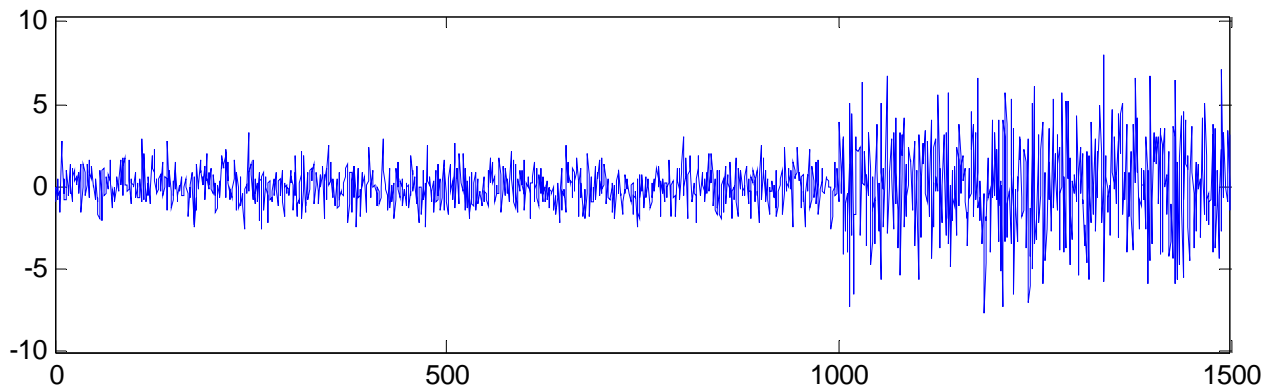
Filter: Moving Average



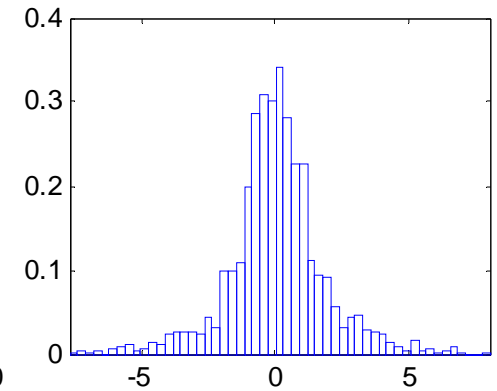
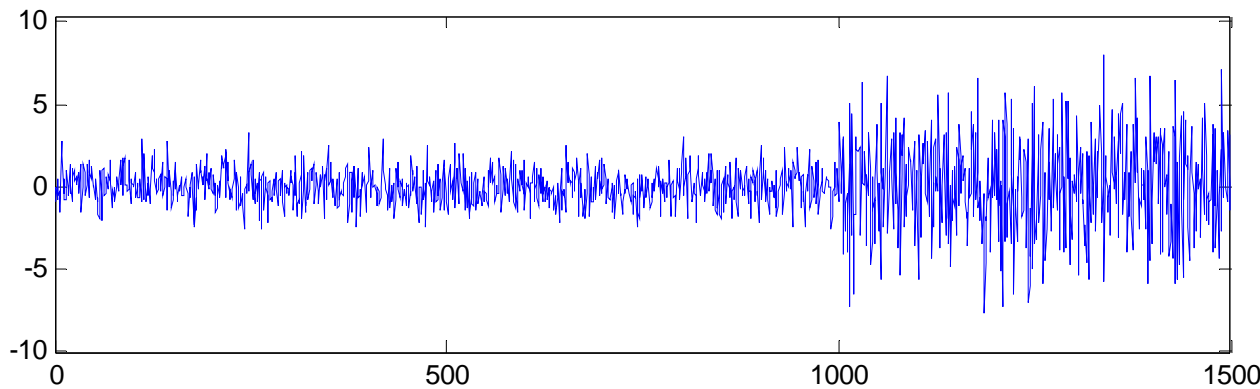
Filter: Moving Average



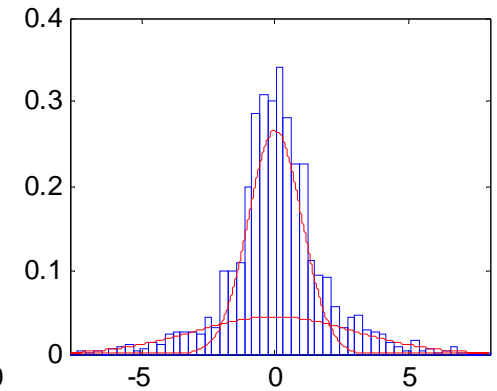
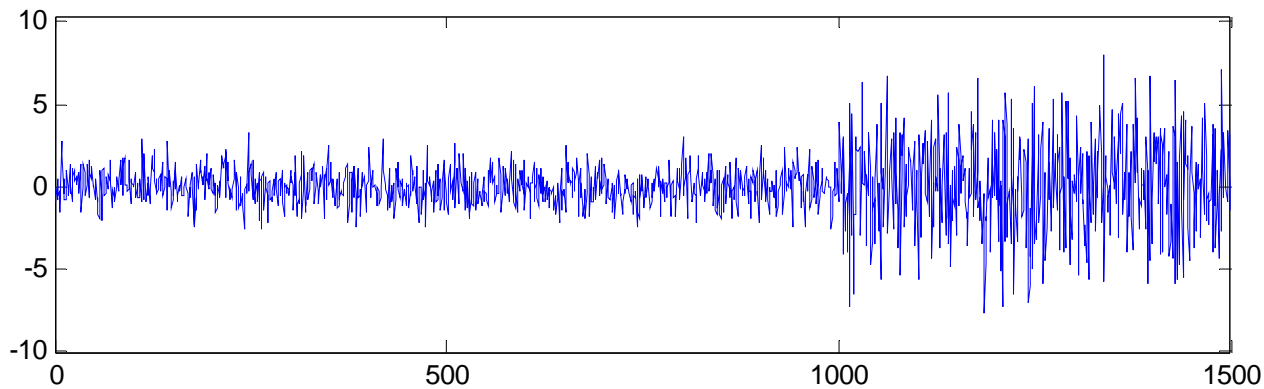
Filter: Moving Variance



