Accuracy, Sensitivity, and Performance Criteria For Instrumentation

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Introduction

- Instrumentation is designed and built to perform some particular task.
- It is then tested to see how well it will perform this task, i.e. if it meets specifications.

Introduction (Continued)

Lord Kelvin's Dictum:

"I cannot discuss something unless I can measure it."

Introduction (Continued)

- Murphy's Law as it applies to the real world of instrumentation:

Not only will the instrument not respond perfectly to the intended quantity, but it will also respond to extraneous influences which will cause unexpected errors.

Instrumentation Errors

There are two types of instrumentation errors:

- Systematic Errors (Predictable)
- Statistical Errors (Random)

Instrumentation Errors (Continued)

- These two types of errors are independent of one another.

- Limits of the magnitude of each of these errors are determined by application requirements.

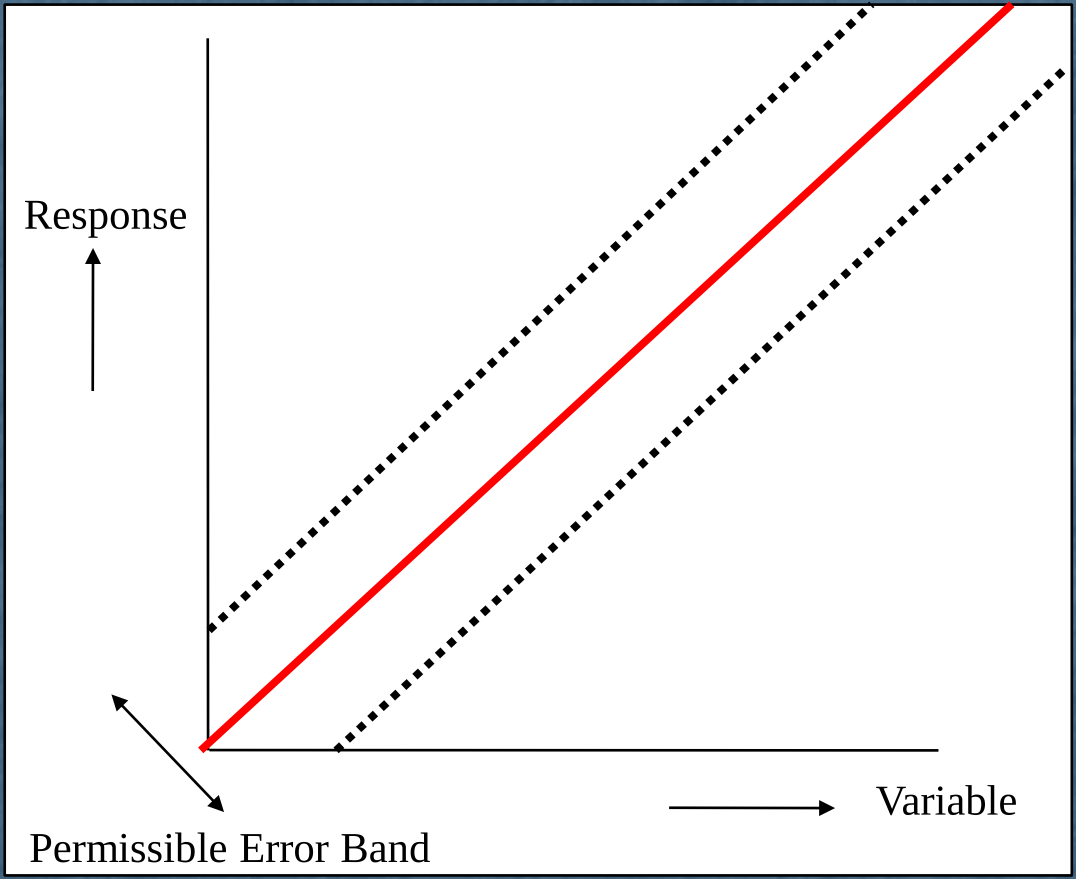
- ”Caveat Emptor” - Be careful when you interpret manufacturer's claims.

