StationXML-Docs

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unknown

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CHAPTER

ONE

INTRODUCTION

1.1 Introducing StationXML

StationXML is an XML representation of metadata that describes the data collected by geophysical instrumentation.

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metadata

- Information that describes how/where/when data was collected
- Data that describes data

XML = eXtensible Markup Language

- Designed to be self-descriptive
- Commonly used to distribute data over the internet

StationXML is defined by a schema that specifies the allowable format of StationXML files.

1.1.1 StationXML Example

Example of stationxml **Show/Hide Code**

```
<?xml version='1.0' encoding='UTF-8'?>
   <FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1">
      <Source>IRIS-DMC</Source>
      <Sender>IRIS-DMC</Sender>
      <Module>IRIS WEB SERVICE: fdsnws-station | version: 1.1.35</Module>
      <ModuleURI>http://service.iris.edu/fdsnws/station/1/query?starttime=1990-01-
↪27T06&network=IU;level=response</ModuleURI>
      <Created>2018-11-08T14:57:56.000000Z</Created>
      <Network code="IU" endDate="2500-12-31T23:59:59.000000Z" restrictedStatus="open
↪" startDate="1988-01-01T00:00:00.000000Z">
         <Description>Global Seismograph Network (GSN - IRIS/USGS)</Description>
         <TotalNumberStations>269</TotalNumberStations>
         <SelectedNumberStations>6</SelectedNumberStations>
         <Station code="ANMO" endDate="1995-07-14T00:00:00.000000Z" restrictedStatus=
↪"open" startDate="1989-08-29T00:00:00.000000Z">
            <Channel>
               <Response>
                  ...
```

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```
            </Response>
         </Channel>
         <Channel>
            <Response>
               ...
            </Response>
         </Channel>
      </Station>
      <Station code="CCM" endDate="1998-05-26T00:00:00.000000Z" restrictedStatus=
↪"open" startDate="1989-08-29T00:00:00.000000Z">
      </Station>
   </Network>
</FDSNStationXML>
```

Note that each XML element must have a start tag (e.g., <Station>) and an end tag (</Station>) and the element hierarchy must be maintained (e.g., a <Channel> may not exist outside of a <Station> and a <Station> may not exist outside of a <Network>, etc.).

1.1.2 The FDSN and StationXML schema

StationXML was developed through the International Federation of Digital Seismograph Networks (FDSN) to provide a standardized format for geophysical metadata.

Notice that the example stationXML excerpt above contains the following line:

```
<FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1">
```

This specifies the location and version of the schema to which the stationxml example must conform.

The FDSN maintains all versions of the stationxml schema at:

> https://www.fdsn.org/xml/station/

For instance, at the time of this writing, the latest schema version is v1.1 and is located at:

> https://www.fdsn.org/xml/station/fdsn-station-1.1.xsd

1.2 How This Documentation is Organized

This documentation has 5 parts:

1. This introduction
2. StationXML Reference - Over time, once users have absorbed the other parts of the documentation, it is expected that this reference section will be the most frequently used. The reference section is auto-generated directly from the FDSN schema so that it should always be in sync with the schema. The reference itself is broken out by the 5 levels of response detail:
   - FDSNStationXML
   - Network
   - Station
   - Channel
   - Response

3. Specifying and using response information - In this section you will find theory and examples to help you create instrument responses for your own stations.
4. StationXML tools - contains examples of 3rd party tools available to help users create and edit StationXML files. This is expected to be a fluid page that changes as new tools become available and older tools are deprecated.
5. Appendices - In here you will find more technical details on specific parts of StationXML and metadata. For instance, the first section, Mapping SEED to StationXML, is meant to be used as a reference to help users migrate their SEED format metadata to StationXML

1.3 Some History - SEED

For many years, the Standard for the Exchange of Earthquake Data (SEED) was the standard format for archiving and distributing metadata within the seismological community.

StationXML was developed through the FDSN (International Federation of Digital Seismograph Networks) as a replacement and extension of the SEED standard.

The purpose of the FDSN StationXML schema (fdsn-station.xsd) is to define an XML representation of the most important and commonly used structures of SEED 2.4 metadata with enhancements.

The goal is to allow mapping between SEED 2.4 dataless SEED volumes and this schema with as little transformation or loss of information as possible while at the same time simplifying station metadata representation when possible. Also, content and clarification has been added where lacking in the SEED standard.

1.4 ChangeLog

History of changes to FDSN schema

```
Changes from version 1.0 to 1.1 (2019-5-3)
(Edited 2019-12-18 for small clarifications)

* Add (persistent) <Identifier> element to all base nodes (Network, Station, Channel)

* Unify response elements, allow "number" and disallow "unit" attribute to <Numerator>
↪ and <Denominator>

* Allow <CreationDate> to be optional

* Use xs:double for <ApproximationLowerBound>, <ApproximationUpperBound> and
↪<MaximumError>

* Include data availability elements described in the fdsn-station+availability-1.0.
↪xsd extension schema as optional elements of the main schema

* Remove <StorageFormat> from <Channel>

* Limit each <Operator> to a single <Agency>

* Allow more than a single <Equipment> occurrence in <Channel>, same as in <Station>

* Allow <Operator> at the <Network> level, same as in <Station>

* Add "sourceID" attribute, with URI value, to the base node type for <Network>,
↪<Station>,<Channel>
```

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```
* Do not require and disallow <StageGain> and <Decimation> for <Polynomial> response␣
↪stages

* Add "measurementMethod" attribute to "uncertaintyDouble" attribute group used by␣
↪azimuth, dip, distance, latitude, longitude, elevation, etc. types

* Add <WaterLevel> within <Station> and <Channel>

* Add "subject" attribute to <Comment> to allow relating comments, make "id"␣
↪attribute optional.
```

CHAPTER

TWO

STATIONXML REFERENCE

2.1 <FDSNStationXML> required

Top-level for StationXML. Contains information about who produced the StationXML and where it came from.

attribute	type	required	description	example
schemaVersion	decimal	yes	The schema version compatible with the document.	

2.1.1 <Source> required

FDSNStationXML Source

type:string

Initiator of the information contained in the document. Likely to be the Network ID of the institution sending the message.

2.1.2 <Sender>

FDSNStationXML Sender

type:string

Name of the institution sending this message. Default is IRIS.

2.1.3 <Module>

FDSNStationXML Module

type:string

Name of the software module that that generated this document. The module is about the senders, e.g. seiscomp3.

Example: <Module>Seiscomp3</Module>

2.1.4 <ModuleURI>

FDSNStationXML ModuleURI

type:anyURI

This is the address of the query that generated the document, or, if applicable, the address of the software that generated this document.

2.1.5 <Created> required

FDSNStationXML Created

type:dateTime

The documentation's creation date.

2.2 <Network> required

This represents the Network layer, all station metadata is contained within this element. The official name of the network or other descriptive information can be included in the Description element. The Network level contains 0 or more Stations.

Example: <Network code="IU" startDate=2016-01-27T13:00:00>

attribute	type	required	description	example
alternateCode	string	no	A code used for display or association.	alternateCode='IX'
code	string	yes	Identifying code/name.	For Network Name 'IU', code='IU'
endDate	dateTime	no	End date of network/station/channel epoch	endDate=2018-01-27T00:00:00
historicalCode	string	no	A previously used code if different from the current code.	historicalCode='II'
restrictedStatus	RestrictedStatusType	no	One of: open, closed, partial	restrictedStatus = open
sourceID	anyURI	no	A data source identifier in URI form	sourceID='http://some/path'
startDate	dateTime	no	Start date of network/station/channel epoch	startDate=2016-07-01T00:00:00

2.2.1 <Description>

Network Description

type:string

Description of the Network.

Example: <Description>This is a description</Description>

2.2.2 <Identifier>

Network Identifier

type:string

A type to document persistent identifiers. Identifier values should be specified without a URI scheme (prefix), instead the identifer type is documented as an attribute.

attribute	type	required	description	example
type	string	no		

2.2.3 <Comment>

Network Comment

Container for a comment or log entry.

attribute	type	required	description	example
id	CounterType	no	An id for this comment	id=12345
subject	string	no	A subject for this comment. Multiple comments with the same subject should be considered related.	subject='Scheduled maintenance'

<Value> required

Network Comment Value

type:string

This is where the comment text goes.

Example: <Value>GPS clock is lost</Value>

<BeginEffectiveTime>

Network Comment BeginEffectiveTime

type:dateTime

This is where the comment text goes.

Example: <BeginEffectiveTime>2008-09-15T00:00:00</BeginEffectiveTime>

<EndEffectiveTime>

Network Comment EndEffectiveTime

type:dateTime

End time for where comment applies.

Example: <EndEffectiveTime>2008-09-16T12:00:00</EndEffectiveTime>

<Author>

Network Comment Author

Element to hold contact information of Author of Comment. A person can belong to multiple agencies and have multiple email addresses and phone numbers.

<Name>

Network Comment Author Name

type:string

Name of contact or author.

Example: <Name>Alfred E. Neuman</Name>

<Agency>

Network Comment Author Agency

type:string

Agency of contact or author.

Example: <Agency>Mad Magazine, Inc.</Agency>

<Email>

Network Comment Author Email

type:string

Email of contact or author.

Example: <Email>a.neuman@gmail.com</Email>

<Phone>

Network Comment Author Phone

Phone of contact or author.

attribute	type	required	description	example
description	string	no		

<CountryCode>

Network Comment Author Phone CountryCode

type:integer

Telephone country code.

Example: <CountryCode>64</CountryCode>

<AreaCode> required

Network Comment Author Phone AreaCode

type:integer

Telephone area code.

Example: <AreaCode>408</CountryCode>

<PhoneNumber> required

Network Comment Author Phone PhoneNumber

type:string

Telephone phonenumber.

Example: <PhoneNumber>5551212</PhoneNumber>

2.2.4 <DataAvailability>

Network DataAvailability

A description of time series data availability. This information should be considered transient and is primarily useful as a guide for generating time series data requests. The information for a DataAvailability:Span may be specific to the time range used in a request that resulted in the document or limited to the availability of data withing the request range. These details may or may not be retained when synchronizing metadata between data centers.

<Extent>

Network DataAvailability Extent

Data availability extents, the earliest and latest data available. No information is included about the continuity of the data is included or implied.

attribute	type	required	description	example
end	dateTime	yes	end date of extent	end=1988-12-31T00:00:00
start	dateTime	yes	start date of extent	start=1988-01-01T00:00:00

<Span>

Network DataAvailability Span

A type for describing data availability spans, with variable continuity. The time range described may be based on the request parameters that generated the document and not necessarily relate to continuity outside of the range. It may also be a smaller time window than the request depending on the data characteristics.

attribute	type	required	description	example
end	dateTime	yes	end date of span	end=1988-12-31T00:00:00
maximumTimeTear	decimal	no	The maximum time tear (gap or overlap) in seconds between time series segments in the specified range.	maximumTimeTear=0.01
numberSegments	integer	yes	The number of continuous time series segments contained in the specified time range. A value of 1 indicates that the time series is continuous from start to end.	numberSegments=2
start	dateTime	yes	start date of span	start=1988-01-01T00:00:00

2.2.5 <Operator>

Network Operator

Agency and contact persons who manage this network.

<Agency> required

Network Operator Agency

type:string

An operating agency and associated contact persons.

Example: <Agency>USGS</Agency>

<Contact>

Network Operator Contact

Person's contact information. A person can belong to multiple agencies and have multiple email addresses and phone numbers.

<Name>

Network Operator Contact Name

type:string

Name of contact or author.

Example: <Name>Alfred E. Neuman</Name>

<Agency>

Network Operator Contact Agency

type:string

Agency of contact or author.

Example: <Agency>Mad Magazine, Inc.</Agency>

<Email>

Network Operator Contact Email

type:string

Email of contact or author.

Example: <Email>a.neuman@gmail.com</Email>

<Phone>

Network Operator Contact Phone

Phone of contact or author.

attribute	type	required	description	example
description	string	no		

<CountryCode>

Network Operator Contact Phone CountryCode

type:integer

Telephone country code.

Example: <CountryCode>64</CountryCode>

<AreaCode> required

Network Operator Contact Phone AreaCode

type:integer

Telephone area code.

Example: <AreaCode>408</CountryCode>

<PhoneNumber> required

Network Operator Contact Phone PhoneNumber

type:string

Telephone phonenumber.

Example: <PhoneNumber>5551212</PhoneNumber>

<WebSite>

Network Operator WebSite

type:anyURI

Website of operating agency.

Example: <WebSite>http://usgs.gov</WebSite>

2.2.6 <TotalNumberStations>

Network TotalNumberStations

Warning

This field isn't super useful and is likely to be deprecated in future versions of StationXML

type:decimal range:TotalNumberStations ≥ 0

The total number of stations contained in this network, including inactive or terminated stations.

Example: <TotalNumberStations>24</TotalNumberStations>

2.2.7 <SelectedNumberStations>

Network SelectedNumberStations

Warning

This field isn't super useful and is likely to be deprecated in future versions of StationXML

---

type:decimal range:SelectedNumberStations ≥ 0

The SelectedNumberOfStations will be some number less than the possible number of stations for this Network. For instance, if you requested only 12 stations for a 24 station network, then SelectedNumberOfStations=12.

Example: <SelectedNumberStations>12</SelectedNumberStations>

2.3 <Station>

This type represents a Station epoch. It is common to only have a single station epoch with the station's creation and termination dates as the epoch start and end dates.

attribute	type	required	description	example
alternateCode	string	no	A code used for display or association.	alternateCode='IX'
code	string	yes	Identifying code/name.	For Station Name 'ANMO', code='ANMO'
endDate	dateTime	no	End date of network/station/channel epoch	endDate=2018-01-27T00:00:00
historicalCode	string	no	A previously used code if different from the current code.	historicalCode='II'
restrictedStatus	RestrictedStatusType	no	One of: open, closed, partial	restrictedStatus = open
sourceID	anyURI	no	A data source identifier in URI form	sourceID='http://some/path'
startDate	dateTime	no	Start date of network/station/channel epoch	startDate=2016-07-01T00:00:00

2.3.1 <Description>

Station Description

type:string

Description of the Station.

Example: <Description>This is a description</Description>

2.3.2 <Identifier>

Station Identifier

type:string

A type to document persistent identifiers. Identifier values should be specified without a URI scheme (prefix), instead the identifer type is documented as an attribute.

attribute	type	required	description	example
type	string	no		

2.3.3 <Comment>

Station Comment

Container for a comment or log entry.

attribute	type	required	description	example
id	CounterType	no	An id for this comment	id=12345
subject	string	no	A subject for this comment. Multiple comments with the same subject should be considered related.	subject='Scheduled maintenance'

<Value> required

Station Comment Value

type:string

This is where the comment text goes.

Example: <Value>GPS clock is lost</Value>

<BeginEffectiveTime>

Station Comment BeginEffectiveTime

type:dateTime

This is where the comment text goes.

Example: <BeginEffectiveTime>2008-09-15T00:00:00</BeginEffectiveTime>

<EndEffectiveTime>

Station Comment EndEffectiveTime

type:dateTime

End time for where comment applies.

Example: <EndEffectiveTime>2008-09-16T12:00:00</EndEffectiveTime>

<Author>

Station Comment Author

Element to hold contact information of Author of Comment. A person can belong to multiple agencies and have multiple email addresses and phone numbers.

<Name>

Station Comment Author Name

type:string

Name of contact or author.

Example: <Name>Alfred E. Neuman</Name>

<Agency>

Station Comment Author Agency

type:string

Agency of contact or author.

Example: <Agency>Mad Magazine, Inc.</Agency>

<Email>

Station Comment Author Email

type:string

Email of contact or author.

Example: <Email>a.neuman@gmail.com</Email>

<Phone>

Station Comment Author Phone

Phone of contact or author.

attribute	type	required	description	example
description	string	no		

<CountryCode>

Station Comment Author Phone CountryCode

type:integer

Telephone country code.

Example: <CountryCode>64</CountryCode>

<AreaCode> required

Station Comment Author Phone AreaCode

type:integer

Telephone area code.

Example: <AreaCode>408</CountryCode>

<PhoneNumber> required

Station Comment Author Phone PhoneNumber

type:string

Telephone phonenumber.

Example: <PhoneNumber>5551212</PhoneNumber>

2.3.4 <DataAvailability>

Station DataAvailability

A description of time series data availability. This information should be considered transient and is primarily useful as a guide for generating time series data requests. The information for a DataAvailability:Span may be specific to the time range used in a request that resulted in the document or limited to the availability of data withing the request range. These details may or may not be retained when synchronizing metadata between data centers.

<Extent>

Station DataAvailability Extent

Data availability extents, the earliest and latest data available. No information is included about the continuity of the data is included or implied.

attribute	type	required	description	example
end	dateTime	yes	end date of extent	end=1988-12-31T00:00:00
start	dateTime	yes	start date of extent	start=1988-01-01T00:00:00

<Span>

Station DataAvailability Span

A type for describing data availability spans, with variable continuity. The time range described may be based on the request parameters that generated the document and not necessarily relate to continuity outside of the range. It may also be a smaller time window than the request depending on the data characteristics.

attribute	type	required	description	example
end	dateTime	yes	end date of span	end=1988-12-31T00:00:00
maximumTimeTear	decimal	no	The maximum time tear (gap or overlap) in seconds between time series segments in the specified range.	maximumTimeTear=0.01
numberSegments	integer	yes	The number of continuous time series segments contained in the specified time range. A value of 1 indicates that the time series is continuous from start to end.	numberSegments=2
start	dateTime	yes	start date of span	start=1988-01-01T00:00:00

2.3.5 <Latitude> required

Station Latitude

type:double range:-90.0 $\leq$ Latitude

Station latitude coordinate, where the bulk of the equipment is located (or another appropriate site location).