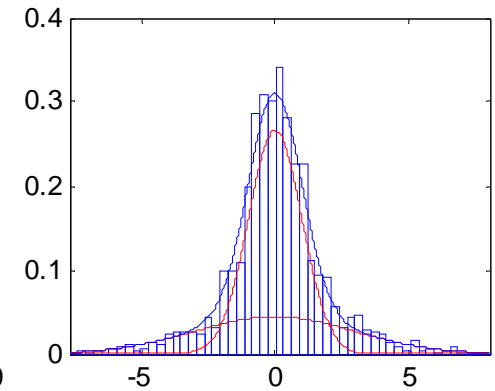
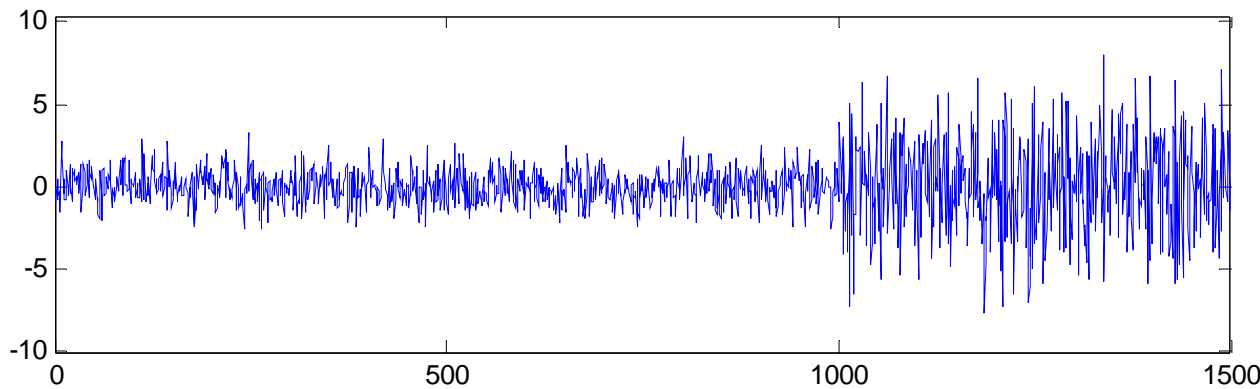
Filter: Moving Variance



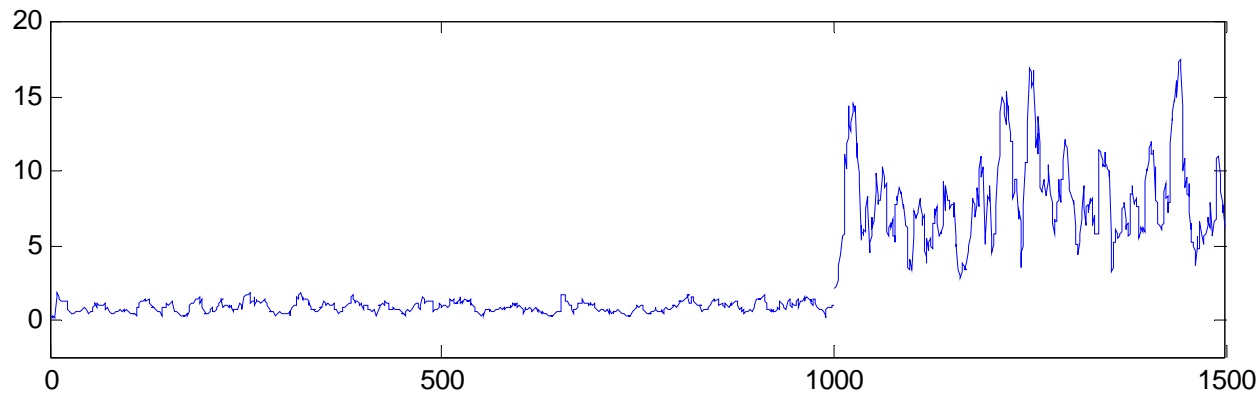
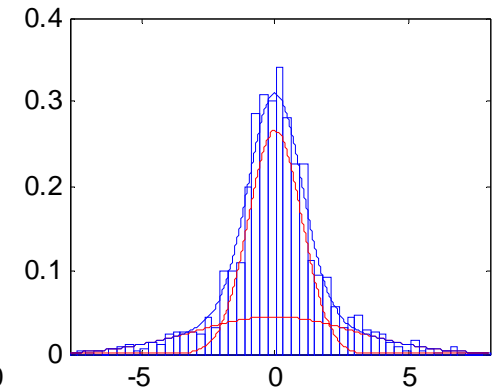
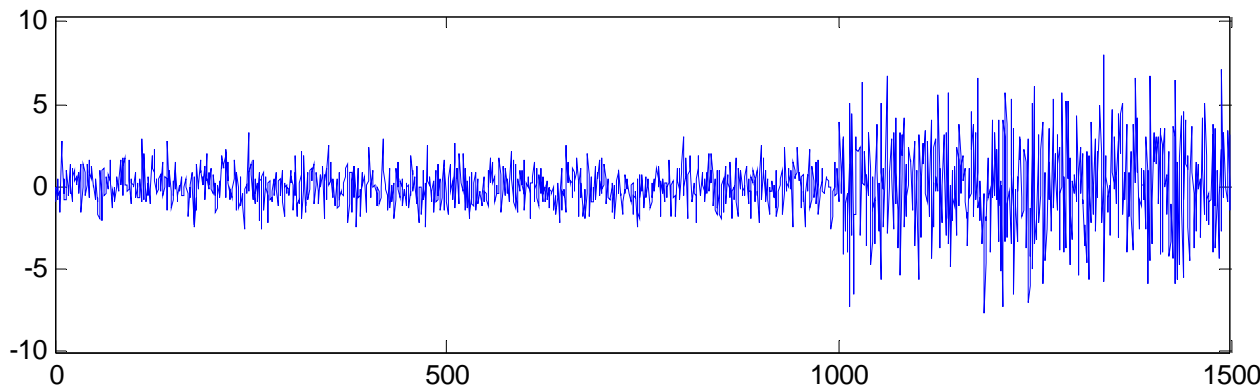
Filter: Moving Variance