Systematic (”Predictable”) Errors to Instrument Response

Process Engineering terms for errors – Direct Response

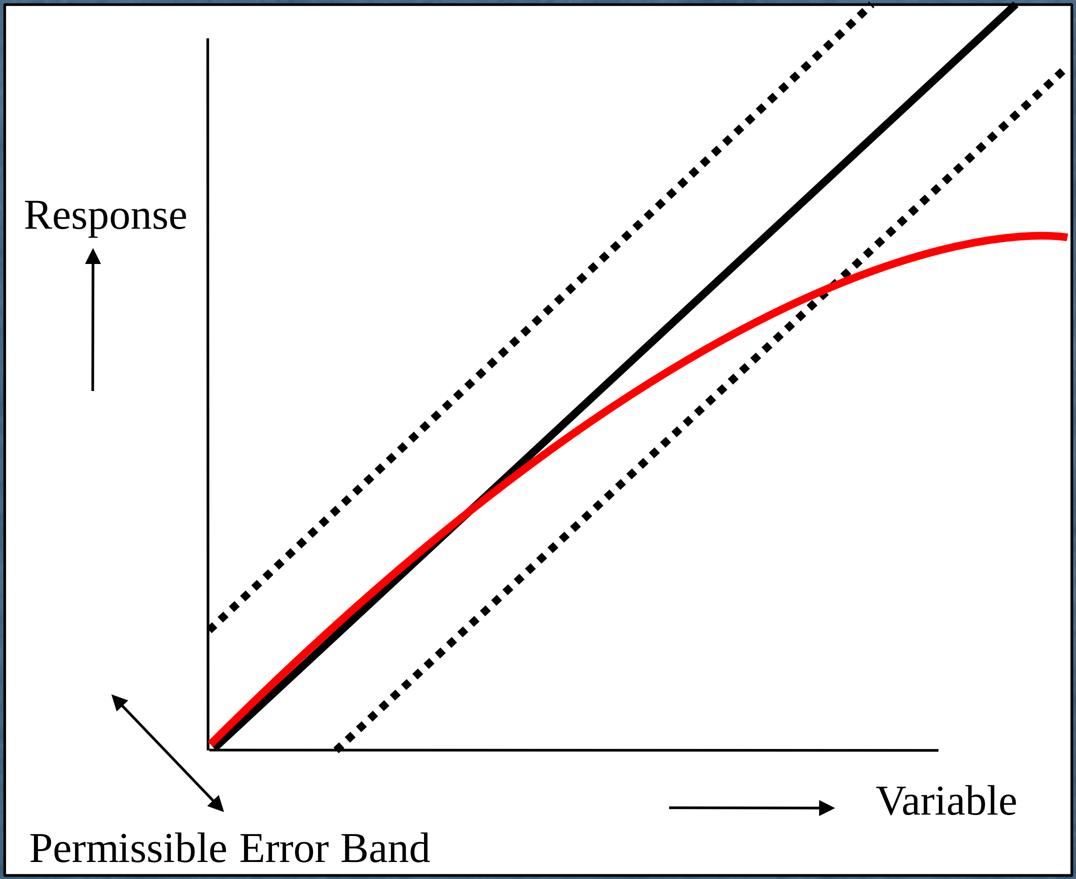
- Zero – Offset
- Span – Tangent
- Linearity