Example: <Latitude unit="DEGREES" datum="WGS84">34.9459</Latitude>

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		
datum	NMTOKEN	no		

2.3.6 <Longitude> required

Station Longitude

type:double range:-180.0 ≤ Longitude

Station longitude coordinate, where the bulk of the equipment is located (or another appropriate site location).

Example: <Longitude unit="DEGREES" datum="WGS84">-106.4572</Longitude>

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		
datum	NMTOKEN	no		

2.3.7 <Elevation> required

Station Elevation

type:double

Station elevation.

Example: <Elevation unit="m">1850.0</Elevation>

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

2.3.8 <Site> required

Station Site

These fields describe the location of the station using geopolitical entities (country, city, etc.).

<Name> required

Station Site Name

type:string

Name of the site.

Example: <Name>Albuquerque, New Mexico</Name>

<Description>

Station Site Description

type:string

A longer description of the location of this station.

Example: <Description>NW corner of Yellowstone National Park</Description>

<Town>

Station Site Town

type:string

The town or city closest to the station.

Example: <Town>Albuquerque</Town>

<County>

Station Site County

type:string

The county where the station is located.

Example: <County>Bernalillo</County>

<Region>

Station Site Region

type:string

The state, province, or region of this site.

Example: <Region>Southwest U.S.</Region>

<Country>

Station Site Country

type:string

The country of this site.

Example: <Country>U.S.A.</Country>

2.3.9 <WaterLevel>

Station WaterLevel

type:double

Elevation of the water surface in meters for underwater sites, where 0 is sea level. For example, an OBS on the bottom of a lake will have elevation equal to the elevation of the lake surface ??.

Example: <WaterLevel>1200.</WaterLevel>

attribute	type	required	description	example
unit	string	no	The unit of measurement	unit='DEGREES'
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

2.3.10 <Vault>

Station Vault

type:string

Type of vault, e.g. WWSSN, tunnel, transportable array, etc.

2.3.11 <Geology>

Station Geology

type:string

Type of rock and/or geologic formation.

2.3.12 <Equipment>

Station Equipment

Equipment used by all channels at a station.

attribute	type	required	description	example
resourceId	string	no	This field contains a string that should serve as a unique resource identifier. This identifier can be interpreted differently depending on the datacenter/software that generated the document. Also, we recommend to use something like GENERATOR:Meaningful ID. As a common behaviour equipment with the same ID should contains the same information/be derived from the same base instruments.	

<Type>

Station Equipment Type

type:string

<Description>

Station Equipment Description

type:string

<Manufacturer>

Station Equipment Manufacturer

type:string

<Vendor>

Station Equipment Vendor

type:string

<Model>

Station Equipment Model

type:string

<SerialNumber>

Station Equipment SerialNumber

type:string

<InstallationDate>

Station Equipment InstallationDate

type:dateTime

<RemovalDate>

Station Equipment RemovalDate

type:dateTime

<CalibrationDate>

Station Equipment CalibrationDate

type:dateTime

2.3.13 <Operator>

Station Operator

An operator and associated contact persons.

<Agency> required

Station Operator Agency

type:string

An operating agency and associated contact persons.

Example: <Agency>USGS</Agency>

<Contact>

Station Operator Contact

Person's contact information. A person can belong to multiple agencies and have multiple email addresses and phone numbers.

<Name>

Station Operator Contact Name

type:string

Name of contact or author.

Example: <Name>Alfred E. Neuman</Name>

<Agency>

Station Operator Contact Agency

type:string

Agency of contact or author.

Example: <Agency>Mad Magazine, Inc.</Agency>

<Email>

Station Operator Contact Email

type:string

Email of contact or author.

Example: <Email>a.neuman@gmail.com</Email>

<Phone>

Station Operator Contact Phone

Phone of contact or author.

attribute	type	required	description	example
description	string	no		

<CountryCode>

Station Operator Contact Phone CountryCode

type:integer

Telephone country code.

Example: <CountryCode>64</CountryCode>

<AreaCode> required

Station Operator Contact Phone AreaCode

type:integer

Telephone area code.

Example: <AreaCode>408</CountryCode>

<PhoneNumber> required

Station Operator Contact Phone PhoneNumber

type:string

Telephone phonenumber.

Example: <PhoneNumber>5551212</PhoneNumber>

<WebSite>

Station Operator WebSite

type:anyURI

Website of operating agency.

Example: <WebSite>http://usgs.gov</WebSite>

2.3.14 <CreationDate>

Station CreationDate

type:dateTime

Date and time (UTC) when the station was first installed.

2.3.15 <TerminationDate>

Station TerminationDate

type:dateTime

Date and time (UTC) when the station was terminated or will be terminated. Do not include this field if it is irrelevant.

2.3.16 <TotalNumberChannels>

Station TotalNumberChannels

Warning

This field isn't super useful and is likely to be deprecated in future versions of StationXML

---

type:decimal range:TotalNumberChannels ≥ 0

Total number of channels recorded at this station.

2.3.17 <SelectedNumberChannels>

Station SelectedNumberChannels

Warning

This field isn't super useful and is likely to be deprecated in future versions of StationXML

---

type:decimal range:SelectedNumberChannels ≥ 0

Number of channels recorded at this station and selected by the query that produced this document.

2.3.18 <ExternalReference>

Station ExternalReference

URI of any type of external report.

<URI> required

Station ExternalReference URI

type:anyURI

<Description> required

Station ExternalReference Description

type:string

2.4 <Channel>

Parent element for the related response blockettes.

attribute	type	required	description	example
alternateCode	string	no	A code used for display or association.	alternateCode='IX'
code	string	yes	Identifying code/name.	code='IU' or code='ANMO'
endDate	dateTime	no	End date of network/station/channel epoch	endDate=2018-01-27T00:00:00
historicalCode	string	no	A previously used code if different from the current code.	historicalCode='II'
locationCode	string	yes	The locationCode is typically used to group channel coming from a common sensor. For example, the channels of the primary sensor at global IDA-IRIS stations has locationCode = '00': 00-BHZ, 00-BHE, 00-BHN, 00-LHZ, . . . , etc. Even though it is required, it may be an empty string.	locationCode='30'
restrictedStatus	RestrictedStatusType	no	One of: open, closed, partial	restrictedStatus = open
sourceID	anyURI	no	A data source identifier in URI form	sourceID='http://some/path'
startDate	dateTime	no	Start date of network/station/channel epoch	startDate=2016-07-01T00:00:00

2.4.1 <Description>

Channel Description

type:string

Description of the Channel.

Example: <Description>This is a description</Description>

2.4.2 <Identifier>

Channel Identifier

type:string

A type to document persistent identifiers. Identifier values should be specified without a URI scheme (prefix), instead the identifer type is documented as an attribute.

attribute	type	required	description	example
type	string	no		

2.4.3 <Comment>

Channel Comment

Container for a comment or log entry.

attribute	type	required	description	example
id	CounterType	no	An id for this comment	id=12345
subject	string	no	A subject for this comment. Multiple comments with the same subject should be considered related.	subject='Scheduled maintenance'

<Value> required

Channel Comment Value

type:string

This is where the comment text goes.

Example: <Value>GPS clock is lost</Value>

<BeginEffectiveTime>

Channel Comment BeginEffectiveTime

type:dateTime

This is where the comment text goes.

Example: <BeginEffectiveTime>2008-09-15T00:00:00</BeginEffectiveTime>

<EndEffectiveTime>

Channel Comment EndEffectiveTime

type:dateTime

End time for where comment applies.

Example: <EndEffectiveTime>2008-09-16T12:00:00</EndEffectiveTime>

<Author>

Channel Comment Author

Element to hold contact information of Author of Comment. A person can belong to multiple agencies and have multiple email addresses and phone numbers.

<Name>

Channel Comment Author Name

type:string

Name of contact or author.

Example: <Name>Alfred E. Neuman</Name>

<Agency>

Channel Comment Author Agency

type:string

Agency of contact or author.

Example: <Agency>Mad Magazine, Inc.</Agency>

<Email>

Channel Comment Author Email

type:string

Email of contact or author.

Example: <Email>a.neuman@gmail.com</Email>

<Phone>

Channel Comment Author Phone

Phone of contact or author.

attribute	type	required	description	example
description	string	no		

<CountryCode>

Channel Comment Author Phone CountryCode

type:integer

Telephone country code.

Example: <CountryCode>64</CountryCode>

<AreaCode> required

Channel Comment Author Phone AreaCode

type:integer

Telephone area code.

Example: <AreaCode>408</CountryCode>

<PhoneNumber> required

Channel Comment Author Phone PhoneNumber

type:string

Telephone phonenumber.

Example: <PhoneNumber>5551212</PhoneNumber>

2.4.4 <DataAvailability>

Channel DataAvailability

A description of time series data availability. This information should be considered transient and is primarily useful as a guide for generating time series data requests. The information for a DataAvailability:Span may be specific to the time range used in a request that resulted in the document or limited to the availability of data withing the request range. These details may or may not be retained when synchronizing metadata between data centers.

<Extent>

Channel DataAvailability Extent

Data availability extents, the earliest and latest data available. No information is included about the continuity of the data is included or implied.

attribute	type	required	description	example
end	dateTime	yes	end date of extent	end=1988-12-31T00:00:00
start	dateTime	yes	start date of extent	start=1988-01-01T00:00:00

<Span>

Channel DataAvailability Span

A type for describing data availability spans, with variable continuity. The time range described may be based on the request parameters that generated the document and not necessarily relate to continuity outside of the range. It may also be a smaller time window than the request depending on the data characteristics.

attribute	type	required	description	example
end	dateTime	yes	end date of span	end=1988-12-31T00:00:00
maximumTimeTear	decimal	no	The maximum time tear (gap or overlap) in seconds between time series segments in the specified range.	maximumTimeTear=0.01
numberSegments	integer	yes	The number of continuous time series segments contained in the specified time range. A value of 1 indicates that the time series is continuous from start to end.	numberSegments=2
start	dateTime	yes	start date of span	start=1988-01-01T00:00:00

2.4.5 <ExternalReference>

Channel ExternalReference

URI of any type of external report, such as data quality reports.

<URI> required

Channel ExternalReference URI

type:anyURI

<Description> required

Channel ExternalReference Description

type:string

2.4.6 <Latitude> required

Channel Latitude

type:double range:-90.0 ≤ Latitude

Latitude coordinate of this channel's sensor. Should be the same as the Station's latitudee. If they are different, then the Channel's latitude should be used and the Station's shouldn't be.

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		
datum	NMTOKEN	no		

2.4.7 <Longitude> required

Channel Longitude

type:double range:-180.0 ≤ Longitude

Longitude coordinate of this channel's sensor. Should be the same as the Station's longitude. If they are different, then the Channel's longitude should be used and the Station's shouldn't be.

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		
datum	NMTOKEN	no		

2.4.8 <Elevation> required

Channel Elevation

type:double

Elevation of the sensor.

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

2.4.9 <Depth> required

Channel Depth

type:double

The local depth or overburden of the instrument's location in meters. For downhole instruments, the depth of the instrument under the surface ground level. For underground vaults, the distance from the instrument to the local ground level. above.

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

2.4.10 <Azimuth>

Channel Azimuth

type:double range:$0.0 \leq$ Azimuth

Azimuth of the sensor in degrees from True North, clockwise.

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

2.4.11 <Dip>

Channel Dip

type:double range:-90.0 ≤ Dip

Dip of the instrument in degrees, down from horizontal.

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

2.4.12 <WaterLevel>

Channel WaterLevel

type:double

Elevation of the water surface in meters for underwater sites, where 0 is sea level.

attribute	type	required	description	example
unit	string	no	The unit of measurement	unit='DEGREES'
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

2.4.13 <Type>

Channel Type

type:string

The type of data this channel collects. Corresponds to channel flags in SEED blockette 52. The SEED volume producer could use the first letter of an Output value as the SEED channel flag.

2.4.14 <SampleRate> required

Channel SampleRate

type:double

Sample rate in samples per second.

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

2.4.15 <SampleRateRatio>

Channel SampleRateRatio

Sample rate expressed as number of samples in a number of seconds.

<NumberSamples> required

Channel SampleRateRatio NumberSamples

type:integer

<NumberSeconds> required

Channel SampleRateRatio NumberSeconds

type:integer

2.4.16 <ClockDrift>

Channel ClockDrift

type:double range:ClockDrift ≥ 0.0

A tolerance value, measured in seconds per sample, used as a threshold for time error detection in data from the channel.

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

2.4.17 <CalibrationUnits>

Channel CalibrationUnits

A type to document true SI units.

<Name> required

Channel CalibrationUnits Name

type:string

Name of true SI units, e.g. “m/s”, “V”, “Pa”, “C”.

<Description>

Channel CalibrationUnits Description

type:string

Description of true SI units, e.g. “Velocity in meters per second”, “Volts”, “Pascals”, “Degrees Celsius”.

2.4.18 <Sensor>

Channel Sensor

If this was entered at the Station level, it is not necesary to do it for each Channel, unless you have differences in equipment. If using a sensor, use this field.

attribute	type	required	description	example
resourceId	string	no	This field contains a string that should serve as a unique resource identifier. This identifier can be interpreted differently depending on the datacenter/software that generated the document. Also, we recommend to use something like GENERATOR:Meaningful ID. As a common behaviour equipment with the same ID should contains the same information/be derived from the same base instruments.	

<Type>

Channel Sensor Type

type:string

<Description>

Channel Sensor Description

type:string

<Manufacturer>

Channel Sensor Manufacturer

type:string

<Vendor>

Channel Sensor Vendor

type:string

<Model>

Channel Sensor Model

type:string

<SerialNumber>

Channel Sensor SerialNumber

type:string

<InstallationDate>

Channel Sensor InstallationDate

type:dateTime

<RemovalDate>

Channel Sensor RemovalDate

type:dateTime

<CalibrationDate>

Channel Sensor CalibrationDate

type:dateTime

2.4.19 <PreAmplifier>

Channel PreAmplifier

If this was entered at the Station level, it is not necesary to do it for each Channel, unless you have differences in equipment. If using a preamplifier, use this field.

attribute	type	required	description	example
resourceId	string	no	This field contains a string that should serve as a unique resource identifier. This identifier can be interpreted differently depending on the datacenter/software that generated the document. Also, we recommend to use something like GENERATOR:Meaningful ID. As a common behaviour equipment with the same ID should contains the same information/be derived from the same base instruments.	

<Type>

Channel PreAmplifier Type

type:string

<Description>

Channel PreAmplifier Description

type:string

<Manufacturer>

Channel PreAmplifier Manufacturer

type:string

<Vendor>

Channel PreAmplifier Vendor

type:string

<Model>

Channel PreAmplifier Model

type:string

<SerialNumber>

Channel PreAmplifier SerialNumber

type:string

<InstallationDate>

Channel PreAmplifier InstallationDate

type:dateTime

<RemovalDate>

Channel PreAmplifier RemovalDate

type:dateTime

<CalibrationDate>

Channel PreAmplifier CalibrationDate

type:dateTime

2.4.20 <DataLogger>

Channel DataLogger

If this was entered at the Station level, it is not necesary to do it for each Channel, unless you have differences in equipment. If using a datalogger, use this field.

attribute	type	required	description	example
resourceId	string	no	This field contains a string that should serve as a unique resource identifier. This identifier can be interpreted differently depending on the datacenter/software that generated the document. Also, we recommend to use something like GENERATOR:Meaningful ID. As a common behaviour equipment with the same ID should contains the same information/be derived from the same base instruments.	

<Type>

Channel DataLogger Type

type:string

<Description>

Channel DataLogger Description

type:string

<Manufacturer>

Channel DataLogger Manufacturer

type:string

<Vendor>

Channel DataLogger Vendor

type:string

<Model>

Channel DataLogger Model

type:string

<SerialNumber>

Channel DataLogger SerialNumber

type:string

<InstallationDate>

Channel DataLogger InstallationDate

type:dateTime

<RemovalDate>

Channel DataLogger RemovalDate

type:dateTime

<CalibrationDate>

Channel DataLogger CalibrationDate

type:dateTime

2.4.21 <Equipment>

Channel Equipment

If the Equipment is entered at the Station level, it is not necesary to do it for each Channel, unless you have differences in equipment. If using a preamplifier, sensor, or datalogger, use their appropriate fields instead.

attribute	type	required	description	example
resourceId	string	no	This field contains a string that should serve as a unique resource identifier. This identifier can be interpreted differently depending on the datacenter/software that generated the document. Also, we recommend to use something like GENERATOR:Meaningful ID. As a common behaviour equipment with the same ID should contains the same information/be derived from the same base instruments.	