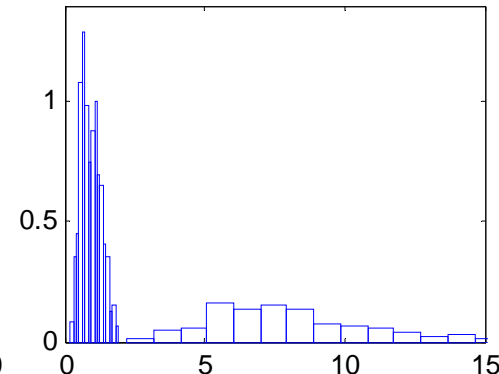
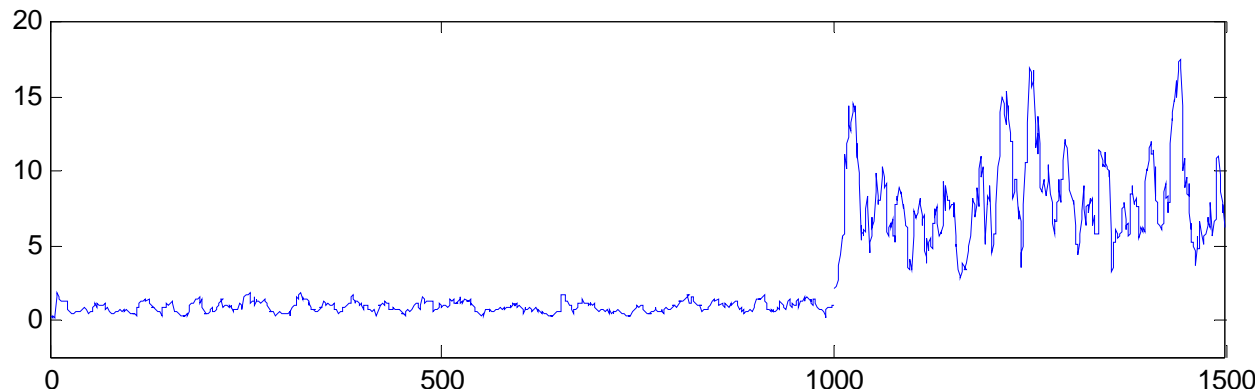
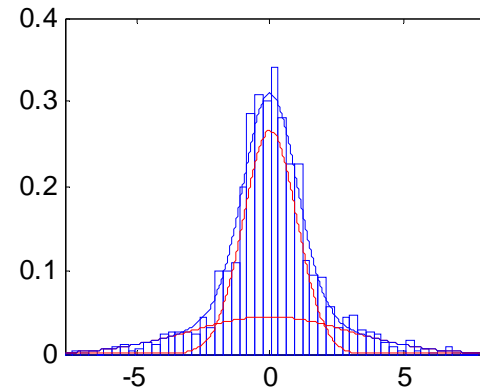
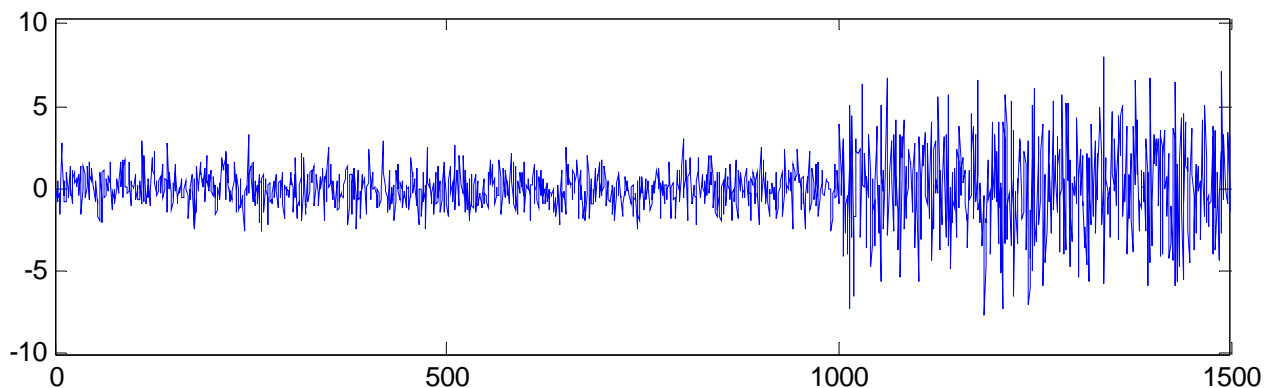
Filter: Moving Variance