Systematic ("Predictable") Errors to Instrument Response



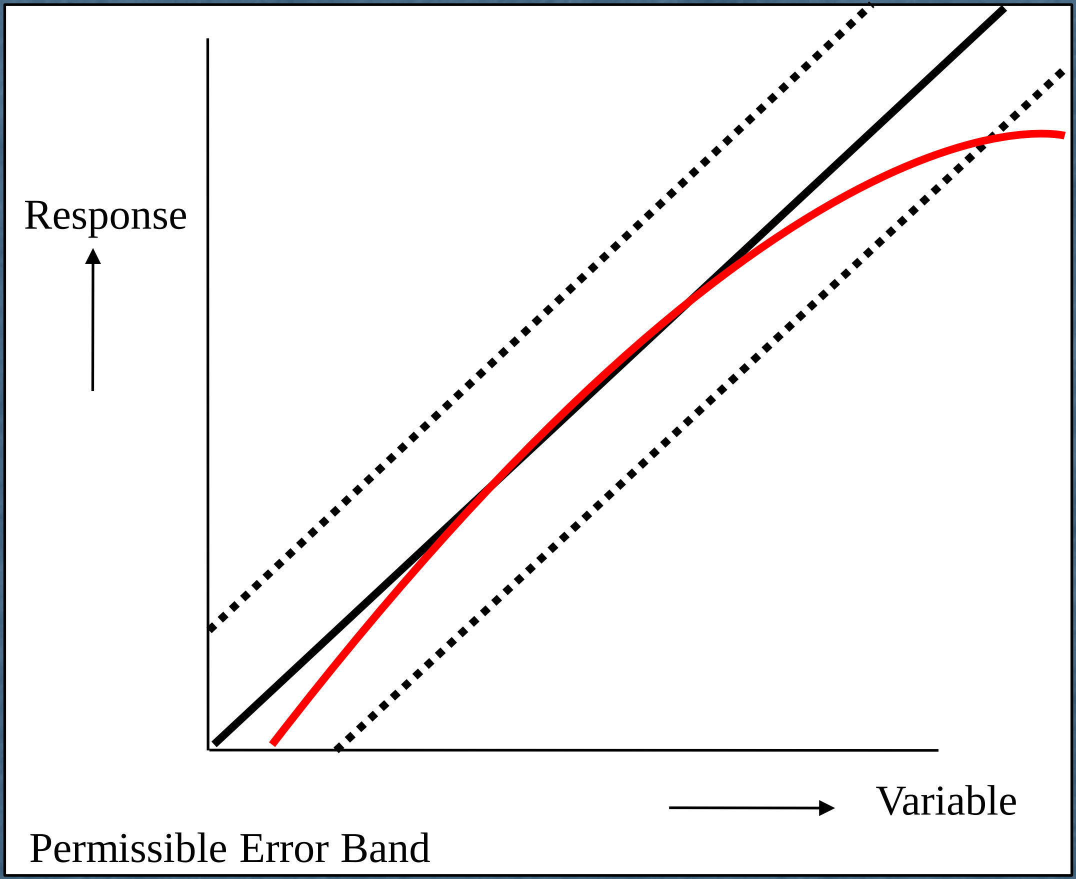
Ideal Response

Systematic ("Predictable") Errors to Instrument Response



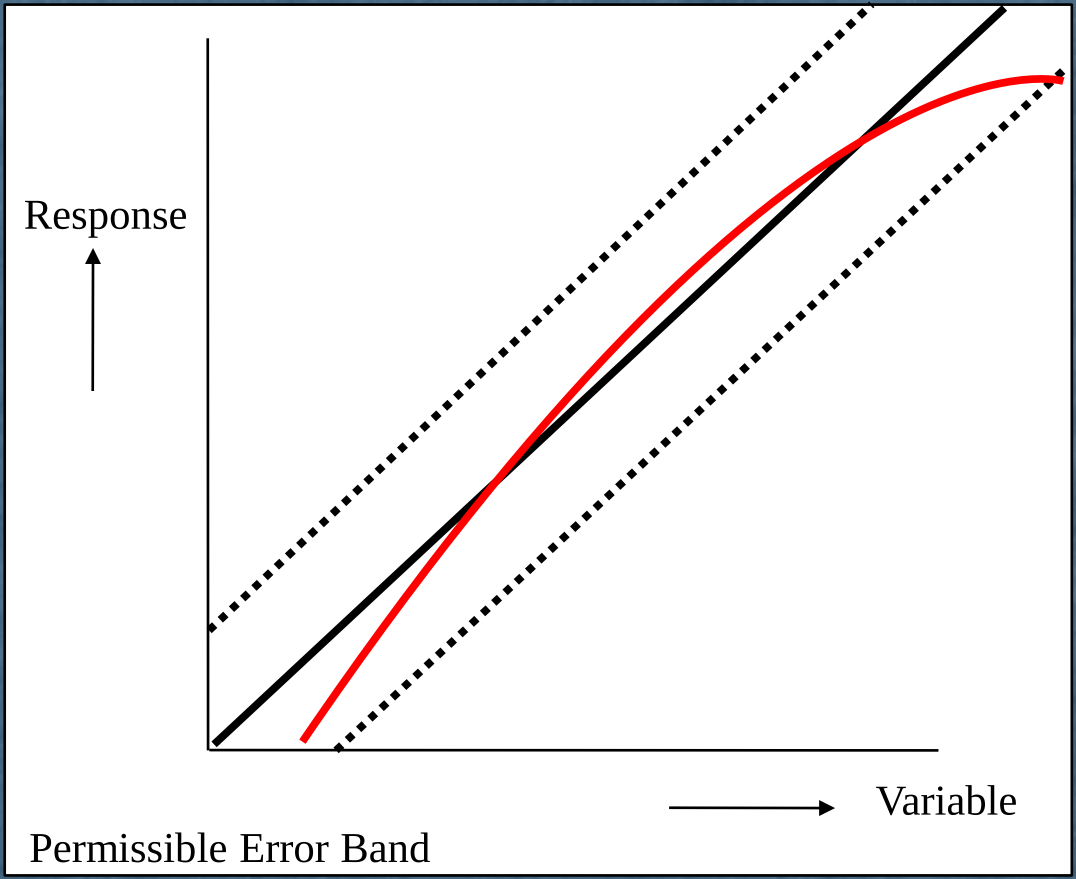
Response with Instrument Saturation

Systematic ("Predictable") Errors to Instrument Response



Shifting Span and Zero to Compensate

Systematic ("Predictable") Errors to Instrument Response



Shifting Span and Zero to Compensate

Random Errors

Random Errors are caused by unrelated influences, most notably environmental effects.

Typical random errors:

- *Temperature*
- *Pressure*
- *Humidity*
- *Ageing*
- *Statistical Errors*
- *Phases of the moon*

How Much Accuracy Do You Really Need?

- Performance requirements and degree of permissible errors are determined by the needs of the intended application.

- Examples of Stringent Requirements:

- Zero: Sometimes even small zero errors can be critical, i.e. your bank balance
- Span: Accuracy of clocks

A Tale of Two Carpenters...

Or at least that of John Harrison (March 1693 – March 1776)

A Tale of Two Carpenters... (Continued)

- Inventor of modern pendulum clock and balance wheel chronometer.
- Also invented the roller bearing and the clock grasshopper escarpment.
- He changed the face of the earth for a period of 50 to 100 years.

Britannia waves the rules...

Britannia rules the waves...

A Tale of Two Carpenters... (Continued)

- Navigation requires determination of both latitude and longitude through the use of the sextant and chronometer.
- Accuracy of the temperature compensated chronometer is of the order of one part in 100,000.
- In other words a two mile error in a voyage from England to Barbados in the 1765.
- This type of chronometer was in use until the invention of the quartz clock about 50 years ago!