<Type>

Channel Equipment Type

type:string

<Description>

Channel Equipment Description

type:string

<Manufacturer>

Channel Equipment Manufacturer

type:string

<Vendor>

Channel Equipment Vendor

type:string

<Model>

Channel Equipment Model

type:string

<SerialNumber>

Channel Equipment SerialNumber

type:string

<InstallationDate>

Channel Equipment InstallationDate

type:dateTime

<RemovalDate>

Channel Equipment RemovalDate

type:dateTime

<CalibrationDate>

Channel Equipment CalibrationDate

type:dateTime

2.5 <Response>

Instrument sensitivities, or the complete system sensitivity, can be expressed using either a sensitivity value or a polynomial. The information can be used to convert raw data to Earth at a specified frequency or within a range of frequencies. It is suggested that either InstrumentSensitivity or InstrumentPolynomial should be present.

attribute	type	required	description	example
resourceId	string	no	Same meaning as Equipment:resourceId.	

2.5.1 <InstrumentSensitivity>

Response InstrumentSensitivity

The total sensitivity for a channel, representing the complete acquisition system expressed as a scalar. Equivalent to SEED stage 0 gain (blockette 58) with the ability to specify a frequency range.

<Value> required

Response InstrumentSensitivity Value

type:double

A scalar that, when applied to the data values, converts the data to different units (e.g. Earth units).

<Frequency> required

Response InstrumentSensitivity Frequency

type:double

The frequency (in Hertz) at which the Value is valid.

<InputUnits> required

Response InstrumentSensitivity InputUnits

The units of the data as input from the perspective of data acquisition. After correcting data for this response, these would be the resulting units.

<Name> required

Response InstrumentSensitivity InputUnits Name

type:string

Name of true SI units, e.g. "m/s", "V", "Pa", "C".

<Description>

Response InstrumentSensitivity InputUnits Description

type:string

Description of true SI units, e.g. "Velocity in meters per second", "Volts", "Pascals", "Degrees Celsius".

<OutputUnits> required

Response InstrumentSensitivity OutputUnits

The units of the data as output from the perspective of data acquisition. These would be the units of the data prior to correcting for this response.

<Name> required

Response InstrumentSensitivity OutputUnits Name

type:string

Name of true SI units, e.g. "m/s", "V", "Pa", "C".

<Description>

Response InstrumentSensitivity OutputUnits Description

type:string

Description of true SI units, e.g. "Velocity in meters per second", "Volts", "Pascals", "Degrees Celsius".

<FrequencyStart> required

Response InstrumentSensitivity FrequencyStart

type:double

<FrequencyEnd> required

Response InstrumentSensitivity FrequencyEnd

type:double

<FrequencyDBVariation> required

Response InstrumentSensitivity FrequencyDBVariation

type:double

Variation in decibels within the specified range.

2.5.2 <InstrumentPolynomial>

Response InstrumentPolynomial

The total sensitivity for a channel, representing the complete acquisition system expressed as a polynomial. Equivalent to SEED stage 0 polynomial (blockette 62).

attribute	type	required	description	example
name	string	no	A name given to this filter.	
resourceId	string	no	Same meaning as Equipment:resourceId.	

<Description>

Response InstrumentPolynomial Description

type:string

<InputUnits> required

Response InstrumentPolynomial InputUnits

The units of the data as input from the perspective of data acquisition. After correcting data for this response, these would be the resulting units.

<Name> required

Response InstrumentPolynomial InputUnits Name

type:string

Name of true SI units, e.g. “m/s”, “V”, “Pa”, “C”.

<Description>

Response InstrumentPolynomial InputUnits Description

type:string

Description of true SI units, e.g. "Velocity in meters per second", "Volts", "Pascals", "Degrees Celsius".

<OutputUnits> required

Response InstrumentPolynomial OutputUnits

The units of the data as output from the perspective of data acquisition. These would be the units of the data prior to correcting for this response.

<Name> required

Response InstrumentPolynomial OutputUnits Name

type:string

Name of true SI units, e.g. "m/s", "V", "Pa", "C".

<Description>

Response InstrumentPolynomial OutputUnits Description

type:string

Description of true SI units, e.g. "Velocity in meters per second", "Volts", "Pascals", "Degrees Celsius".

<ApproximationType> required

Response InstrumentPolynomial ApproximationType

type:string

<FrequencyLowerBound> required

Response InstrumentPolynomial FrequencyLowerBound

type:double

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<FrequencyUpperBound> required

Response InstrumentPolynomial FrequencyUpperBound

type:double

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<ApproximationLowerBound> required

Response InstrumentPolynomial ApproximationLowerBound

type:double

<ApproximationUpperBound> required

Response InstrumentPolynomial ApproximationUpperBound

type:double

<MaximumError> required

Response InstrumentPolynomial MaximumError

type:double

<Coefficient> required

Response InstrumentPolynomial Coefficient

type:double

attribute	type	required	description	example
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		
number	CounterType	no		

2.5.3 <Stage>

Response Stage

This complex type represents channel response and covers SEED blockettes 53 to 56.

<PolesZeros>

Response Stage PolesZeros

Response: complex poles and zeros. Corresponds to SEED blockette 53.

attribute	type	required	description	example
name	string	no	A name given to this filter.	
resourceId	string	no	Same meaning as Equipment:resourceId.	

<Description>

Response Stage PolesZeros Description

type:string

<InputUnits> required

Response Stage PolesZeros InputUnits

The units of the data as input from the perspective of data acquisition. After correcting data for this response, these would be the resulting units.

<Name> required

Response Stage PolesZeros InputUnits Name

type:string

Name of true SI units, e.g. "m/s", "V", "Pa", "C".

<Description>

Response Stage PolesZeros InputUnits Description

type:string

Description of true SI units, e.g. "Velocity in meters per second", "Volts", "Pascals", "Degrees Celsius".

<OutputUnits> required

Response Stage PolesZeros OutputUnits

The units of the data as output from the perspective of data acquisition. These would be the units of the data prior to correcting for this response.

<Name> required

Response Stage PolesZeros OutputUnits Name

type:string

Name of true SI units, e.g. “m/s”, “V”, “Pa”, “C”.

<Description>

Response Stage PolesZeros OutputUnits Description

type:string

Description of true SI units, e.g. “Velocity in meters per second”, “Volts”, “Pascals”, “Degrees Celsius”.

<PzTransferFunctionType> required

Response Stage PolesZeros PzTransferFunctionType

type:string

<NormalizationFactor> required

Response Stage PolesZeros NormalizationFactor

type:double

Should be positive.

<NormalizationFrequency> required

Response Stage PolesZeros NormalizationFrequency

type:double

Should be within the passband, and the same for all stages.

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<Zero>

Response Stage PolesZeros Zero

Complex numbers used as poles or zeros in channel response.

attribute	type	required	description	example
number	integer	no		

<Real> required

Response Stage PolesZeros Zero Real

type:double

attribute	type	required	description	example
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<Imaginary> required

Response Stage PolesZeros Zero Imaginary

type:double

attribute	type	required	description	example
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<Pole>

Response Stage PolesZeros Pole

Complex numbers used as poles or zeros in channel response.

attribute	type	required	description	example
number	integer	no		

<Real> required

Response Stage PolesZeros Pole Real

type:double

attribute	type	required	description	example
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<Imaginary> required

Response Stage PolesZeros Pole Imaginary

type:double

attribute	type	required	description	example
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<Coefficients>

Response Stage Coefficients

Response: coefficients for FIR filter. Laplace transforms or IIR filters can be expressed using type as well but the PolesAndZerosType should be used instead. Corresponds to SEED blockette 54.

attribute	type	required	description	example
name	string	no	A name given to this filter.	
resourceId	string	no	Same meaning as Equipment:resourceId.	

<Description>

Response Stage Coefficients Description

type:string

<InputUnits> required

Response Stage Coefficients InputUnits

The units of the data as input from the perspective of data acquisition. After correcting data for this response, these would be the resulting units.

<Name> required

Response Stage Coefficients InputUnits Name

type:string

Name of true SI units, e.g. “m/s”, “V”, “Pa”, “C”.

<Description>

Response Stage Coefficients InputUnits Description

type:string

Description of true SI units, e.g. “Velocity in meters per second”, “Volts”, “Pascals”, “Degrees Celsius”.

<OutputUnits> required

Response Stage Coefficients OutputUnits

The units of the data as output from the perspective of data acquisition. These would be the units of the data prior to correcting for this response.

<Name> required

Response Stage Coefficients OutputUnits Name

type:string

Name of true SI units, e.g. “m/s”, “V”, “Pa”, “C”.

<Description>

Response Stage Coefficients OutputUnits Description

type:string

Description of true SI units, e.g. “Velocity in meters per second”, “Volts”, “Pascals”, “Degrees Celsius”.

<CfTransferFunctionType> required

Response Stage Coefficients CfTransferFunctionType

type:string

<Numerator>

Response Stage Coefficients Numerator

type:double

attribute	type	required	description	example
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		
number	CounterType	no		

<Denominator>

Response Stage Coefficients Denominator

type:double

attribute	type	required	description	example
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		
number	CounterType	no		

<ResponseList>

Response Stage ResponseList

Response: list of frequency, amplitude and phase values. Corresponds to SEED blockette 55.

attribute	type	required	description	example
name	string	no	A name given to this filter.	
resourceId	string	no	Same meaning as Equipment:resourceId.	

<Description>

Response Stage ResponseList Description

type:string

<InputUnits> required

Response Stage ResponseList InputUnits

The units of the data as input from the perspective of data acquisition. After correcting data for this response, these would be the resulting units.

<Name> required

Response Stage ResponseList InputUnits Name

type:string

Name of true SI units, e.g. “m/s”, “V”, “Pa”, “C”.

<Description>

Response Stage ResponseList InputUnits Description

type:string

Description of true SI units, e.g. “Velocity in meters per second”, “Volts”, “Pascals”, “Degrees Celsius”.

<OutputUnits> required

Response Stage ResponseList OutputUnits

The units of the data as output from the perspective of data acquisition. These would be the units of the data prior to correcting for this response.

<Name> required

Response Stage ResponseList OutputUnits Name

type:string

Name of true SI units, e.g. “m/s”, “V”, “Pa”, “C”.

<Description>

Response Stage ResponseList OutputUnits Description

type:string

Description of true SI units, e.g. "Velocity in meters per second", "Volts", "Pascals", "Degrees Celsius".

<ResponseListElement>

Response Stage ResponseList ResponseListElement

<Frequency> required

Response Stage ResponseList ResponseListElement Frequency

type:double

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<Amplitude> required

Response Stage ResponseList ResponseListElement Amplitude

type:double

Representation of floating-point numbers used as measurements.

attribute	type	required	description	example
unit	string	no	The unit of measurement	unit='DEGREES'
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<Phase> required

Response Stage ResponseList ResponseListElement Phase

type:double range:-360.0 ≤ Phase

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<FIR>

Response Stage FIR

Response: FIR filter. Specifically for symmetrical filters. Corresponds to SEED blockette 61. FIR filters are also commonly documented using the CoefficientsType element.

attribute	type	required	description	example
name	string	no	A name given to this filter.	
resourceId	string	no	Same meaning as Equipment:resourceId.	

<Description>

Response Stage FIR Description

type:string

<InputUnits> required

Response Stage FIR InputUnits

The units of the data as input from the perspective of data acquisition. After correcting data for this response, these would be the resulting units.

<Name> required

Response Stage FIR InputUnits Name

type:string

Name of true SI units, e.g. “m/s”, “V”, “Pa”, “C”.

<Description>

Response Stage FIR InputUnits Description

type:string

Description of true SI units, e.g. "Velocity in meters per second", "Volts", "Pascals", "Degrees Celsius".

<OutputUnits> required

Response Stage FIR OutputUnits

The units of the data as output from the perspective of data acquisition. These would be the units of the data prior to correcting for this response.

<Name> required

Response Stage FIR OutputUnits Name

type:string

Name of true SI units, e.g. "m/s", "V", "Pa", "C".

<Description>

Response Stage FIR OutputUnits Description

type:string

Description of true SI units, e.g. "Velocity in meters per second", "Volts", "Pascals", "Degrees Celsius".

<Symmetry> required

Response Stage FIR Symmetry

type:string

<NumeratorCoefficient>

Response Stage FIR NumeratorCoefficient

type:double

attribute	type	required	description	example
i	integer	no		

<Decimation>

Response Stage Decimation

Corresponds to SEED blockette 57.

<InputSampleRate> required

Response Stage Decimation InputSampleRate

type:double

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<Factor> required

Response Stage Decimation Factor

type:integer

<Offset> required

Response Stage Decimation Offset

type:integer

<Delay> required

Response Stage Decimation Delay

type:double

The estimated pure delay for the stage. This value will almost always b positive to indicate a delayed signal. Due to the difficulty in estimating the pure delay of a stage and because dispersion is neglected, this value should be considered nominal. Normally the delay would be corrected by the recording system and the correction applied would be specified in <Correction> below. See Decimation Section Fig. XX for a schematic description of delay sign convention.

attribute	type	required	description	example
unit	string	no	The unit of measurement	unit='DEGREES'
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<Correction> required

Response Stage Decimation Correction

type:double

The time shift, if any, applied to correct for the delay at this stage. The sign convention used is opposite the <Delay> above; a positive sign here indicates that the trace was corrected to an earlier time to cancel the delay caused by the stage and indicated in the <Delay> element. Commonly, the estimated delay and the applied correction are both positive to cancel each other. A zero indicates no correction was applied. See Decimation Section Fig. XX for a schematic description of delay sign convention.

attribute	type	required	description	example
unit	string	no	The unit of measurement	unit='DEGREES'
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<StageGain> required

Response Stage StageGain

The gain at the stage of the encapsulating response element at a specific frequencey and corresponds to SEED blockette 58. In the SEED convention, stage 0 gain represents the overall sensitivity of the channel. In this schema, stage 0 gains are allowed but are considered deprecated. Overall sensitivity should be specified in the InstrumentSensitivity element.

<Value> required

Response Stage StageGain Value

type:double

A scalar that, when applied to the data values, converts the data to different units (e.g. Earth units).

<Frequency> required

Response Stage StageGain Frequency

type:double

The frequency (in Hertz) at which the Value is valid.

<Polynomial> required

Response Stage Polynomial

Response: expressed as a polynomial (allows non-linear sensors to be described). Corresponds to SEED blockette 62. Can be used to describe a stage of acquisition or a complete system.

attribute	type	required	description	example
name	string	no	A name given to this filter.	
resourceId	string	no	Same meaning as Equipment:resourceId.	

<Description>

Response Stage Polynomial Description

type:string

<InputUnits> required

Response Stage Polynomial InputUnits

The units of the data as input from the perspective of data acquisition. After correcting data for this response, these would be the resulting units.

<Name> required

Response Stage Polynomial InputUnits Name

type:string

Name of true SI units, e.g. “m/s”, “V”, “Pa”, “C”.

<Description>

Response Stage Polynomial InputUnits Description

type:string

Description of true SI units, e.g. “Velocity in meters per second”, “Volts”, “Pascals”, “Degrees Celsius”.

<OutputUnits> required

Response Stage Polynomial OutputUnits

The units of the data as output from the perspective of data acquisition. These would be the units of the data prior to correcting for this response.

<Name> required

Response Stage Polynomial OutputUnits Name

type:string

Name of true SI units, e.g. "m/s", "V", "Pa", "C".

<Description>

Response Stage Polynomial OutputUnits Description

type:string

Description of true SI units, e.g. "Velocity in meters per second", "Volts", "Pascals", "Degrees Celsius".

<ApproximationType> required

Response Stage Polynomial ApproximationType

type:string

<FrequencyLowerBound> required

Response Stage Polynomial FrequencyLowerBound

type:double

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<FrequencyUpperBound> required

Response Stage Polynomial FrequencyUpperBound

type:double

attribute	type	required	description	example
unit	string	no		
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		

<ApproximationLowerBound> required

Response Stage Polynomial ApproximationLowerBound

type:double

<ApproximationUpperBound> required

Response Stage Polynomial ApproximationUpperBound

type:double

<MaximumError> required

Response Stage Polynomial MaximumError

type:double

<Coefficient> required

Response Stage Polynomial Coefficient

type:double

attribute	type	required	description	example
plusError	double	no	plus uncertainty or error in measured value.	plusError=0.1
minusError	double	no	minus uncertainty or error in measured value.	minusError=0.1
measurementMethod	string	no		
number	CounterType	no		

CHAPTER

THREE

SPECIFYING AND USING RESPONSE INFORMATION

–By Mike Hagerty & Adam Ringler

3.1 Theory of Instrument Response

In geophysics, instrument responses are often specified in the frequency domain, by transforming the time domain response. Depending on the application, one or more of the following transforms may be used: The Fourier Transform, the Laplace Transform and the z-Transform.

3.1.1 The Fourier Transform

Introduction

The Fourier Transform ($t \rightarrow \omega$) is defined by

$$X(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt$$

while the Inverse Fourier Transform ($\omega \rightarrow t$) is given by

$$x(t) = \int_{-\infty}^{\infty} X(\omega) e^{+j\omega t} d\omega$$

Note that the choice of which transform (forward vs. reverse) has which sign of the complex exponent and which gets the $\frac{1}{2\pi}$ scalefactor is optional.

For instance, some authors prefer to scale each transform by $\frac{1}{\sqrt{2\pi}}$.

What is important is that the signs of the exponents in each transform must be opposite, and the product of their scalefactors must equal $\frac{1}{2\pi}$.