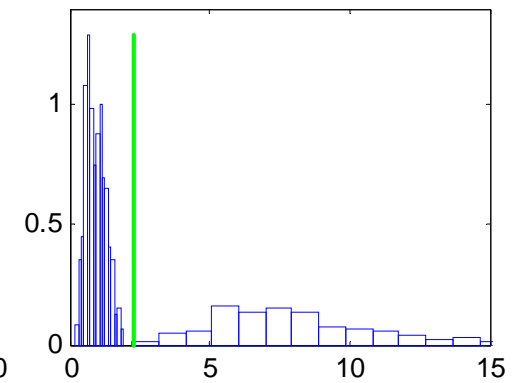
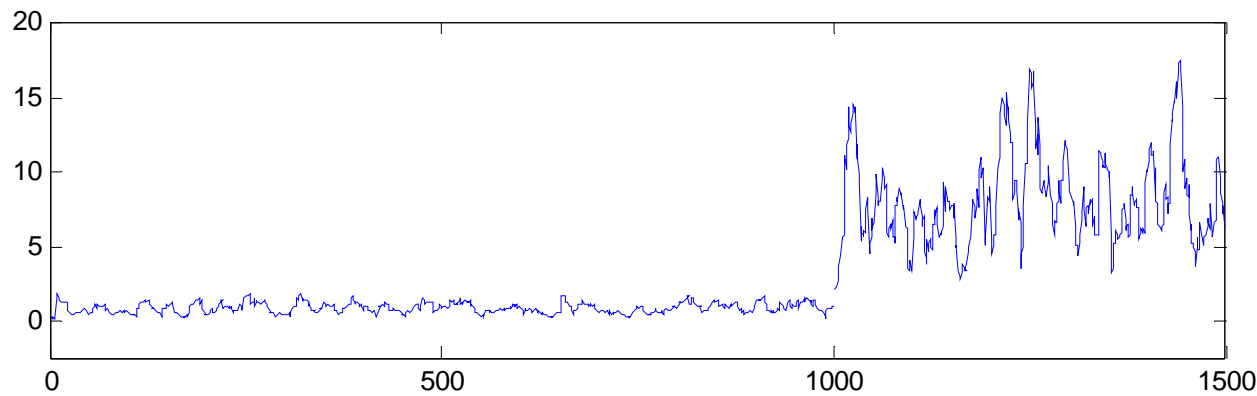
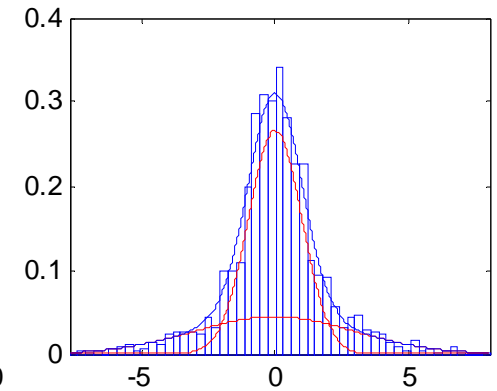
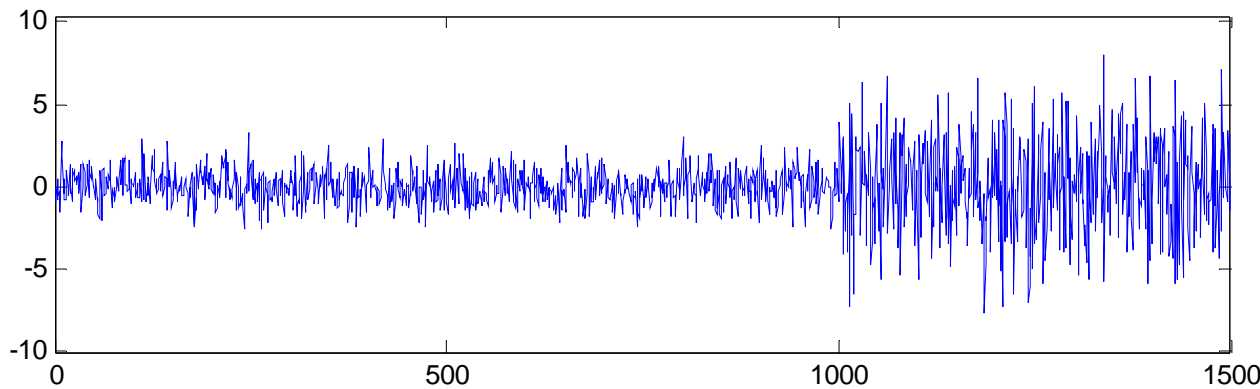
Filter: Moving Variance