Statistical Errors – Poisson Distribution

- G.M. Counters
- Scintillation Counters
- Proportional Counters
- Ion Chamber Detectors – Tritium Monitors
- Alpha Cams

Tritium Monitors, Sources of Error

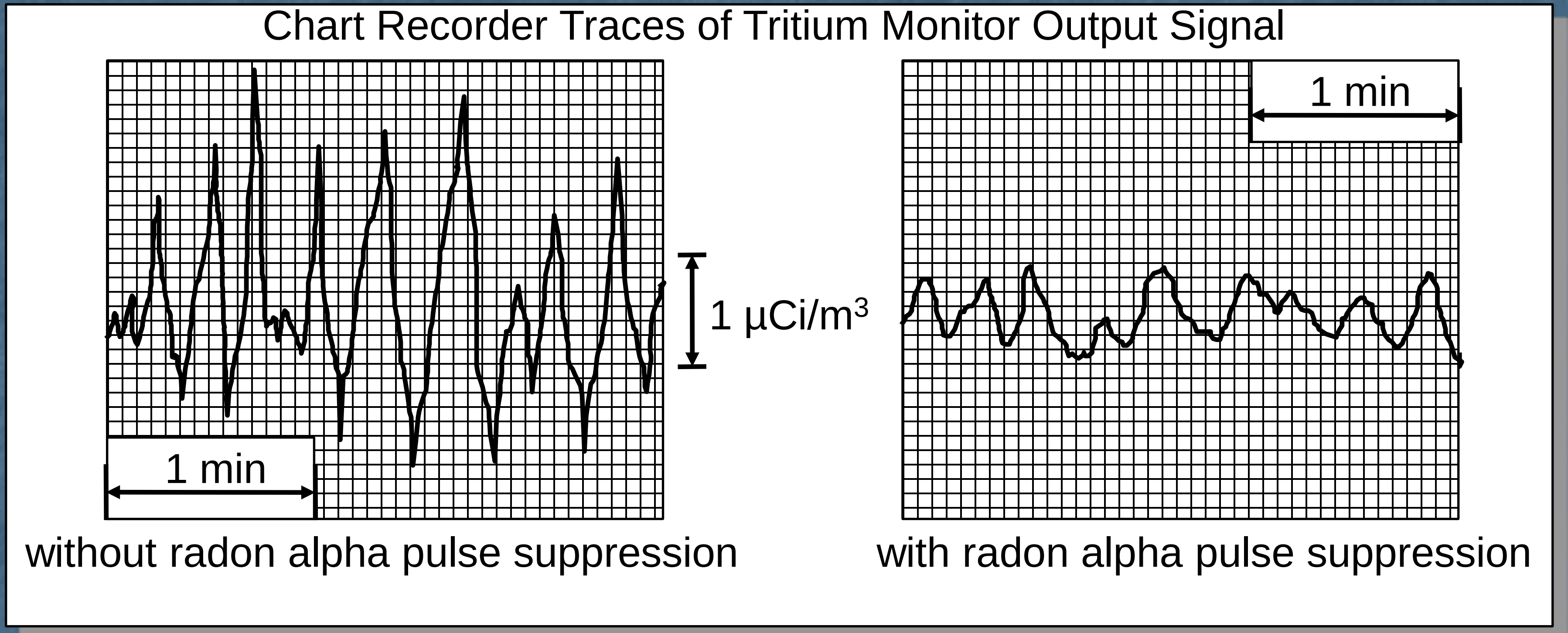
- Temperature sensitivity of the electronics, i.e., warm up, drift of zero. Takes up to 24 hours to settle.
- Temperature effects on span - up to 2000 ppm
- Pressure changes in ion chambers used for process control
- Humidity if close up to 100% relative humidity
- Radon for room air monitors

Tritium Monitors, Sources of Error (Continued)

- Radon pulses have energies of almost 5 MeV as compared to mean beta energy of 5-6 KeV.
- Radon levels can change by 10 to 1 from one day to the next.

Tritium Monitors, Sources of Error (Continued)

- Monitors which respond to Radon will show randomly changing zero offsets up to 2 to 3 µC/m^3 as well as statistical noise levels of 5 µC/m^3 or even more.



Questions?