Discrete Time Fourier Transform (DTFT)

In the Fourier transform pair above, both time (t) and frequency (ω) are continuous parameters. In contrast, for signals sampled discretely in time, we may define the related Discrete Time Fourier Transform (DTFT) as

$$X(\omega) = \frac{1}{2\pi} \sum_{n=-\infty}^{\infty} x[n] e^{-j\omega n}$$

$$x[n] = \int_{0}^{2\pi} X(\omega) e^{+j\omega n} d\omega$$

where n is the discrete sample number, and ω is still continuous.

Discrete Fourier Transform (DFT)

And finally, when both time and frequency are discrete, we define the Discrete Fourier Transform (DFT) pair by

$$X[k] = \frac{1}{N} \sum_{n=0}^{N-1} x[n] e^{-j2\pi kn/N}$$

$$x[n] = \sum_{k=0}^{N-1} X[k] e^{+j2\pi kn/N}$$

Note that the popular Fast Fourier Transform (FFT) is a particular implementation of the DFT.

3.1.2 The Laplace Transform

Introduction

The Laplace Transform is defined by

$$X(\sigma, \omega) = \int_{-\infty}^{\infty} x(t) e^{-\sigma t} e^{-j\omega t} dt$$

If we make the substitution, $s = \sigma + j\omega$, this becomes

$$X(s) = \int_{-\infty}^{\infty} x(t) e^{-st} dt$$

Each point in the complex s-plane is associated with a frequency, ω and an exponent σ. Thus, each point in the s-plane describes a sinusoid of frequency ω that is either exponentially growing ($\sigma > 0$) or exponentially decaying ($\sigma < 0$) with time.

Note that the Laplace transform evaluated along the imaginary axis (where the attenuation parameter, $\sigma = 0$), reduces to the complex Fourier transform, $X(\omega)$.

The Laplace transform at point s is a measure of the similarlity between the input signal, $x(t)$, and the corresponding exponentially growing/decaying sinusoid corresponding to that value of s. A large value of $X(s)$ corresponds to a strong similarity between the input signal and the sinusoid $e^{-(\sigma+j\omega)t}$, indicating a strong presence of the sinusoid in the input signal.

In practice, we are often only interested in causal signals that begin at $t = 0$. Using the unit step function,

$$u(t) = \begin{cases} 1 & t \geq 0 \\ 0 & t < 0 \end{cases}$$

$t < 0$

we may ensure causality by writing $x(t) = u(t)x(t)$, so that the Laplace Transform becomes

$$X(s) = \int_{0}^{\infty} x(t) e^{-st} dt$$

Poles and Zeros

Suppose we have a data processing system (e.g., analog sensor + datalogger) that can be characterized by the linear differential equation,

$$a_2\ddot{y}(t) + a_1\dot{y}(t) + a_0y(t) = b_2\ddot{x}(t) + b_1\dot{x}(t) + b_0x(t)$$

where $x(t)$ is the input signal (e.g., the ground motion), $y(t)$ is the output signal (the signal recorded) and a_k and b_k are constant (time-invariant) coefficients. If we assume the system is causal, so that the signals + derivatives are all 0 for $t < 0$, then the Laplace Transform of the equation gives

$$a_2s^2Y(s) + a_1sY(s) + a_0Y(s) = b_2s^2X(s) + b_1sX(s) + b_0X(s)$$

or

$$(a_2s^2 + a_1s + a_0)Y(s) = (b_2s^2 + b_1s + b_0)X(s)$$

From this we can write the system transfer function relating the output to the input as

$$H(s) = \frac{Y(s)}{X(s)} = \frac{b_2s^2 + b_1s + b_0}{a_2s^2 + a_1s + a_0}$$

or more generally,

$$H(s) = \frac{\sum_{k=0}^{M} b_k s^n}{\sum_{k=0}^{N} a_n s^n}$$

This is the coefficient representation of the transfer function. It represents the transfer function as the ratio of two polynomials. The roots of the numerator polynomial are called ‘zeros’, while the roots of the denomenator polynomial are called ‘poles’.

Often, for analog stages, it is more convenient to factor the transfer function in terms of these poles and zeros:

$$H(s) = \frac{\Pi_{k=1}^{M}(s - z_k)}{\Pi_{k=1}^{N}(s - p_k)}$$

where z_k are the M zeros of the system, and p_k are the N poles.

Because the coefficients of the numerator and denominator polynomials are real, the corresponding roots (poles and zeros) must occur in complex conjugate pairs.

Thus, the poles and zeros are either real or form pairs that are symmetric with respect to the real axis in the complex s-plane. In addition, it can be shown that for systems that are stable and causal, the poles all have real parts ≤ 0.

Recall that the Laplace transform variable is given by $s = \sigma + j\omega$. Along the imaginary axis, $\sigma = 0$ and hence $s = j\omega$. Thus, we may express the complex frequency response of the analog stage by calculating its polezero expansion

$$H(f) = A_0\frac{\Pi_{k=1}^{M}(s - z_k)}{\Pi_{k=1}^{N}(s - p_k)}$$

where $s = j2\pi f$ [rad/s] or $s = jf$ [Hz].

Thus, given the poles and zeros of an analog stage, in order to properly calculate the stage frequency response, we must know the units of s used to calculate the poles and zeros.

In StationXML, these units are specified by the PzTransferFunctionType element within the PolesZerosType response stage:

```
<Stage number="1">
<PolesZeros>
   ...
   </OutputUnits>
      <PzTransferFunctionType>LAPLACE (RADIANS/SECOND)</
↪PzTransferFunctionType>
      <NormalizationFactor>1.0</NormalizationFactor>
      <NormalizationFrequency unit="HERTZ">1.0</NormalizationFrequency>
```

where the possibile values for PzTransferfunctionType are:

1. "LAPLACE (RADIANS/SECOND)"
2. "LAPLACE (HERTZ)"
3. "DIGITAL (Z-TRANSFORM)" (Discussed in next section)

Note also the <NormalizationFactor> with unit "HERTZ". These units are distinct from those used to identify s above. The <NormalizationFrequency> specifies the frequency (in Hz) at which the polezero transfer function is normalized. The recommended practice is to choose a value of normalization factor, A_0, that normalizes the polezero expansion to unity at the specified normalization frequency, f_n:

$$|H(f_n)| = 1.0$$

3.1.3 The z-Transform

Introduction

The z-Transform is defined by

$$X(z) = \sum_{n=0}^{\infty} x[n] z^{-n}$$

where

$$z = re^{j\omega}$$
$$z^{-n} = r^{-n} e^{-j\omega n}$$

Notice that on the unit circle, where $|z| \equiv |r| = 1$ and $z = e^{j\omega}$, the z-transform reduces to the discrete Fourier transform (DTFT):

$$X(e^{j\omega}) = \sum_{n=0}^{\infty} x[n] e^{-j\omega n}$$

The z-transform measures the similarity between the input signal $x[n]$ and the signal z^{-n}.

z^{-n} represents exponentially increasing (for r < 0) or decreasing (r > 0) sinusoids. e.g., $e^{-j\omega n}$ is a sinusoid with angular frequency ω [radians/sample] that expands with sample number n.

Thus, the location (value) of z in the complex plane controls what z^{-n} looks like.

The fractional or angular frequency, ω [radians/sample] is related to the linear frequency of the sinusoid through

$$2\pi[radians/cycle] = \omega[radians/sample] \cdot N[samples/cycle]$$

so the number of samples/cycle is given by

$$N = \frac{2\pi}{\omega} samples/cycle$$

and this corresponds to a period of $T = N\Delta t$ [seconds],

where Δt is the sampling interval (secs) and is related to the sampling rate by: $f_s = \frac{1}{\Delta t}$. Then the frequency of oscillation is given by $f = \frac{1}{T} = \frac{1}{N\Delta t} = \frac{f_s}{N}$ [Hz]

In other words, as the angle in the complex z-plane goes from $\omega = 0$ to $\omega = \pi$, the linear frequency goes from $f = 0$ to $f = f_{Nyq}$ [Hz], where the *Nyquist* frequency, $f_{Nyq} = \frac{f_s}{2}$ [Hz].

Thus, in implementing the frequency response of the z-transform (e.g., when calulating the response of a FIR filter), it is common to write it in a way that removes the dependency on the actual sample rate, or

$$X(e^{j\omega}) = \sum_{n=0}^{\infty} x[n]e^{-j2\pi n\frac{f}{f_s}} = \sum_{n=0}^{\infty} x[n]e^{-j2\pi nf\Delta t}$$

Difference Equations

z-transforms of linear time-invariant (LTI) systems described by difference equations play an important role in signal processing.

The general form of a difference equation is:.

$$\sum_{k=0}^{N} a_k y[n-k] = \sum_{k=0}^{M} b_k x[n-k],$$

where $a_0 \neq 0$ (the coefficient of y[n] can't be zero)

Taking the z-transform of both sides,

$$\sum_{k=0}^{N} a_k z^{-k} Y(z) = \sum_{k=0}^{M} b_k z^{-k} X(z)$$

or

$$Y(z) = \frac{\sum_{k=0}^{M} b_k z^{-k}}{\sum_{k=0}^{N} a_k z^{-k}} X(z)$$

From this we can write the system transfer function

$$H(z) = \frac{Y(z)}{X(z)} = \frac{\sum_{k=0}^{M} b_k z^{-k}}{\sum_{k=0}^{N} a_k z^{-k}}$$

The transfer function is the z-transform of the system impulse response, $h[n]$, or

$$H(z) = \sum_{n=0}^{\infty} h[n]z^{-n}$$

The transfer function can also be factored in terms of poles and zeros (for $b_0 \neq 0$)

$$H(z) = \frac{b_0}{a_0} \frac{\Pi_{k=1}^{M}(1 - c_k z^{-1})}{\Pi_{k=1}^{N}(1 - d_k z^{-1})}$$

where c_k are the M zeros of the system, and d_k are the N poles.

For a system to be both stable and causal, its poles must lie inside the unit circle, or $|d_k| < 1$ for $k = 1, N$.

z-Transform Frequency Response

How does the location of the poles and zeros of the z-transform influence the complex frequency response, $H(f)$?

We start by only considering the magnitude response, $|H(f)|$.

The z-transform only exists within a region of the complex z-plane where the infinite sum [eqn X] converges. We call this region the Radius of Convergence (ROC) of the system.

If our system, described by difference equations, is stable, then the ROC must include the unit circle, $|z| = 1$ where

$$H(z) = \frac{Y(z)}{X(z)} = \frac{b_0}{a_0} \frac{\Pi_{k=1}^{M}(1 - c_k z^{-1})}{\Pi_{k=1}^{N}(1 - d_k z^{-1})}$$
$$H(e^{-j\omega}) = \frac{b_0}{a_0} \frac{\Pi_{k=1}^{M}(1 - c_k e^{-j\omega})}{\Pi_{k=1}^{N}(1 - d_k e^{-j\omega})}$$

The magnitude of the product is equal to the product of the magnitude, thus

$$|H(e^{-j\omega})| = \frac{|b_0|}{|a_0|} \frac{\Pi_{k=1}^{M}|(1 - c_k e^{-j\omega})|}{\Pi_{k=1}^{N}|(1 - d_k e^{-j\omega})|} \quad (3.1)$$

$= |b_0| \frac{}{|a_0| \frac{\Pi_{k=1}^{M}|e^{-j\omega}(e^{j\omega}-c_k)|}{\Pi_{k=1}^{N}|e^{-j\omega}(e^{j\omega}-d_k)|}}$ (3.2)

$|H(e^{-j\omega})| = \frac{|b_0|}{|a_0|} \frac{\Pi_{k=1}^{M}|(e^{j\omega}-c_k)|}{\Pi_{k=1}^{N}|(e^{j\omega}-d_k)|}$ (3.3)In other words, as we traverse the unit circle through circular 'frequency', ω, from $0 - 2\pi$, the magnitude of the response depends on the distance between the point on the unit circle, $e^{j\omega}$, and the zeros, $|e^{j\omega} - c_k|$, as well as the distance between the point and the poles, $|e^{j\omega} - d_k|$, or

$$|H(e^{-j\omega})| = \frac{|b_0|}{|a_0|} \frac{\Pi_{k=1}^{M}|distance - to - zeros|}{\Pi_{k=1}^{N}|distance - to - poles|}$$

Thus, $|H(e^{j\omega})|$ is small when $e^{j\omega}$ is near the zeros and it is large when $e^{j\omega}$ is near the poles.

Examples

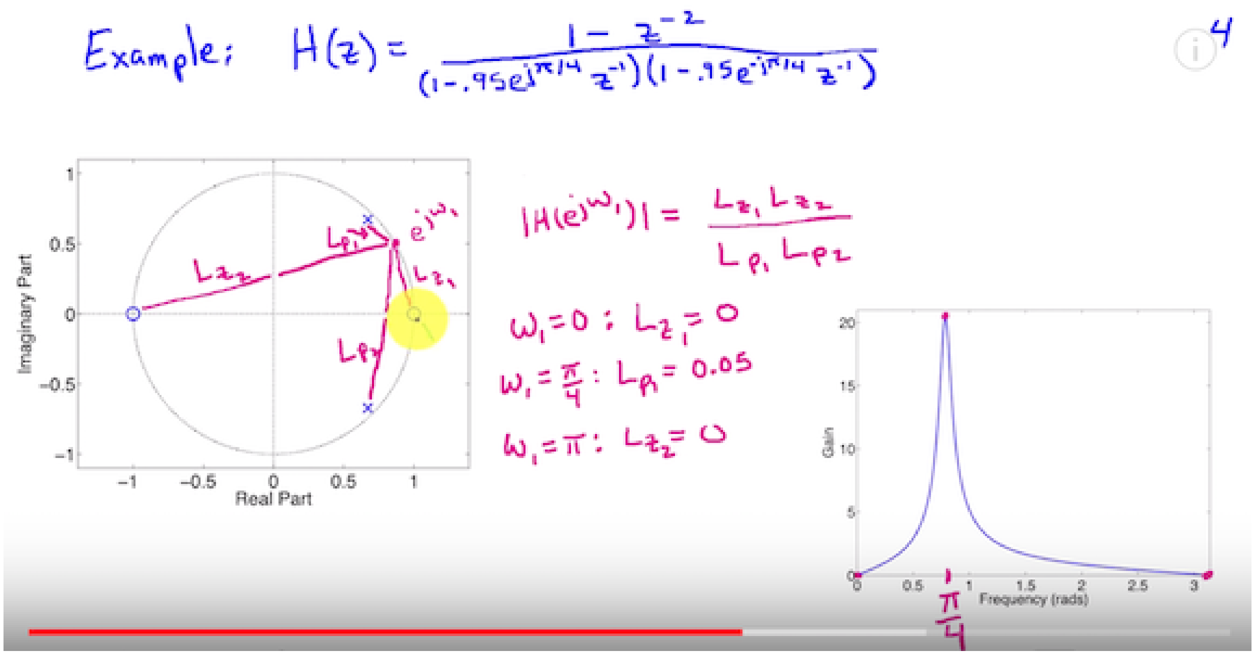
Example 1

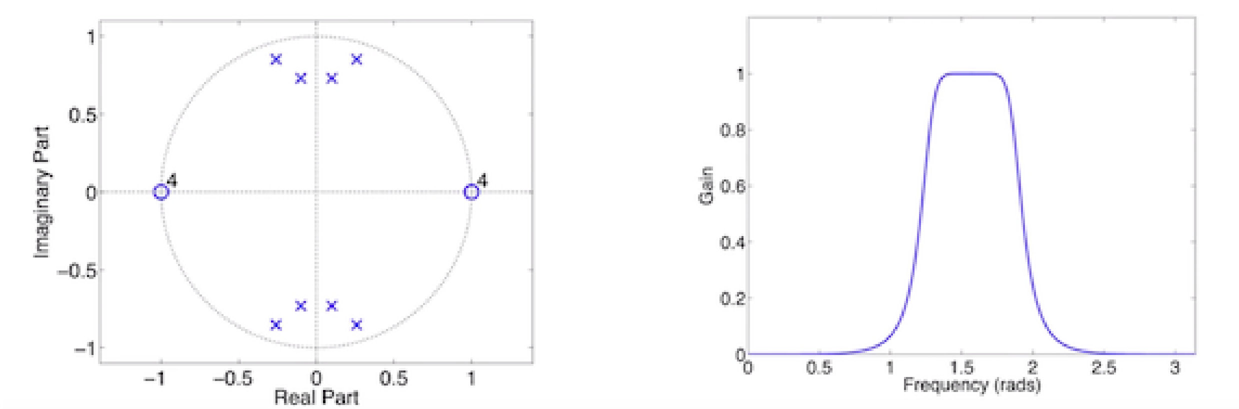
Consider a system with zeros at $z = 1, -1$ and poles at $z = \pm .95e^{j\pi/4}$

Poles near the unit cirlcle push the magnitude response up at those frequencies, while zeros near the unit circle pull it down; if the zero is actually *on* the unit circle, then it forces the magnitude response to be exactly 0 at that frequency.

Example 2

Here's an example pass-band filter comprised of 8 poles and 8 zeros. We can predict from the position of the poles and zeros that the frequency response will be 0 at $\omega = 0$ and will be maximum near $\omega = \frac{\pi}{2}$.