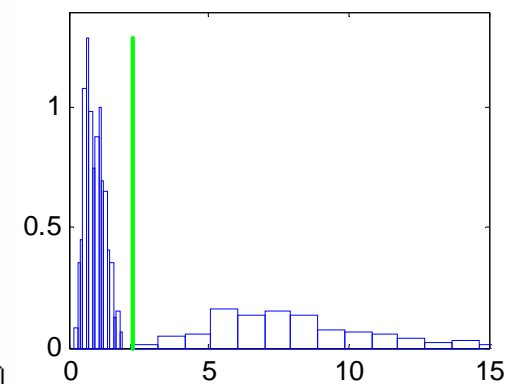
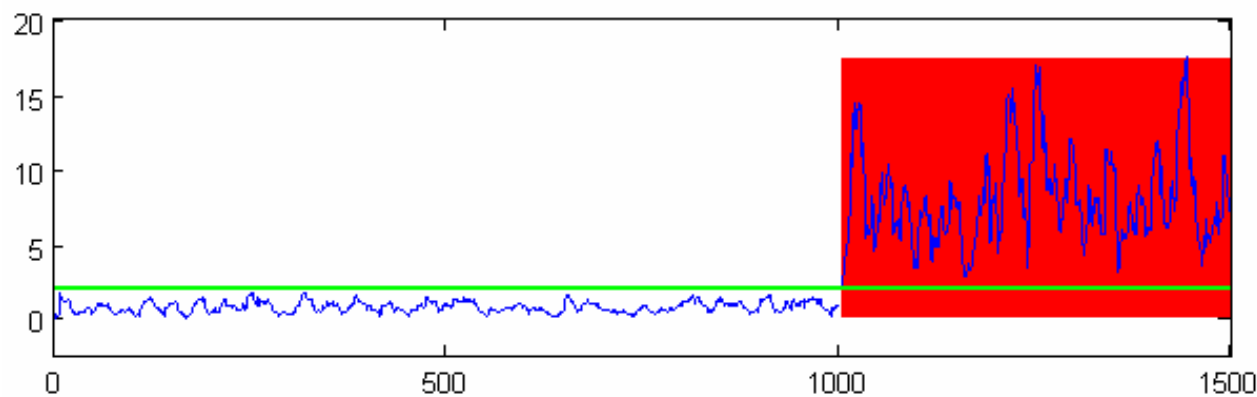
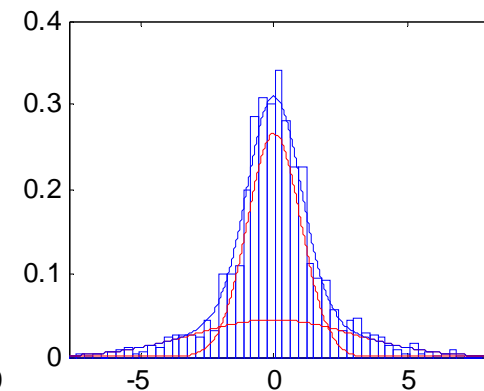
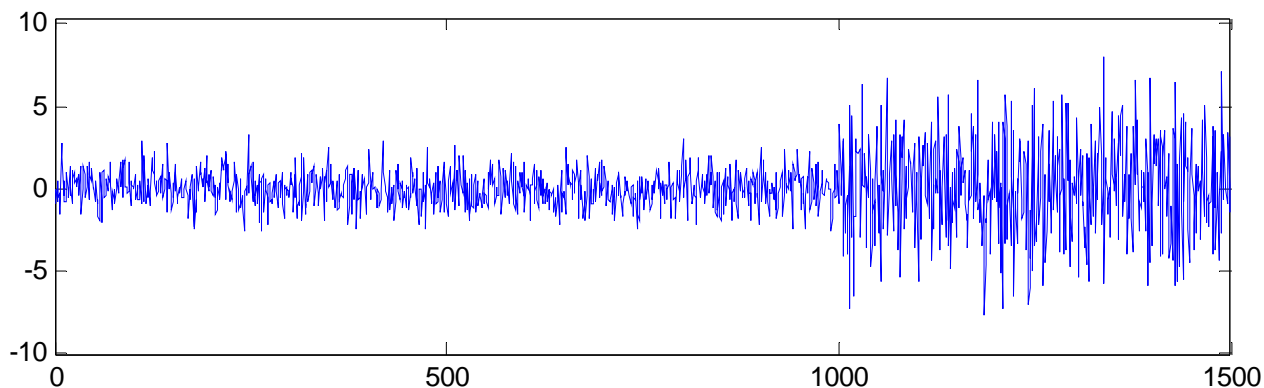
Filter: Moving Variance