Example: H(z) = 1 − z^-2 / (1 − .95e^jπ/4 z^-1)(1 − .95e^-jπ/4 z^-1)
|H(e^jω1)| = Lz1 Lz2 / Lp1 Lp2
ω1 = 0 : Lz1 = 0
ω1 = π/4 : Lp1 = 0.05
ω1 = π : Lz2 = 0
Imaginary Part
Real Part
Gain
Frequency (rads)


Imaginary Part
Real Part
Gain
Frequency (rads)

3.1.4 FIR-IIR Filters

Introduction

As we'll see in the next section, each of the multiple stages that comprise an instrument response can be thought of as a filter that modifies the amplitude and phase of the original signal (e.g., ground motion) in some way.

In fact, to truly understand instrument response and data processing in general, it is necessary to have some familiarity with digital signal processing.

There are two categories of discrete-time filters that we routinely encounter in seismology:

1. FIR filters (Finite Impulse Response)
2. IIR filters (Infinite Impulse Response)

Both filters can be constructed using difference equations, hence, they are often represented in terms of their z-transforms.

FIR filters can be written as:

$$y[n] = \sum_{k=0}^{M} b_k x[n-k]$$

while IIR filters can be written as:

$$y[n] = \sum_{k=0}^{M} b_k x[n-k] + \sum_{k=1}^{N} a_k y[n-k]$$

FIR filters can be thought of as a sum of weighted values of past inputs, $x[n-k]$ (the so called *moving average* filter). IIR filters have this same moving average component, but also offer the possibility of feedback, since the current output $y[n]$ can also depend on a weighted combination of past outputs, $y[n-k]$.

For a finite input impulse, the subsequent impulse response of a FIR filter is finite. However, because of the dependence on past outputs, the impulse response of the IIR filter is, at least in theory, infinite; it continues long after the input signal has finished.

In the FIR case, the system function, found by taking the z-transform of the difference equation, can be written

$$H(z) = \sum_{k=0}^{M} b_k z^{-k}$$

while for the IIR case, the system function is

$$H(z) = \frac{\sum_{k=0}^{M} b_k z^{-k}}{\sum_{k=0}^{N} a_k z^{-k}}$$

where $a_0 = 1$.

The system functions can be factored in terms of their poles and zeros as

$$H_{FIR}(z) \quad = \quad b_0 \Pi_{k=1}^{M} (1 - c_k z^{-1}) \tag{3.4}$$

H$_{IIR}(z) = \frac{b_0 \Pi_{k=1}^{M} (1 - c_k z^{-1})}{\Pi_{k=1}^{N} (1 - d_k z^{-1})}$(3.5)

(3.6)

Thus, the FIR filter has arbitrary zeros, but only has poles at the origin ($z = 0$). However, poles (or zeros for that matter) at the origin don't affect the frequency response since they are located a fixed distance ($|z| = 1$) from the unit circle.

In contrast, the IIR filter may have both zeros and poles at arbitrary locations, making them especially flexible.

The corresponding impulse responses are found by taking the inverse z-transform of the system functions,

$$to$$

$$h_{FIR}[n] =$$

$$\begin{cases} b_n & 0 \leq n \leq M \\ 0 & else \end{cases} \quad (3.7)$$

=

$$\begin{cases} b_n & 0 \leq n \leq M \\ 0 & else \end{cases}$$

Thus the FIR impulse response is given by the difference equation coefficients, b_k, themselves, and the impulse response dies after M terms.

The impulse response of the causal parts of the IIR filter can be written as

$$to$$

$$h_{IIR}[n] =$$

$$\sum_{k=1}^{N} A_k (d_k)^n u[n] (3.7)$$

=

$$\sum_{k=1}^{N} A_k (d_k)^n u[n]$$

where $u[n]$ is the unit step function ($u[n] = 1, n \geq 0$).

Because of the geometric series d_k^n, the IIR impulse response decays but never actually reaches zero.

FIR vs IIR

The primary distinguishing factor between FIR and IIR filters is this:

FIR filters are guaranteed to have a linear phase response, which is much easier to deal with, while IIR filters have non-linear phase response.

Some pros and cons of each filter type is summarized below.

FIR Filters:

- **Pros**
  - Can be designed using optimization techniques to match a desired magnitude/phase response
  - Allow for arbitrary magnitude/phase response
  - Allow for linear or zero phase response (no distortion)
  - Are always stable
- **Cons**
  - Can require a large number of coefficients (e.g., $M \approx 100$) to achieve desired accuracy, particularly for steep filters.

IIR Filters:

- **Pros**
  - Can be implemented very efficiently - fewer coefficients than FIR for comparable frequency selective filter accuracy (e.g., $M \approx N \approx 8$)
  - Filtering is fast
- **Cons**
  - Generally can't use optimization techniques to design
  - Better approach is to start from a well-known analog filter design and transform it to discrete-time filter.
  - Limited to frequency selective filters (e.g., bandpass, high-pass, etc)
  - Phase is nonlinear (will always cause phase distortion within the passband)
  - Zero phase filters are impossible to implement exactly (you can get this by filtering forward + backward, but this can't be implemented in real-time!)

In spite of the cons listed above, there are some instances where IIR filters are preferred. For instance, for implementing maximally flat selective filters (e.g., Butterworth bandpass filters) or for modeling the behavior of systems with feedback.

Nevertheless, the vast majority of filters encountered in seismic metadata are *anti-alias* filters used at each decimation stage of the digitizer, and the digital anti-alias filters most commonly used are linear phase FIR filters that produce a constant time shift.

Hence, in what follows we will concentrate on FIR filters.

Classification of FIR Filters

FIR filter frequency response can be written

$$H(e^{j\omega}) = \sum_{k=0}^{M} b_k z^{-k} = \sum_{k=0}^{M} b_k e^{-j\omega k} = \sum_{k=0}^{M} h[k] e^{-j\omega k}$$

where in the last expression, we identify the filter coefficients b_k as the inpulse response values: $h[k] = b_k$ to show that the output of the FIR filter is the convolution of the input signal $x[n]$ with the filter impulse response.

It can be shown that the FIR filter response has generalized linear phase of the form,

$$H(e^{j\omega}) = A(e^{j\omega}) e^{-j(\omega\alpha+\beta)}$$

where $A(e^{j\omega})$ describes the real amplitude, β is a constant phase factor, and α is the constant group delay.

A consequence of this constant group delay (also called *phase* delay) is that the shape of the input waveform is not changed; all frequencies are delayed the right amount so that they add together in the same way to form the output signal. The resulting output signal has the same shape as the input signal but is delayed in time.

Some general observations about FIR filters are:

- FIR filters contain as many poles as they have zeros.
- The number of zeros (poles), M, is called the *order* of the FIR filter
- All the poles are located at the origin (inside the unit circle), hence FIR filters are said to be *stable*.
- These poles don't affect the magnitude of the frequency response, only the phase.

Note that a filter of order M has length M+1.

FIR filters with generalized linear phase are often divided into 4 types depending on whether the order M is even or odd, so that the number of points is either odd or even, and whether the impulse response (=FIR coefficients) exhibits even or odd symmetry about the middle point.

FIR filters with symmetrical impulse response are often called *two-sided* or *acausal*. As a consequence of the symmetry of the filter impulse response, the onsets of very impulsive signals (with energy at frequencies near the Nyquist cut-off for the FIR filter), may be contaminated by precursory (=acausal) oscillations.

Type I: M even

M even + even symmetry about the midpoint M/2

Note that in this case, there will be M+1 (odd) points in the filter and M/2 will fall on an index right in the middle:

$$h[k] = h[M-k], 0 \leq k \leq M$$

We can write out the frequency response and use symmetry to simplify,

$$H(e^{j\omega}) \quad = \quad \sum_{k=0}^{M} h[k] e^{-j\omega k} \tag{3.7}$$

=h[0]+h[1]e$^{-j\omega\cdot 1} + h[2]e^{-j\omega\cdot 2} + ... + h[M-1]e^{-j\omega\cdot(M-1)} + h[M]e^{-j\omega\cdot M}$(3.8)

=e$^{-j\omega\frac{M}{2}}\left[h[0]e^{+j\omega\frac{M}{2}} + h[1]e^{-j\omega\cdot 1}e^{+j\omega\frac{M}{2}} + ... + h[M-1]e^{-j\omega\cdot(\frac{M}{2}-1)} + h[M]e^{-j\omega\frac{M}{2}}\right]$(3.9)

$=e^{-j\omega\frac{M}{2}}\left[h[0]e^{+j\omega\frac{M}{2}}+h[M]e^{-j\omega\frac{M}{2}}+h[1]e^{-j\omega\cdot 1}e^{+j\omega\frac{M}{2}}+...+h[M/2+1]e^{-j\omega\cdot 1}+h[M/2]\right]$(3.10)

$=e^{-j\omega\frac{M}{2}}\left[h[0](e^{+j\omega\frac{M}{2}}+e^{-j\omega\frac{M}{2}})+h[1](e^{+j\omega(\frac{M}{2}-1)}+e^{-j\omega(\frac{M}{2}-1)})+...+h[M/2-1](e^{+j\omega}+e^{-j\omega})+h[M/2]\right]$(3.11)

$=e^{-j\omega\frac{M}{2}}\left[h[0]2cos(\frac{M}{2}\omega)+h[1]2cos((\frac{M}{2}-1)\omega)+...+h[M/2-1]2cos(\omega)+h[M/2]\right]$(3.12)

$H(e^{j\omega})=e^{-j\omega\frac{M}{2}}\sum_{k=0}^{M/2}a[k]cos(\omega k)$(3.13)

(3.14)

where $a[0]=h[M/2], a[1]=2h[M/2-1], ..., a[M/2]=2h[0]$.

In general, $a[0]=h[\frac{M}{2}]$, and $a[k]=2h[\frac{M}{2}-k], k=1,...,\frac{M}{2}$.

The $a[k]$ coefficients are real, hence the sum is real, and the response satisfies the generalizd linear phase property:

$$H(e^{j\omega})=A(e^{j\omega})e^{-j(\omega\alpha+\beta)}$$

Hence for Type I, the amp is: $A(e^{j\omega})=\sum_{k=0}^{M/2}a[k]cos(\omega k)$, while the phase term is: $e^{-j\omega\frac{M}{2}}$ and the corresponding group delay is: $\alpha=\frac{M}{2}$.

Type II: M odd

M odd + even symmetry about the midpoint M/2

Note that in this case, there will be M+1 (even) points in the filter, hence the symmetry mid-point falls between two sample points.

$$h[k]=h[M-k], 0\leq k\leq M$$

By similar algebra as above, we can write the frequency response as

$$H(e^{j\omega})=e^{-j\omega\frac{M}{2}}\sum_{k=1}^{\frac{(M+1)}{2}}b[k]cos(\omega(k-\frac{1}{2}))$$

where $b[k]=2h[(\frac{(M+1)}{2}-k], k=1,...,\frac{(M+1)}{2}$.

Thus, this system also has group delay $\alpha=\frac{M}{2}$.

Type III/IV anti-symmetric

Type III (M even) and Type IV (M odd) FIR filters exhibit anti-symmetry about the midpoint: $h[k]=-h[M-k]$.

As a result, their expansions reduce to summation of sine functions and can’t be used to implement low-pass filters, hence they aren’t used for anti-alias filtering.

Practical Concerns

Thus, we normally use FIR filters of type I or II for anti-alias filtering. Because of their symmetry, only half the coefficients need to be stored in the metadata.

In StationXML, a symmetric filter can be represented using a FIR response stage, with sub-element indicating the symmetry (odd/even).

In contrast, a non-symmetrical FIR can only be stored in a more general Coefficients response stage, which retains all of the coefficients.

In practice, even symmetric FIR filter coefficients are often stored in a Coefficients response stage.

This is how the FIR response is calculated in ObsPy, which uses the venerable evalresp C code underneath the hood. Note that in evalresp, this type of filter is termed *FIR_ASYM*, meaning it can handle both symmetric (about the mid-point) and non-symmetric FIR coefficients. All of the coefficients are used in the expansion to calculate the filter response.

In contrast, IIR filter coefficients can't be stored in a FIR response stage, since it only allows for numerator coefficients. IIR filter coefficients can be stored in a Coefficients response stage. However, IIR responses are very sensitive to round-off errors in the values of the stored coefficients and can become unstable. Therefore, many IIR filters are instead stored as a PolesZeros response stage of type 'D' (digital) and are expanded in terms of the poles and zeros of the z-transform as discussed above.

3.2 Practical Instrument Response

3.2.1 Introduction

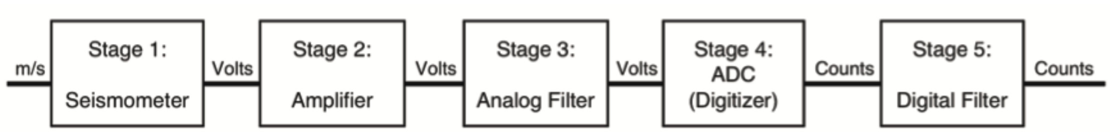
Geophysical data are recorded by an instrument that imparts its own signature onto the data. When the data are later analyzed, one of the first steps is to remove the effect of the instrumentation used to record it, the so-called instrument response. This is typically done in the frequency domain, by dividing the complex Fourier Transform of the data by the complex Fourier Transform of the instrument response.

$$Z(f) = \frac{X(f)}{I(f)}$$

where $X(f)$ is the Fourier Transform of the recorded time series, $I(f)$ is the Fourier Transform of the instrument response, and $Z(f)$ is the Fourier Transform of the data with the instrument response removed.

So how does one obtain the Fourier Transform of the instrument response ? Very often, this is is calculated by combining the information describing each stage of the instrument response in specific formats.

3.2.2 Sensor Response as a Linear Sequence of Stages



A recording system (sensor + datalogger) represents a linear, time-invariant system. As such, the total response of the system (= the instrument response) can be calculated by linearly combining the response of each individual stage in the system. In the time domain, the operator that represents linear combination in this way is convolution, however, it's difficult to visualize the result of convolving several stages together. Fortunately, in the frequency domain, the operator that links the individual stage responses together is multiplication, and it's trival to combine stage responses together.

The schematic show in the figure above represents a generic ideal of the instrument response as a sequence of stages. Where each stage is implemented in the hardware, e.g., whether it physically resides in the sensor or the datalogger (or whether these are integrated into a single unit) is not specified.

A more specific description of instrument response particular to most seismic instrumentation is this: The ground motion (typically velocity or acceleration) is "input" to the seismic sensor which outputs continuous voltage (an analog signal) proportional to the input in some way. This continuous voltage could then be amplified, either by an external preamplifier (+ filter possibly) or, more commonly, by circuitry within the datalogger itself. Next, the continuous signal is sampled by the ADC (analog-to-digital conversion) circuit of the datalogger, resulting in discrete data samples.

Typically, the sampling is done over a sequence of stages where the first stage highly oversamples the input data. Each subsequent stage is a combination of low-pass filter, typically implemented using a FIR filter, followed by decimation of the data stream by some decimation factor. This anti-alias FIR filter is necessary at each decimation step to avoid aliasing of energy above the Nyquist frequency, which would contaminate the signal of interest. This cascade of filter/decimate stages begins at the high sample rate (e.g., 102400 samples per second for the Reftek RT130) and continues, with typical integer decimation factors (2,4,5,8,10,16 etc) at each step, until the final desired output sample rate is reached. Thus, the input units of the first sensor stage is the ground motion (e.g., m/s), while the input units of the first datalogger stage is Volts. After the ADC, the input/output units for each subsequent stage is Counts.

3.2.3 Stage 1: The Analog Sensor

The first stage of the response often represents the effect of an analog sensor (e.g., seismometer, microphone, etc), which takes as input a physical quantity (e.g., ground motion in $\mu m s^{-1}$, air pressure in Pa, temperature in $^{\circ}C$, etc.) and outputs Volts.

We need some way to represent how this sensor stage works and what distortion, if any, it applies to the underlying time series (the input physical quantity).

Commonly, the analog sensor stage is stored as a sequence of poles and zeros of the Laplace Transform (see Laplace Transform description above) along with associated scale factors.

Recall that the Laplace transform variable is given by $s = \sigma + j\omega$. Along the imaginary axis, $\sigma = 0$ and hence $s = j\omega$. Thus, we may express the complex frequency response of the analog stage by calculating its polezero expansion

$$H(f) = A_0 \frac{\Pi_{k=1}^{M}(s - z_k)}{\Pi_{k=1}^{N}(s - p_k)}$$

where $s = j2\pi f$ [rad/s] or $s = jf$ [Hz] , z_k are the M zeros and p_k are the N poles. A_0 is the normalization factor, typically chosen so that $|H(f_n)| = 1.0$ where f_n is the normalization frequency.

Thus, given the poles and zeros of an analog stage, in order to properly calculate the stage frequency response, we must know the units of s (Hz or rad/s) used to calculate the poles and zeros using the expansion above.

With the normalization factor A_0, the polezero expansion results in a complex frequency response with magnitude = 1.0 at the normalization frequency. For seismometers whose response is flat to ground velocity, the normalization frequency is typically chosen somewhere within the flat part of the response spectrum. For broadband sensors, it is also considered good practice to select a normalization frequency lower than two times the lowest sampling frequency. For example, if you are sampling VHZ data at 0.1 sps, then you want to describe A_0 at a frequency 0.05 Hz.

Thus, the poles and zeros give the shape of the sensor response, but not the gain (see Fig. X below).

Analog polezero examples

Below are the poles and zeros for two broadband seismometers (STS-1 and STS-2) and a short-period sensor (L-22D). All have a response that is flat to velocity within some frequency band, which is controlled by the location of the poles and zeros in the s-plane.

Sensor: Streckeisen STS-2 (3rd Generation)			
Gain:	1500 [V/m/s]	**Freq of gain:**	1.0 [Hz]
A0 normalization:	3.4684E+17	**Freq of normalization:**	1.0 [Hz]
Poles:		**Zeros:**	
real	imag	real	imag
-0.037	-0.037	0.0	0.0
-0.037	+0.037	0.0	0.0
-15.54	0.0	15.15	0.0
-97.34	-400.7	-176.6	0.0
-374.8	0.0	-463.1	-430.5
-97.34	+400.7	-463.1	+430.5
-520.3	0.0		
-10530.0	-10050.0		
-10530.0	+10050.0		
-13300.0	0.0		
-255.097	0.0		

Sensor: Streckeisen STS-1			
Gain:	2400 [V/m/s]	**Freq of gain:**	0.02 [Hz]
A0 normalization:	3.94858E+03	**Freq of normalization:**	0.02 [Hz]
Poles:		Zeros:	
real	imag	real	imag
-0.01234	+0.01234	0.0	0.0
-0.01234	-0.01234	0.0	0.0
-39.18	+49.12		
-39.18	-49.12		

Sensor: Sercel L-22D			
Gain:	87.9 [V/m/s]	**Freq of gain:**	10.0 [Hz]
A0 normalization:	1.0	**Freq of normalization:**	10.0 [Hz]
Poles:		**Zeros:**	
real	imag	real	imag
-8.884	+8.887	0.0	0.0
-8.884	-8.887	0.0	0.0

Notice from the table above that the poles always appear in complex conjugate pairs (in the degenerate case this is represented by a single real pole). This will always be the case, since the poles and zeros ultimately relate to a polynomial expression with real coefficients that describes the seismometer response. In addition, notice that all of the poles have a negative real part. This is required for stability reasons as discussed in the theory section above.

The poles and zeros have units in the complex s-plane. For the examples given (and for most analog stages), <PzTransferFunctionType> is "LAPLACE (RADIANS/SECOND)", hence the poles and zeros have units of rad/s.

When viewing the total instrument response as a plot of amplitude and phase versus frequency, most of the shape is controlled by the polezero expansion of the analog sensor stage.

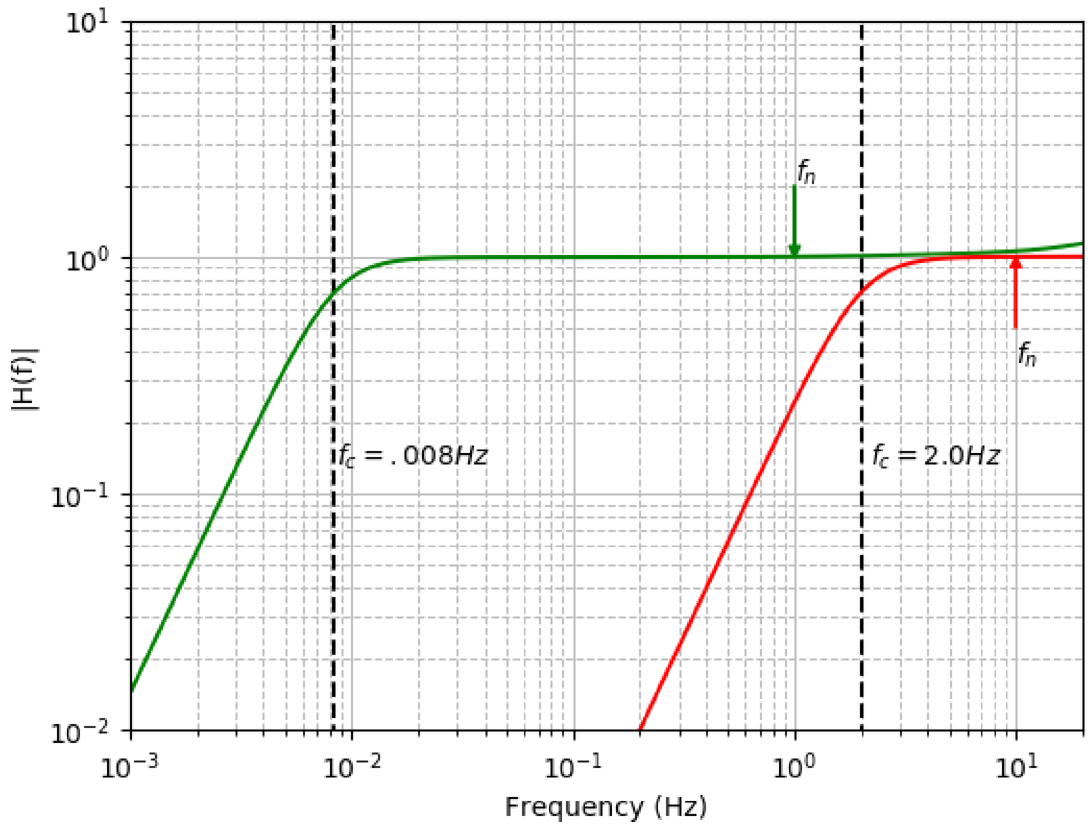


Fig. 1: Fig. X Plot of polezero expansion of analog sensor for Streckeisen STS-2 (green) and Sercel L-22D (red) [see table for polezero values used].

In the figure above we plot the analog stage polezero expansion for a broadband seimometer (STS-2) and a short-period seismometer (L-22D). In both cases, the A0 normalization frequency, f_n is located within the flat part of the spectrum, and each response has a corner frequency, f_c below which the magnitude response rolls off. The corner frequency is the frequency at which the response magnitude is -3dB below the flat part of the spectrum.

Given the poles and zeros, one can determine the low-frequency corner frequency, f_c, from the magnitude of the lowest frequency pole in the s-plane.

For instance, for the STS-2 example shown, the lowest frequency pole is at $-.037 \pm .037j$ in the complex s-plane, and the corresponding corner frequency is:

$$\omega = \sqrt{.037^2 + .037^2} = \sqrt{2} \times .037 = .052326 rad/s$$
$$f_c = \frac{\omega}{2\pi} = 0.0083279 s^{-1} \rightarrow T_c = 1/f_c = 120 sec$$

As expected, the STS-2 sensor has a corner *period* of 120 s.

By similar reasoning, the corner frequency of the short-period L-22D sensor is

$$\omega = \sqrt{8.884^2 + 8.887^2} = 12.566 rad/s$$
$$f_c = \frac{\omega}{2\pi} = 2.0 Hz$$

For many applications the exact instrument response is not needed and it is sufficient to calculate a single scalefactor to convert from recorded COUNTS to ground motion (e.g, M/S). For instance, if the signal of interest only contains energy within the flat part of the spectrum (e.g., band-limited signal), then we might be able to ignore the polezero shape altogether and compute and overall scalefactor (to go from COUNTS to M/S) for the sensor + datalogger.

For instance, if the STS-2 sensor discussed above were connected to a generic Reftek RT-130 datalogger, we can calculate an approximate forward scalefactor:

$$1500[V/m/s] \times 6.291290 \times 10^5 [Counts/V] = 9.4369 \times 10^8 [Counts/m/s]$$

While this is often done to do a quick conversion to ground velocity, several caviats must be mentioned.

1. Very few signals are truly bandlimited this way and we're essentially applying the wrong correction factor to the signals outside the bandwidth
2. Often, the frequency at which the sensor response is normalized, is not the same as the frequency at which the datalogger response is normalized. For instance, the Reftek RT-130 is normalized at 0.05 Hz, while the STS-2 is normalized at 1.0 Hz. This matters because the amplitude response of the datalogger filters are not perfectly flat, hence to compute the overall instrument response (sensor + datalogger), the datalogger gain often has to be recalculated at the frequency of the sensor normalization.
3. It ignores the phase response, which can be very important for modelling waveforms, etc.

Alternatively, when simple scaling is insufficient, it is necessary to use all of the response stages to compute the exact instrument response. When the datalogger normalization frequency is different from the sensor normalization frequency, the datalogger response is *recalculated* at the sensor normalization frequency and the new *sensitivity*, equal to the product of each stage amplitude response at this normalization frequency, is stored in the StationXML <InstrumentSensitivity> element.

Converting s = rad/s to/from Hz

Something here about how to convert poles/zeros/A0 to/from Hz

3.2.4 Stage 2: The Pre-Amplifier

Not all response sequences have a pre-amplifier. When present, it may be implemented using an analog circuit (V->V) or it may be a digital circuit integrated within the analog-to-digital (datalogger) recorder itself.

For example, an analog pre-amplifier stage with a gain of 8 would be represented as:

```
<Stage number="2">
   <StageGain>
      <Value>8</Value>
      <Frequency>1</Frequency>
   </StageGain>
</Stage>
```

where the <Frequency> is normally chosen to be the same as the normalization frequency, f_n in stage 1.

An external pre-amplifier stage could have an associated filter, either implemented using a polezero or coefficient representation.

Often, the preamplifier is integrated with the datalogger and merely adds a uniform scalefactor to the instrument response.

Warning

Using *place-holder* pre-amps at stage 2 may not be good practice.

Some entities (e.g., the Nominal Response Library or NRL) always include a pre-amp at stage 2 in order to standardize the numbering of response stages (e.g., so that the datalogger response always begins at stage 3). If no pre-amp was actually present, then a *place-holder* stage with gain=1 is used.

However, there is disagreement about whether *all* responses should have such a place-holder stage or whether it is better practice to have the response stages more faithfully correspond to the equipment that is actually used.

3.2.5 Stage 2+: The Datalogger

The datalogger, or analog-to-digital converter (ADC) has two main functions: 1. To digitize the analog signal (Volts) coming from the sensor and 2. To output the digitized signal (digital counts) at the desired sample rate(s).

These functions are typically achieved by first highly oversampling the analog signal, and then passing it through a sequence of filter/decimate steps to achieve the desired output sample rate(s).

Each filter/decimate step is represented by a stage in the StationXML response, representing the effects of low-pass filtering (typically implemented with an anti-alias FIR filter) and decimation to a lower sample rate.

FIR anti-alias filter

The recommended practice for storing FIR filters is to normalize the filter response at a specified frequency:

$$to$$

$$G(f) =$$

$$S_d H_c(z)\Big|_{z=e^{j2\pi\Delta t f_s}} =$$

$$S_d \sum_{k=0}^{M} b_k z^{-k}\Big|_{z=e^{j2\pi\Delta t f_s}}$$

$$=$$

$$S_d \sum_{n=0}^{M} b_k e^{-j2\pi f_s k \Delta t}$$

(3.15)

=

$$=S_d H_c(z)\Big|_{z=e^{j2\pi\Delta t f_s}}$$

$$=S_d \sum_{k=0}^{M} b_k z^{-k}\Big|_{z=e^{j2\pi\Delta t f_s}}$$

$$S_d \sum_{n=0}^{M} b_k e^{-j2\pi f_s k \Delta t}$$

where b_k are the FIR coefficients, M is the filter order, Δt is the sample rate [seconds], and f_s is the frequency at which the filter is normalized to have a gain of S_d.

The Quanterra QDP380/QDP680 family of dataloggers employ the 64-element FIR filter described in Table X as a digital anti-alias filter in the stage 4 decimation from 40Hz down to 20 Hz.

The FIR coefficients, b_k are plotted in Fig. X

The FIR filter has 64 coefficients (order M = 64-1 = 63) and is symmetric about the midpoint (which lies in between samples 32 and 33). Hence it is a FIR Type II symmetric filter.

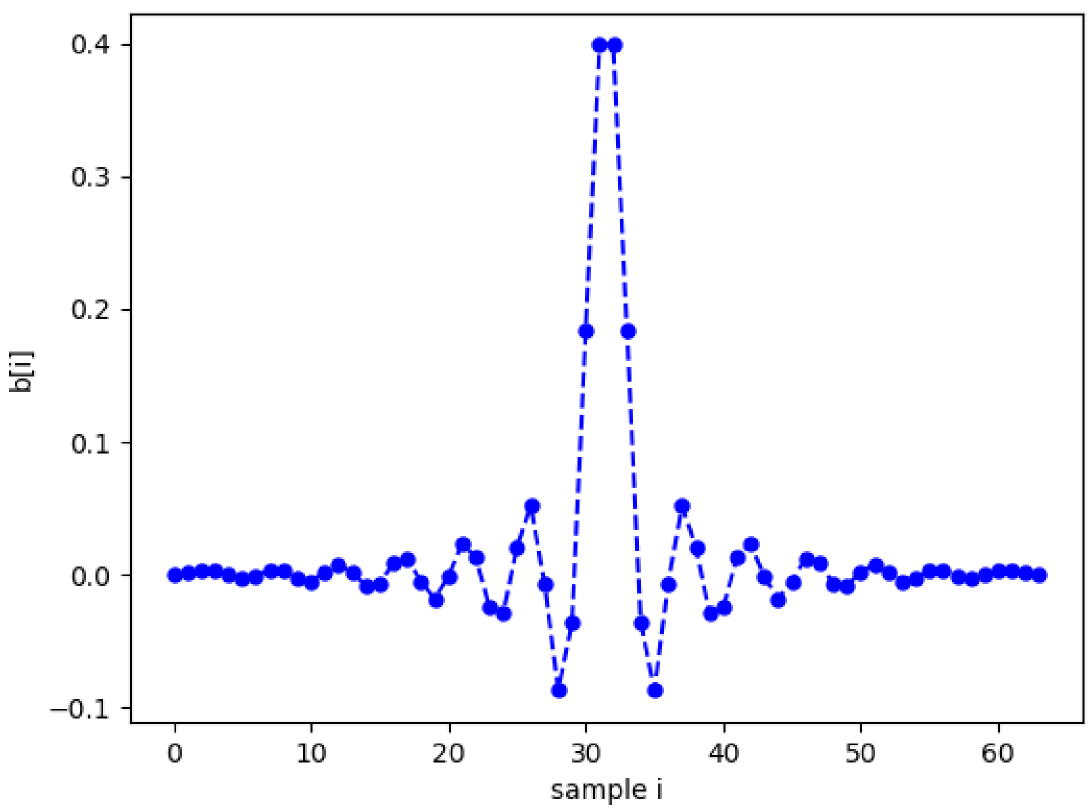


Fig. 2: Fig. X Plot of filter coefficients for Qx80 FIR filter

Decimation

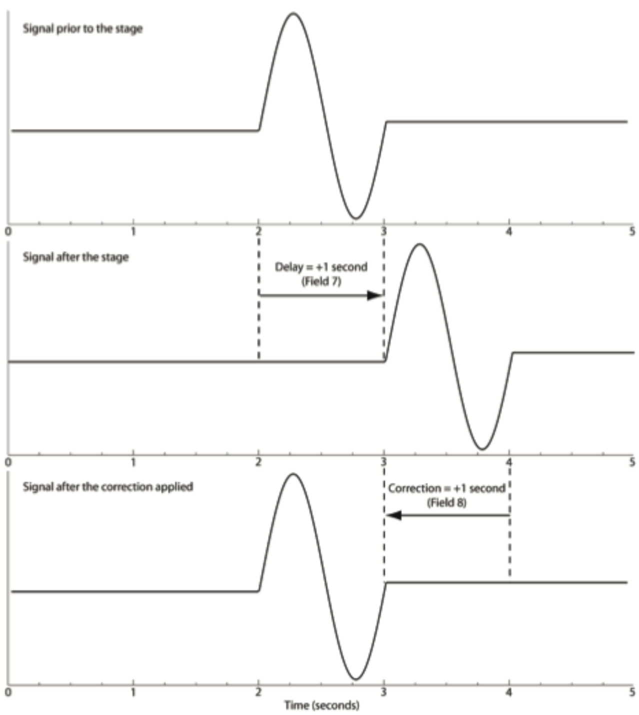
In the normal process by which the datalogger holds and samples information, follwed by decimation, a time delay is often introduced into the recorded trace (see Fig. X). This delay, if known, can be stored in the <Delay> element. For example, a delay of 1.0 seconds would be stored as:

```
<Response>
   <Stage>
      <Decimation>
         <Delay>1.0</Delay>
      </Decimation>
   </Stage>
</Response>
```

while any applied time correction, e.g., to cancel out the delay, can be stored in:

```
<Response>
   <Stage>
      <Decimation>
         <Correction>1.0</Correction>
      </Decimation>
   </Stage>
</Response>
```

An anti-alias FIR filter normally introduces a positive delay into the recorded trace as indicated in the figure. If this delay is removed from the data, e.g., by introducing a negative offset -x prior to recording, then the positive value +x is stored in the <Correction> element.