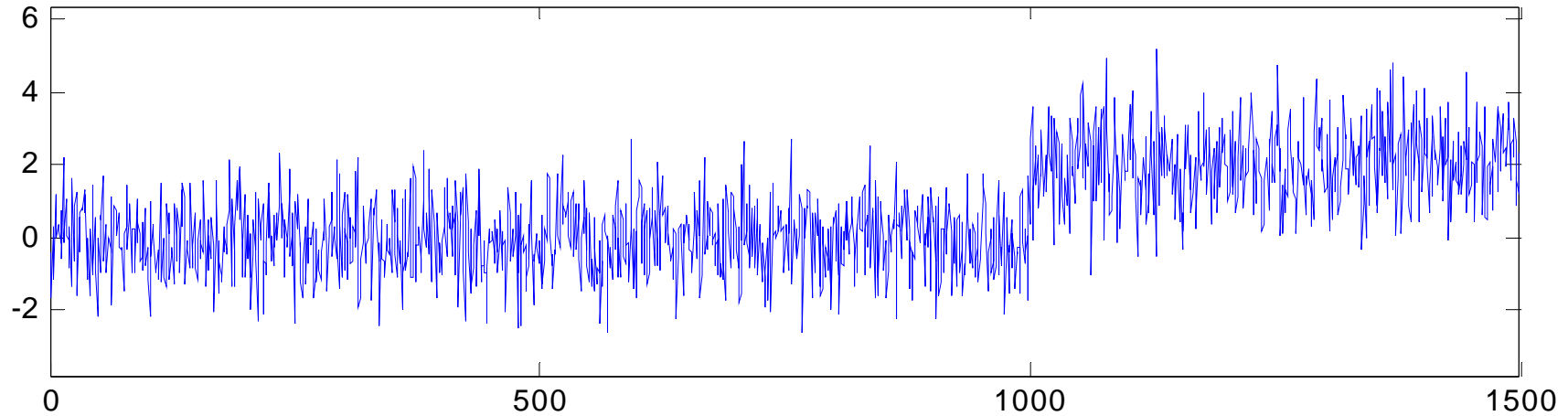
Filter: Moving Variance



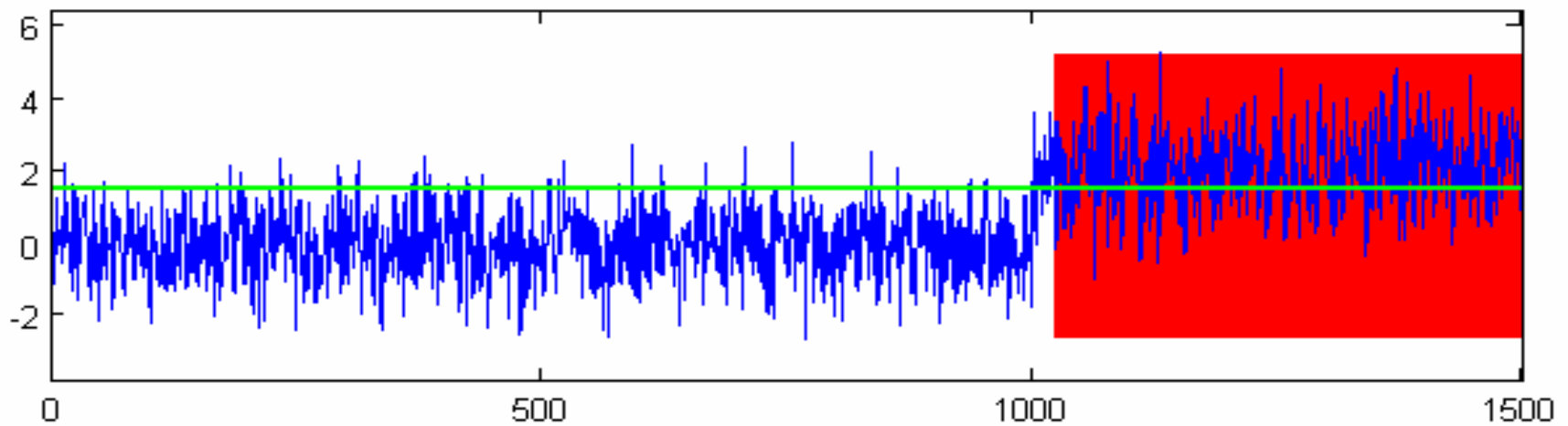
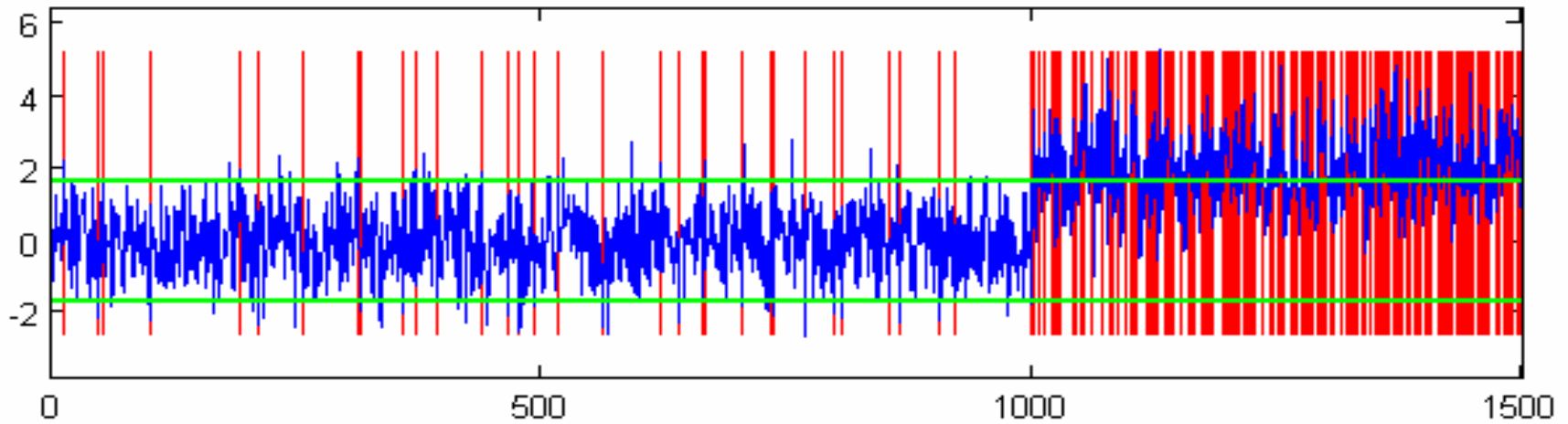
Filter: Moving Variance