3.2.6 Broadband sensor

3rd generation Streckeisen STS-2 sensor + Reftek RT130 datalogger

StationXML **Show/Hide**

```
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<FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1
↪">
  <Network code=..>
    <Station code=..>
      <Channel code=.. locationCode=..>
        ...
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        <Response>
          <InstrumentSensitivity>
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            <Frequency>1.0</Frequency>
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            </InputUnits>
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              <Description>Digital Counts</Description>
            </OutputUnits>
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            <PolesZeros>
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                <Description>Velocity in Meters per Second</Description>
              </InputUnits>
              <OutputUnits>
                <Name>V</Name>
                <Description>Volts</Description>
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↪PzTransferFunctionType>
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              <NormalizationFrequency unit="HERTZ">1.0</
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                <Imaginary>0.0</Imaginary>
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              <Zero number="2">
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              </Zero>
              <Zero number="3">
                <Real>-176.6</Real>
                <Imaginary>0.0</Imaginary>
              </Zero>
```

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```
              <Zero number="4">
                <Real>-463.1</Real>
                <Imaginary>-430.5</Imaginary>
              </Zero>
              <Zero number="5">
                <Real>-463.1</Real>
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              <Pole number="0">
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                <Imaginary>-0.037</Imaginary>
              </Pole>
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              </Pole>
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              </Pole>
            </PolesZeros>
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            </StageGain>
```

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              <OutputUnits>
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              <Numerator>0.0693359</Numerator>
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              <Numerator>0.0820312</Numerator>
```

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```
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        <Numerator>0.0820312</Numerator>
        <Numerator>0.0769043</Numerator>
        <Numerator>0.0693359</Numerator>
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                <Numerator>0.000163837</Numerator>
                <Numerator>3.29668e-05</Numerator>
                <Numerator>-8.59142e-05</Numerator>
                <Numerator>-0.00016084</Numerator>
                <Numerator>-0.000178822</Numerator>
                <Numerator>-0.00014086</Numerator>
                <Numerator>-6.49352e-05</Numerator>
                <Numerator>2.49751e-05</Numerator>
```

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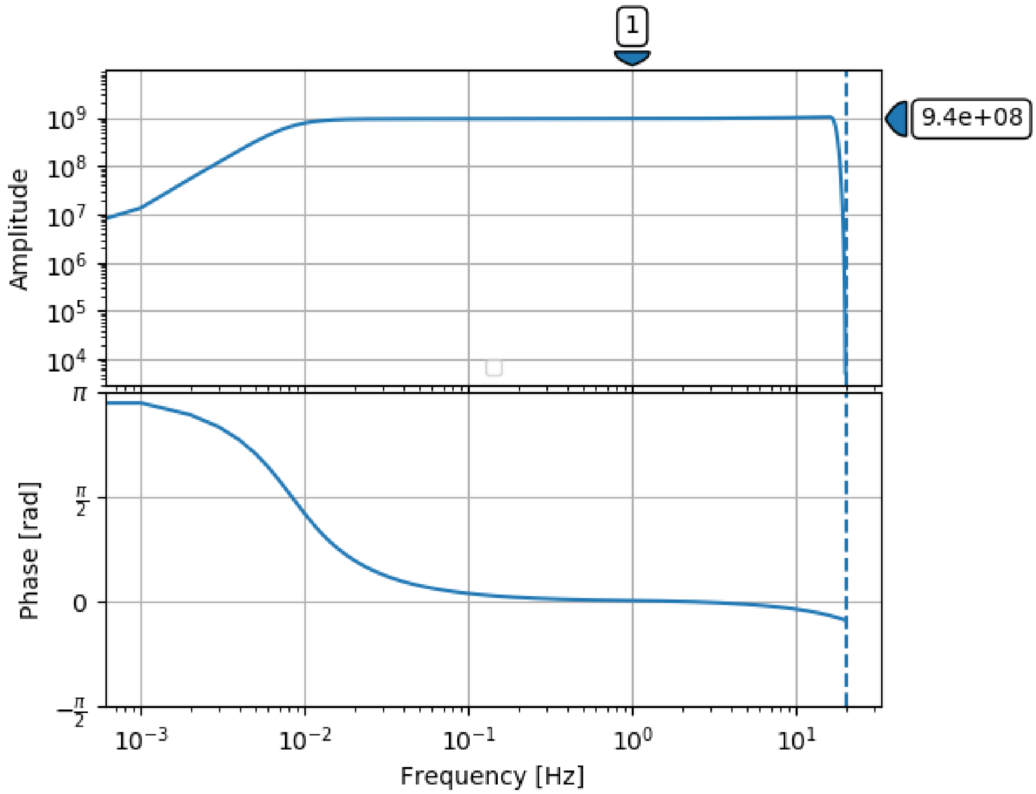
```
              <Numerator>0.000104895</Numerator>
              <Numerator>0.000157843</Numerator>
              <Numerator>0.000174826</Numerator>
              <Numerator>0.000158842</Numerator>
              <Numerator>0.000118881</Numerator>
              <Numerator>6.7932e-05</Numerator>
              <Numerator>1.8981e-05</Numerator>
              <Numerator>-1.8981e-05</Numerator>
              <Numerator>-4.09589e-05</Numerator>
              <Numerator>-4.79522e-05</Numerator>
              <Numerator>-4.39561e-05</Numerator>
              <Numerator>-3.29668e-05</Numerator>
              <Numerator>-1.99798e-05</Numerator>
              <Numerator>-1.09889e-05</Numerator>
            </Coefficients>
            <Decimation>
              <InputSampleRate unit="HERTZ">200.0</InputSampleRate>
              <Factor>5</Factor>
              <Offset>0</Offset>
              <Delay>0.585</Delay>
              <Correction>0.585</Correction>
            </Decimation>
            <StageGain>
              <Value>1.0</Value>
              <Frequency>0.05</Frequency>
            </StageGain>
          </Stage>
        </Response>
      </Channel>
    </Station>
  </Network>
</FDSNStationXML>
```



3.2.7 Broadband sensor

Streckeisen STS-1 sensor (360 s) + Quanterra Qx80 datalogger (80)

StationXML **Show/Hide**


```
<?xml version='1.0' encoding='UTF-8'?>
<FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1
↪">
  <Source>isti</Source>
  <Module>ObsPy 1.2.0rc8.post0+9.gfdab3d4f94.dirty.obspy.master</Module>
  <ModuleURI>https://www.obspy.org</ModuleURI>
  <Created>2020-06-06T01:19:15.736834Z</Created>
  <Network code="BK">
    <Station code="ANMO">
      <Latitude unit="DEGREES">34.945911</Latitude>
      <Longitude unit="DEGREES">-106.457199</Longitude>
      <Elevation unit="METERS">1820.0</Elevation>
      <Site>
        <Name>Albuquerque, New Mexico, USA</Name>
      </Site>
      <CreationDate>1970-01-01T00:00:00.000000Z</CreationDate>
      <Channel code="BHZ" locationCode="10">
        <Latitude unit="DEGREES">34.945911</Latitude>
        <Longitude unit="DEGREES">-106.457199</Longitude>
        <Elevation unit="METERS">1820.0</Elevation>
        <Depth unit="METERS">0.0</Depth>
```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```
        <SampleRate>80.0</SampleRate>
        <Response>
          <InstrumentSensitivity>
            <Value>966938797.852</Value>
            <Frequency>0.02</Frequency>
            <InputUnits>
              <Name>M/S</Name>
              <Description>Velocity in Meters per Second</Description>
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
          </InstrumentSensitivity>
          <Stage number="1">
            <PolesZeros>
              <InputUnits>
                <Name>M/S</Name>
                <Description>Velocity in Meters per Second</Description>
              </InputUnits>
              <OutputUnits>
                <Name>V</Name>
                <Description>Volts</Description>
              </OutputUnits>
              <PzTransferFunctionType>LAPLACE (RADIANS/SECOND)</
↪PzTransferFunctionType>
              <NormalizationFactor>3948.58</NormalizationFactor>
              <NormalizationFrequency unit="HERTZ">0.02</
↪NormalizationFrequency>
              <Zero number="0">
                <Real>0.0</Real>
                <Imaginary>0.0</Imaginary>
              </Zero>
              <Zero number="1">
                <Real>0.0</Real>
                <Imaginary>0.0</Imaginary>
              </Zero>
              <Pole number="0">
                <Real>-0.01234</Real>
                <Imaginary>0.01234</Imaginary>
              </Pole>
              <Pole number="1">
                <Real>-0.01234</Real>
                <Imaginary>-0.01234</Imaginary>
              </Pole>
              <Pole number="2">
                <Real>-39.18</Real>
                <Imaginary>49.12</Imaginary>
              </Pole>
              <Pole number="3">
                <Real>-39.18</Real>
                <Imaginary>-49.12</Imaginary>
              </Pole>
            </PolesZeros>
            <StageGain>
              <Value>2400.0</Value>
              <Frequency>0.02</Frequency>
```

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```
        </StageGain>
      </Stage>
      <Stage number="2">
        <StageGain>
          <Value>1.0</Value>
          <Frequency>0.05</Frequency>
        </StageGain>
      </Stage>
      <Stage number="3">
        <Coefficients>
          <InputUnits>
            <Name>V</Name>
            <Description>Volts</Description>
          </InputUnits>
          <OutputUnits>
            <Name>COUNTS</Name>
            <Description>Digital Counts</Description>
          </OutputUnits>
          <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
          <Numerator>1.0</Numerator>
        </Coefficients>
        <Decimation>
          <InputSampleRate unit="HERTZ">5120.0</InputSampleRate>
          <Factor>1</Factor>
          <Offset>0</Offset>
          <Delay>0.0</Delay>
          <Correction>0.0</Correction>
        </Decimation>
        <StageGain>
          <Value>400000.0</Value>
          <Frequency>0.05</Frequency>
        </StageGain>
      </Stage>
      <Stage number="4">
        <Coefficients>
          <InputUnits>
            <Name>COUNTS</Name>
            <Description>Digital Counts</Description>
          </InputUnits>
          <OutputUnits>
            <Name>COUNTS</Name>
            <Description>Digital Counts</Description>
          </OutputUnits>
          <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
          <Numerator>-0.00111328</Numerator>
          <Numerator>-0.001008</Numerator>
          <Numerator>-0.00135286</Numerator>
          <Numerator>-0.00173045</Numerator>
          <Numerator>-0.00208418</Numerator>
          <Numerator>-0.00238538</Numerator>
          <Numerator>-0.00260956</Numerator>
          <Numerator>-0.00273352</Numerator>
          <Numerator>-0.00273316</Numerator>
          <Numerator>-0.00258472</Numerator>
          <Numerator>-0.00226412</Numerator>
          <Numerator>-0.00174847</Numerator>
          <Numerator>-0.00101403</Numerator>
```

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```
          <Numerator>-3.51682e-05</Numerator>
          <Numerator>0.00123782</Numerator>
          <Numerator>0.00315983</Numerator>
          <Numerator>0.00699945</Numerator>
          <Numerator>0.0090996</Numerator>
          <Numerator>0.0125424</Numerator>
          <Numerator>0.0163123</Numerator>
          <Numerator>0.0202632</Numerator>
          <Numerator>0.0243173</Numerator>
          <Numerator>0.0284051</Numerator>
          <Numerator>0.0324604</Numerator>
          <Numerator>0.0364143</Numerator>
          <Numerator>0.0401987</Numerator>
          <Numerator>0.043745</Numerator>
          <Numerator>0.0469873</Numerator>
          <Numerator>0.0498573</Numerator>
          <Numerator>0.0522796</Numerator>
          <Numerator>0.054114</Numerator>
          <Numerator>0.0543903</Numerator>
          <Numerator>0.0543903</Numerator>
          <Numerator>0.054114</Numerator>
          <Numerator>0.0522796</Numerator>
          <Numerator>0.0498573</Numerator>
          <Numerator>0.0469873</Numerator>
          <Numerator>0.043745</Numerator>
          <Numerator>0.0401987</Numerator>
          <Numerator>0.0364143</Numerator>
          <Numerator>0.0324604</Numerator>
          <Numerator>0.0284051</Numerator>
          <Numerator>0.0243173</Numerator>
          <Numerator>0.0202632</Numerator>
          <Numerator>0.0163123</Numerator>
          <Numerator>0.0125424</Numerator>
          <Numerator>0.0090996</Numerator>
          <Numerator>0.00699945</Numerator>
          <Numerator>0.00315983</Numerator>
          <Numerator>0.00123782</Numerator>
          <Numerator>-3.51682e-05</Numerator>
          <Numerator>-0.00101403</Numerator>
          <Numerator>-0.00174847</Numerator>
          <Numerator>-0.00226412</Numerator>
          <Numerator>-0.00258472</Numerator>
          <Numerator>-0.00273316</Numerator>
          <Numerator>-0.00273352</Numerator>
          <Numerator>-0.00260956</Numerator>
          <Numerator>-0.00238538</Numerator>
          <Numerator>-0.00208418</Numerator>
          <Numerator>-0.00173045</Numerator>
          <Numerator>-0.00135286</Numerator>
          <Numerator>-0.001008</Numerator>
          <Numerator>-0.00111328</Numerator>
        </Coefficients>
        <Decimation>
          <InputSampleRate unit="HERTZ">5120.0</InputSampleRate>
          <Factor>16</Factor>
          <Offset>0</Offset>
          <Delay>0.006152344</Delay>
```


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```
        <Correction>0.006</Correction>
      </Decimation>
      <StageGain>
        <Value>1.014774</Value>
        <Frequency>0.05</Frequency>
      </StageGain>
    </Stage>
    <Stage number="5">
      <Coefficients>
        <InputUnits>
          <Name>COUNTS</Name>
          <Description>Digital Counts</Description>
        </InputUnits>
        <OutputUnits>
          <Name>COUNTS</Name>
          <Description>Digital Counts</Description>
        </OutputUnits>
        <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
        <Numerator>0.000150487</Numerator>
        <Numerator>0.000305924</Numerator>
        <Numerator>0.000442949</Numerator>
        <Numerator>0.000387117</Numerator>
        <Numerator>-4.73787e-05</Numerator>
        <Numerator>-0.000970772</Numerator>
        <Numerator>-0.00230317</Numerator>
        <Numerator>-0.00370638</Numerator>
        <Numerator>-0.00462505</Numerator>
        <Numerator>-0.0044648</Numerator>
        <Numerator>-0.00286984</Numerator>
        <Numerator>7.00861e-06</Numerator>
        <Numerator>0.0033852</Numerator>
        <Numerator>0.00600353</Numerator>
        <Numerator>0.00655094</Numerator>
        <Numerator>0.00425995</Numerator>
        <Numerator>-0.000576024</Numerator>
        <Numerator>-0.00643416</Numerator>
        <Numerator>-0.0109214</Numerator>
        <Numerator>-0.0116364</Numerator>
        <Numerator>-0.00726515</Numerator>
        <Numerator>0.00153727</Numerator>
        <Numerator>0.0119331</Numerator>
        <Numerator>0.0196157</Numerator>
        <Numerator>0.0203516</Numerator>
        <Numerator>0.011868</Numerator>
        <Numerator>-0.00464369</Numerator>
        <Numerator>-0.0241125</Numerator>
        <Numerator>-0.0386383</Numerator>
        <Numerator>-0.0398499</Numerator>
        <Numerator>-0.0218684</Numerator>
        <Numerator>0.0161612</Numerator>
        <Numerator>0.0689624</Numerator>
        <Numerator>0.126003</Numerator>
        <Numerator>0.174229</Numerator>
        <Numerator>0.201834</Numerator>
        <Numerator>0.201834</Numerator>
        <Numerator>0.174229</Numerator>
        <Numerator>0.126003</Numerator>
```

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```
              <Numerator>0.0689624</Numerator>
              <Numerator>0.0161612</Numerator>
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              <Numerator>-0.0398499</Numerator>
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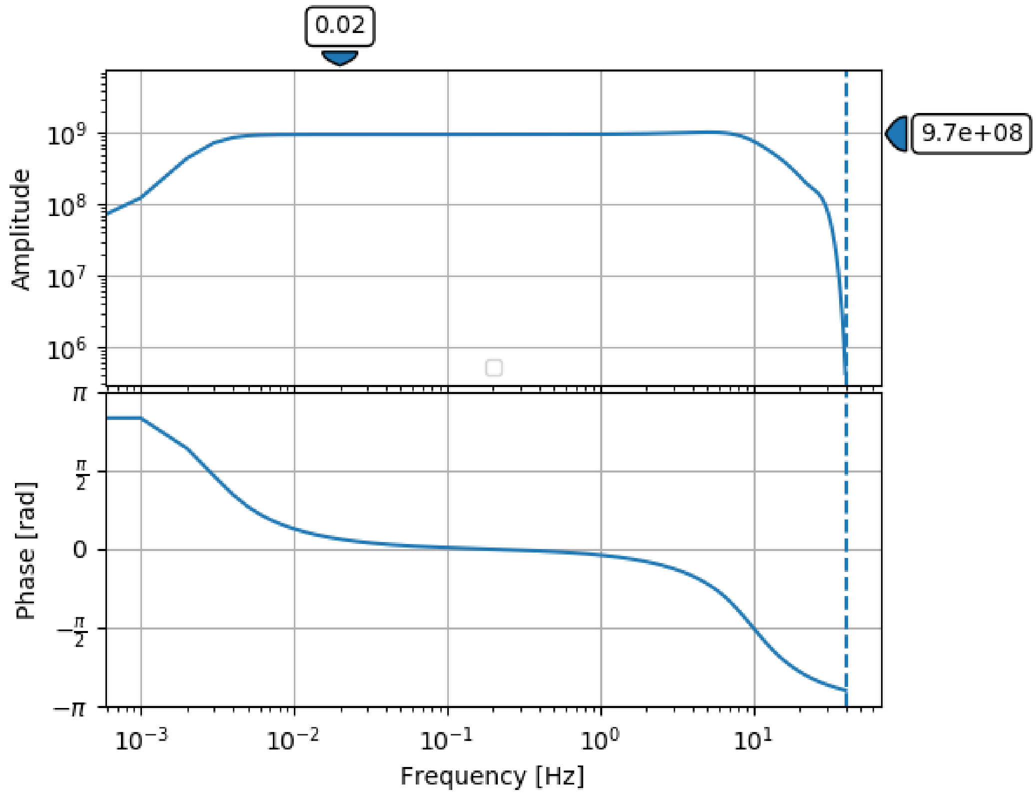
              <Numerator>-0.0241125</Numerator>
              <Numerator>-0.00464369</Numerator>
              <Numerator>0.011868</Numerator>
              <Numerator>0.0203516</Numerator>
              <Numerator>0.0196157</Numerator>
              <Numerator>0.0119331</Numerator>
              <Numerator>0.00153727</Numerator>
              <Numerator>-0.00726515</Numerator>
              <Numerator>-0.0116364</Numerator>
              <Numerator>-0.0109214</Numerator>
              <Numerator>-0.00643416</Numerator>
              <Numerator>-0.000576024</Numerator>
              <Numerator>0.00425995</Numerator>
              <Numerator>0.00655094</Numerator>
              <Numerator>0.00600353</Numerator>
              <Numerator>0.0033852</Numerator>
              <Numerator>7.00861e-06</Numerator>
              <Numerator>-0.00286984</Numerator>
              <Numerator>-0.0044648</Numerator>
              <Numerator>-0.00462505</Numerator>
              <Numerator>-0.00370638</Numerator>
              <Numerator>-0.00230317</Numerator>
              <Numerator>-0.000970772</Numerator>
              <Numerator>-4.73787e-05</Numerator>
              <Numerator>0.000387117</Numerator>
              <Numerator>0.000442949</Numerator>
              <Numerator>0.000305924</Numerator>
              <Numerator>0.000150487</Numerator>
            </Coefficients>
            <Decimation>
              <InputSampleRate unit="HERTZ">320.0</InputSampleRate>
              <Factor>4</Factor>
              <Offset>0</Offset>
              <Delay>0.1109375</Delay>
              <Correction>0.083</Correction>
            </Decimation>
            <StageGain>
              <Value>0.9781118</Value>
              <Frequency>0.05</Frequency>
            </StageGain>
          </Stage>
        </Response>
      </Channel>
    </Station>
  </Network>
</FDSNStationXML>
```