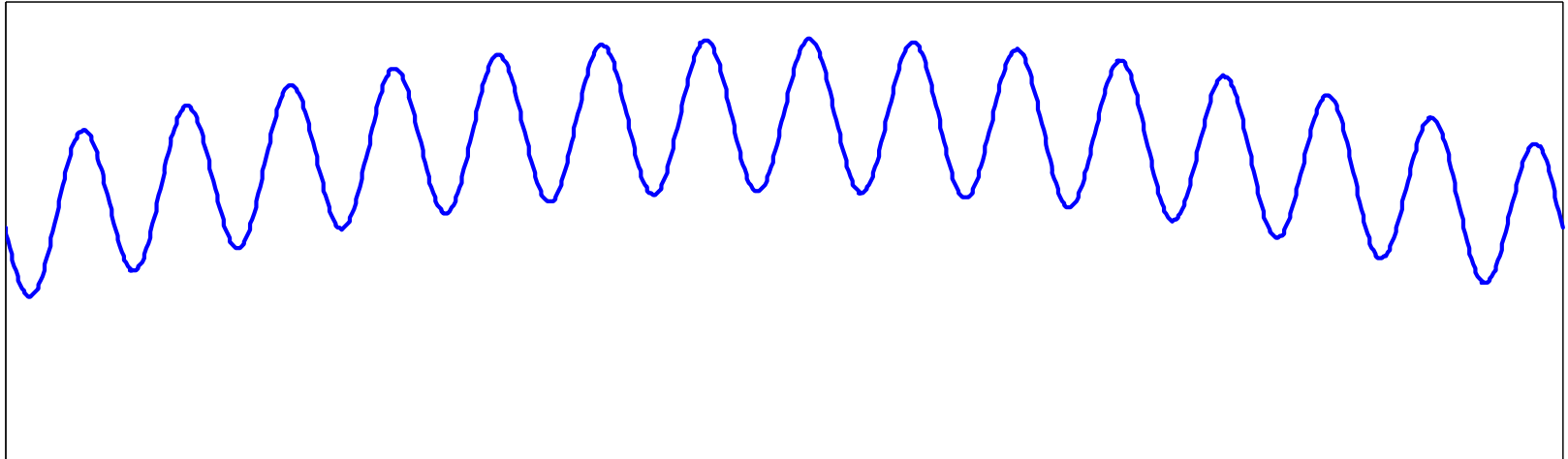
Time Delay



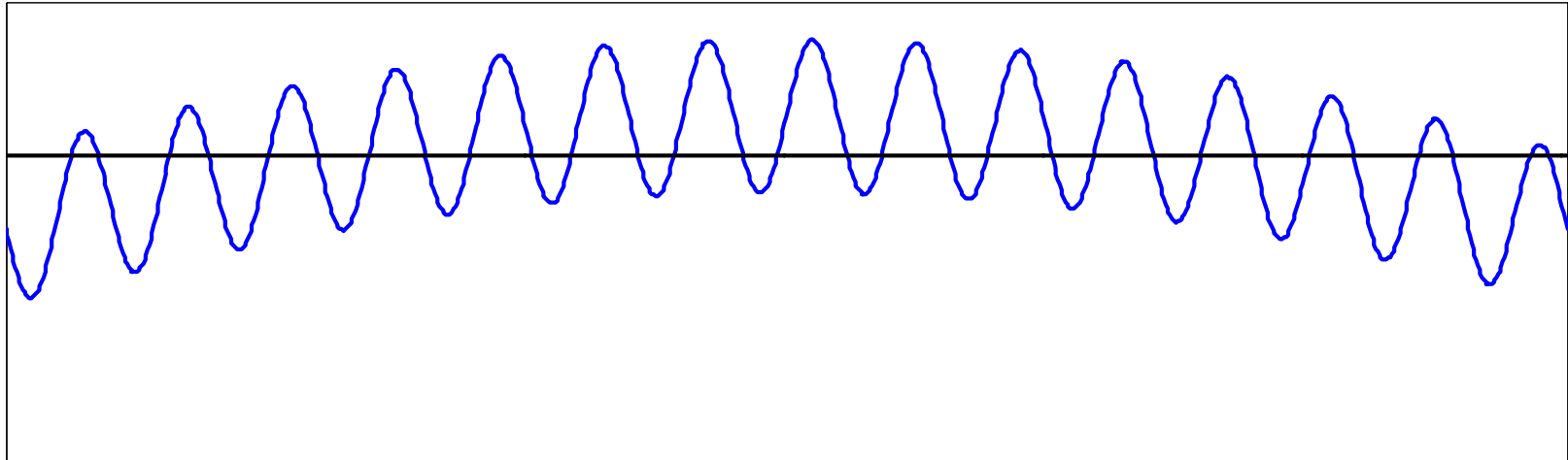
Time Delay



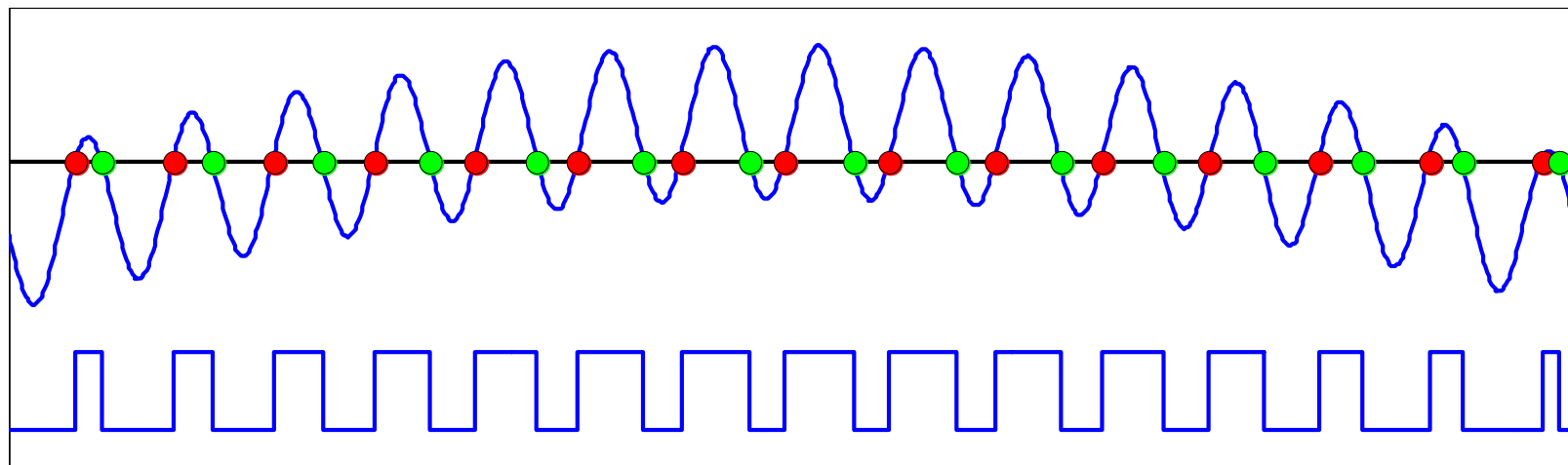
Alarm Chattering - Deadband



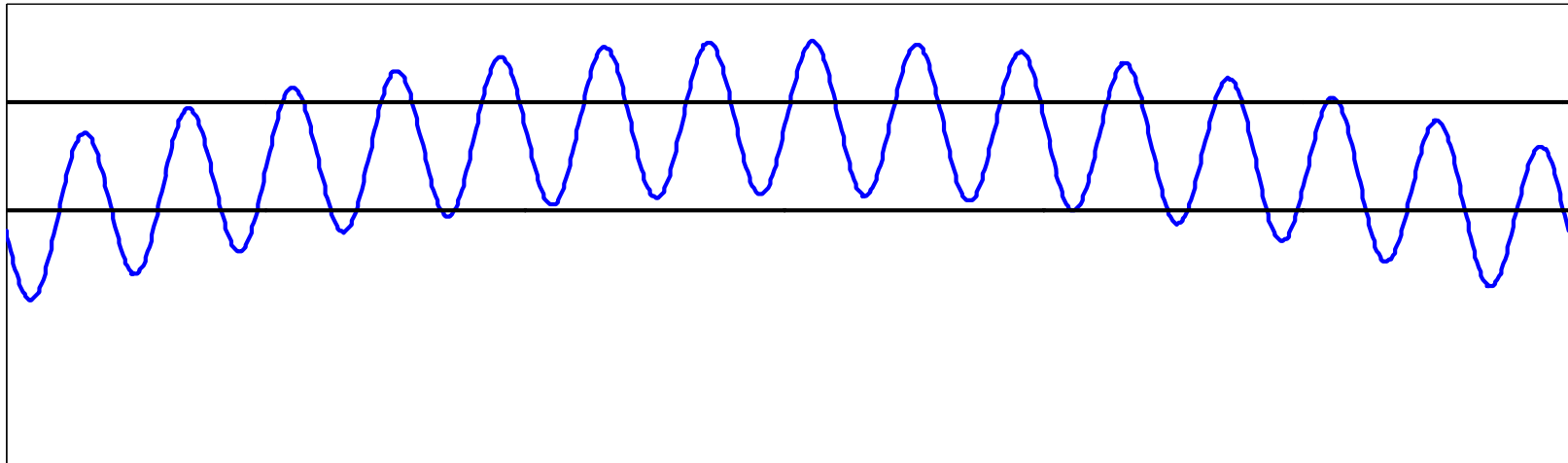
Alarm Chattering - Deadband



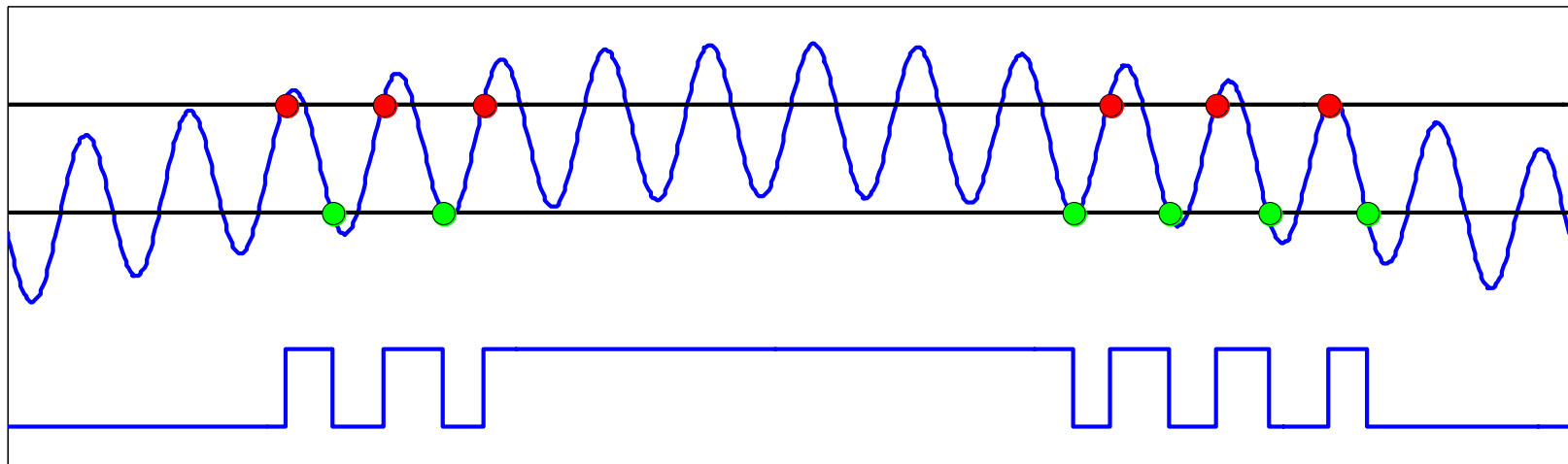
Alarm Chattering - Deadband



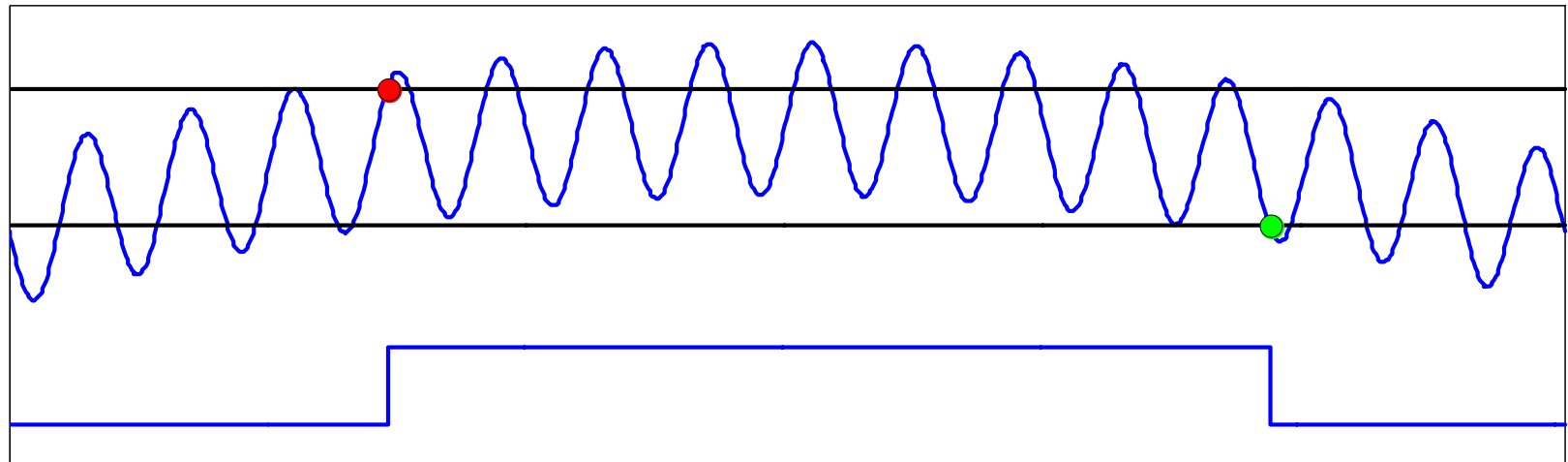
Alarm Chattering - Deadband



Alarm Chattering - Deadband



Alarm Chattering - Deadband



- Performance Monitoring of a Pump

- Performance Monitoring of Electric Motors

Concluding Remarks

- Alarm management and engineering is critical in today's industries.
- Multivariate and model-based methods offer better monitoring performance than univariate and signal-based methods.
- False alarms can be avoided by processing the prediction error and applying simple techniques.
- The major trade-off in alarm design is between detection delay and false alarm rate.

Acknowledgements

- Dr. Dave Shook from Matrikon
- Dr. Sirish Shah and Dr. Tongwen Chen
- CPC Group Members
- NSERC-Matrikon-Suncor-iCORE for financial support