3.2.8 Short-period sensor

Geotech GS-13 short-period sensor + Quanterra Quanterra Qx80 datalogger

StationXML **Show/Hide**

```
<?xml version='1.0' encoding='UTF-8'?>
<FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1
↪">
  <Network code=..>
    <Station code=..>
      <Channel code=.. locationCode=..>
        <SampleRate>80.0</SampleRate>
        <Response>
          <InstrumentSensitivity>
            <Value>264268099.805</Value>
            <Frequency>5.0</Frequency>
            <InputUnits>
              <Name>M/S</Name>
              <Description>Velocity in Meters per Second</Description>
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
          </InstrumentSensitivity>
          <Stage number="1">
```

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```
            <PolesZeros>
              <InputUnits>
                <Name>M/S</Name>
                <Description>Velocity in Meters per Second</Description>
              </InputUnits>
              <OutputUnits>
                <Name>V</Name>
                <Description>Volts</Description>
              </OutputUnits>
              <PzTransferFunctionType>LAPLACE (RADIANS/SECOND)</
↪PzTransferFunctionType>
              <NormalizationFactor>1.0</NormalizationFactor>
              <NormalizationFrequency unit="HERTZ">5.0</
↪NormalizationFrequency>
              <Zero number="0">
                <Real>0.0</Real>
                <Imaginary>0.0</Imaginary>
              </Zero>
              <Zero number="1">
                <Real>0.0</Real>
                <Imaginary>0.0</Imaginary>
              </Zero>
              <Pole number="0">
                <Real>-4.443</Real>
                <Imaginary>4.443</Imaginary>
              </Pole>
              <Pole number="1">
                <Real>-4.443</Real>
                <Imaginary>-4.443</Imaginary>
              </Pole>
            </PolesZeros>
            <StageGain>
              <Value>629.0</Value>
              <Frequency>5.0</Frequency>
            </StageGain>
          </Stage>
          <Stage number="2">
            <StageGain>
              <Value>1.0</Value>
              <Frequency>0.05</Frequency>
            </StageGain>
          </Stage>
          <Stage number="3">
            <Coefficients>
              <InputUnits>
                <Name>V</Name>
                <Description>Volts</Description>
              </InputUnits>
              <OutputUnits>
                <Name>COUNTS</Name>
                <Description>Digital Counts</Description>
              </OutputUnits>
              <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
              <Numerator>1.0</Numerator>
            </Coefficients>
            <Decimation>
              <InputSampleRate unit="HERTZ">5120.0</InputSampleRate>
```

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```
<Factor>1</Factor>
        <Offset>0</Offset>
        <Delay>0.0</Delay>
        <Correction>0.0</Correction>
      </Decimation>
      <StageGain>
        <Value>400000.0</Value>
        <Frequency>0.05</Frequency>
      </StageGain>
    </Stage>
    <Stage number="4">
      <Coefficients>
        <InputUnits>
          <Name>COUNTS</Name>
          <Description>Digital Counts</Description>
        </InputUnits>
        <OutputUnits>
          <Name>COUNTS</Name>
          <Description>Digital Counts</Description>
        </OutputUnits>
        <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
        <Numerator>-0.00111328</Numerator>
        <Numerator>-0.001008</Numerator>
        <Numerator>-0.00135286</Numerator>
        <Numerator>-0.00173045</Numerator>
        <Numerator>-0.00208418</Numerator>
        <Numerator>-0.00238538</Numerator>
        <Numerator>-0.00260956</Numerator>
        <Numerator>-0.00273352</Numerator>
        <Numerator>-0.00273316</Numerator>
        <Numerator>-0.00258472</Numerator>
        <Numerator>-0.00226412</Numerator>
        <Numerator>-0.00174847</Numerator>
        <Numerator>-0.00101403</Numerator>
        <Numerator>-3.51682e-05</Numerator>
        <Numerator>0.00123782</Numerator>
        <Numerator>0.00315983</Numerator>
        <Numerator>0.00699945</Numerator>
        <Numerator>0.0090996</Numerator>
        <Numerator>0.0125424</Numerator>
        <Numerator>0.0163123</Numerator>
        <Numerator>0.0202632</Numerator>
        <Numerator>0.0243173</Numerator>
        <Numerator>0.0284051</Numerator>
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        <Numerator>0.0401987</Numerator>
        <Numerator>0.043745</Numerator>
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        <Numerator>0.0522796</Numerator>
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        <Numerator>0.0543903</Numerator>
        <Numerator>0.0543903</Numerator>
        <Numerator>0.054114</Numerator>
        <Numerator>0.0522796</Numerator>
        <Numerator>0.0498573</Numerator>
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```
              <Numerator>0.0469873</Numerator>
              <Numerator>0.043745</Numerator>
              <Numerator>0.0401987</Numerator>
              <Numerator>0.0364143</Numerator>
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              <Numerator>0.0284051</Numerator>
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              <Numerator>0.0163123</Numerator>
              <Numerator>0.0125424</Numerator>
              <Numerator>0.0090996</Numerator>
              <Numerator>0.00699945</Numerator>
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              <Numerator>0.00123782</Numerator>
              <Numerator>-3.51682e-05</Numerator>
              <Numerator>-0.00101403</Numerator>
              <Numerator>-0.00174847</Numerator>
              <Numerator>-0.00226412</Numerator>
              <Numerator>-0.00258472</Numerator>
              <Numerator>-0.00273316</Numerator>
              <Numerator>-0.00273352</Numerator>
              <Numerator>-0.00260956</Numerator>
              <Numerator>-0.00238538</Numerator>
              <Numerator>-0.00208418</Numerator>
              <Numerator>-0.00173045</Numerator>
              <Numerator>-0.00135286</Numerator>
              <Numerator>-0.001008</Numerator>
              <Numerator>-0.00111328</Numerator>
            </Coefficients>
            <Decimation>
              <InputSampleRate unit="HERTZ">5120.0</InputSampleRate>
              <Factor>16</Factor>
              <Offset>0</Offset>
              <Delay>0.006152344</Delay>
              <Correction>0.006</Correction>
            </Decimation>
            <StageGain>
              <Value>1.014774</Value>
              <Frequency>0.05</Frequency>
            </StageGain>
          </Stage>
          <Stage number="5">
            <Coefficients>
              <InputUnits>
                <Name>COUNTS</Name>
                <Description>Digital Counts</Description>
              </InputUnits>
              <OutputUnits>
                <Name>COUNTS</Name>
                <Description>Digital Counts</Description>
              </OutputUnits>
              <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
              <Numerator>0.000150487</Numerator>
              <Numerator>0.000305924</Numerator>
              <Numerator>0.000442949</Numerator>
              <Numerator>0.000387117</Numerator>
              <Numerator>-4.73787e-05</Numerator>
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```
            <Numerator>-0.000970772</Numerator>
            <Numerator>-0.00230317</Numerator>
            <Numerator>-0.00370638</Numerator>
            <Numerator>-0.00462505</Numerator>
            <Numerator>-0.0044648</Numerator>
            <Numerator>-0.00286984</Numerator>
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            <Numerator>0.0033852</Numerator>
            <Numerator>0.00600353</Numerator>
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            <Numerator>0.00425995</Numerator>
            <Numerator>-0.000576024</Numerator>
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            <Numerator>-0.0116364</Numerator>
            <Numerator>-0.00726515</Numerator>
            <Numerator>0.00153727</Numerator>
            <Numerator>0.0119331</Numerator>
            <Numerator>0.0196157</Numerator>
            <Numerator>0.0203516</Numerator>
            <Numerator>0.011868</Numerator>
            <Numerator>-0.00464369</Numerator>
            <Numerator>-0.0241125</Numerator>
            <Numerator>-0.0386383</Numerator>
            <Numerator>-0.0398499</Numerator>
            <Numerator>-0.0218684</Numerator>
            <Numerator>0.0161612</Numerator>
            <Numerator>0.0689624</Numerator>
            <Numerator>0.126003</Numerator>
            <Numerator>0.174229</Numerator>
            <Numerator>0.201834</Numerator>
            <Numerator>0.201834</Numerator>
            <Numerator>0.174229</Numerator>
            <Numerator>0.126003</Numerator>
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            <Numerator>-0.0398499</Numerator>
            <Numerator>-0.0386383</Numerator>
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            <Numerator>-0.00643416</Numerator>
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            <Numerator>0.0033852</Numerator>
            <Numerator>7.00861e-06</Numerator>
            <Numerator>-0.00286984</Numerator>
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                <Numerator>-0.00370638</Numerator>
                <Numerator>-0.00230317</Numerator>
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              <Decimation>
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        </Channel>
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    </Network>
</FDSNStationXML>
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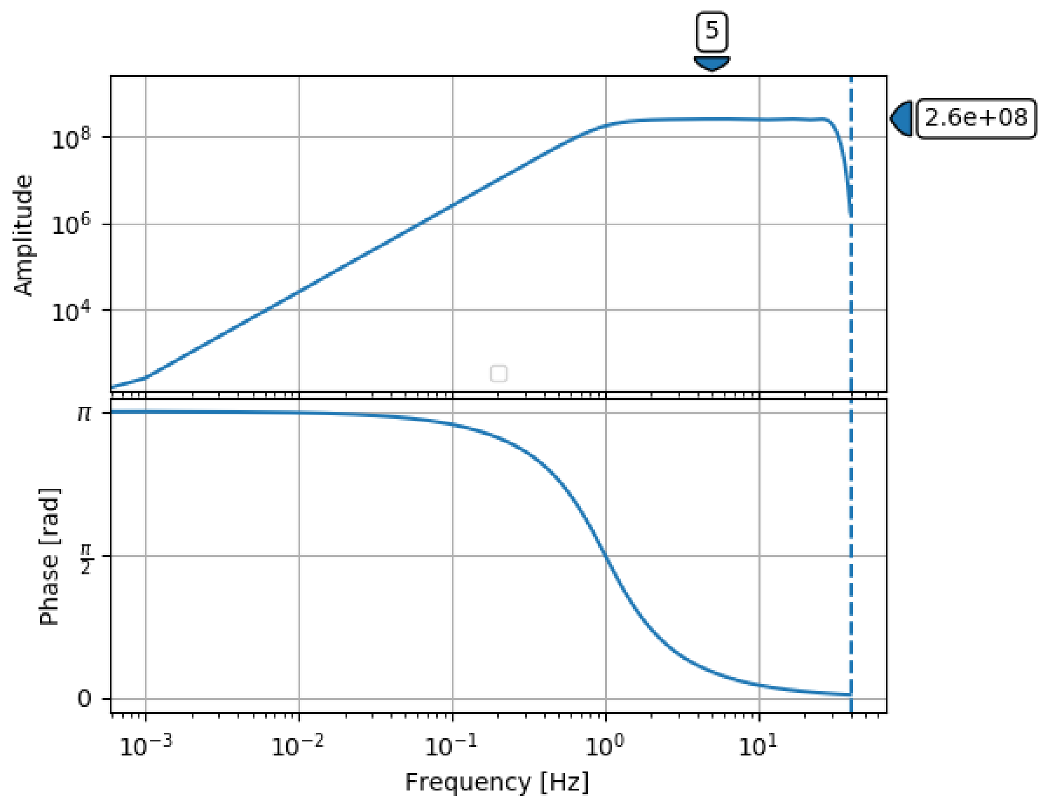

3.2.9 Short-period sensor

Sercel L-22D short-period sensor (Rc=5470 Ohms, Rs=20000 Ohms) + Reftek RT72A-08 24-bit datalogger, 1 stream, 100 Hz, gain 32

StationXML **Show/Hide**

```
<?xml version='1.0' encoding='UTF-8'?>
<FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1
↪">
  <Network code=..>
    <Station code=..>
      <Channel code=.. locationCode=..>
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        <SampleRate>100.0</SampleRate>
        <Response>
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              <Description>Velocity in Meters per Second</Description>
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
          </InstrumentSensitivity>
          <Stage number="1">
            <PolesZeros>
              <InputUnits>
                <Name>M/S</Name>
                <Description>Velocity in Meters per Second</Description>
              </InputUnits>
              <OutputUnits>
                <Name>V</Name>
                <Description>Volts</Description>
              </OutputUnits>
              <PzTransferFunctionType>LAPLACE (RADIANS/SECOND)</
↪PzTransferFunctionType>
              <NormalizationFactor>1.0</NormalizationFactor>
              <NormalizationFrequency unit="HERTZ">10.0</
↪NormalizationFrequency>
              <Zero number="0">
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              <Zero number="1">
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                <Imaginary>0.0</Imaginary>
              </Zero>
              <Pole number="0">
                <Real>-8.884</Real>
                <Imaginary>8.887</Imaginary>
              </Pole>
              <Pole number="1">
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                <Imaginary>-8.887</Imaginary>
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          </Pole>
        </PolesZeros>
        <StageGain>
          <Value>87.9</Value>
          <Frequency>10.0</Frequency>
        </StageGain>
      </Stage>
      <Stage number="2">
        <StageGain>
          <Value>32.2</Value>
          <Frequency>0.05</Frequency>
        </StageGain>
      </Stage>
      <Stage number="3">
        <Coefficients>
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          <OutputUnits>
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            <Description>Digital Counts</Description>
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          <Numerator>1.0</Numerator>
        </Coefficients>
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            <Description>Digital Counts</Description>
          </InputUnits>
          <OutputUnits>
            <Name>COUNTS</Name>
            <Description>Digital Counts</Description>
          </OutputUnits>
          <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
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          <Numerator>-5.60554e-05</Numerator>
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              <Numerator>0.00180478</Numerator>
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              <Numerator>0.0491706</Numerator>
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</Decimation>
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<Name>COUNTS</Name>
<Description>Digital Counts</Description>
</OutputUnits>
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<Numerator>0.000310279</Numerator>
<Numerator>-0.000124111</Numerator>
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              <Numerator>0.000108097</Numerator>
              <Numerator>-0.00427885</Numerator>
              <Numerator>-0.00156841</Numerator>
              <Numerator>0.0027785</Numerator>
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              <Numerator>-0.00213993</Numerator>
              <Numerator>0.000273246</Numerator>
              <Numerator>0.00169853</Numerator>
              <Numerator>0.000406366</Numerator>
              <Numerator>-0.00109999</Numerator>
              <Numerator>-0.000695627</Numerator>
              <Numerator>0.000534481</Numerator>
              <Numerator>0.000692624</Numerator>
              <Numerator>-0.000114103</Numerator>
              <Numerator>-0.000523471</Numerator>
              <Numerator>-0.000124111</Numerator>
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              <Numerator>0.000212191</Numerator>
              <Numerator>-0.000145131</Numerator>
              <Numerator>-0.000292263</Numerator>
              <Numerator>-0.000186167</Numerator>
              <Numerator>-4.7042e-05</Numerator>
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            <Decimation>
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              <Factor>2</Factor>
              <Offset>0</Offset>
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              <Correction>0.235</Correction>
            </Decimation>
            <StageGain>
              <Value>1.0</Value>
              <Frequency>0.05</Frequency>
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        </Response>
      </Channel>
    </Station>
  </Network>
</FDSNStationXML>
```

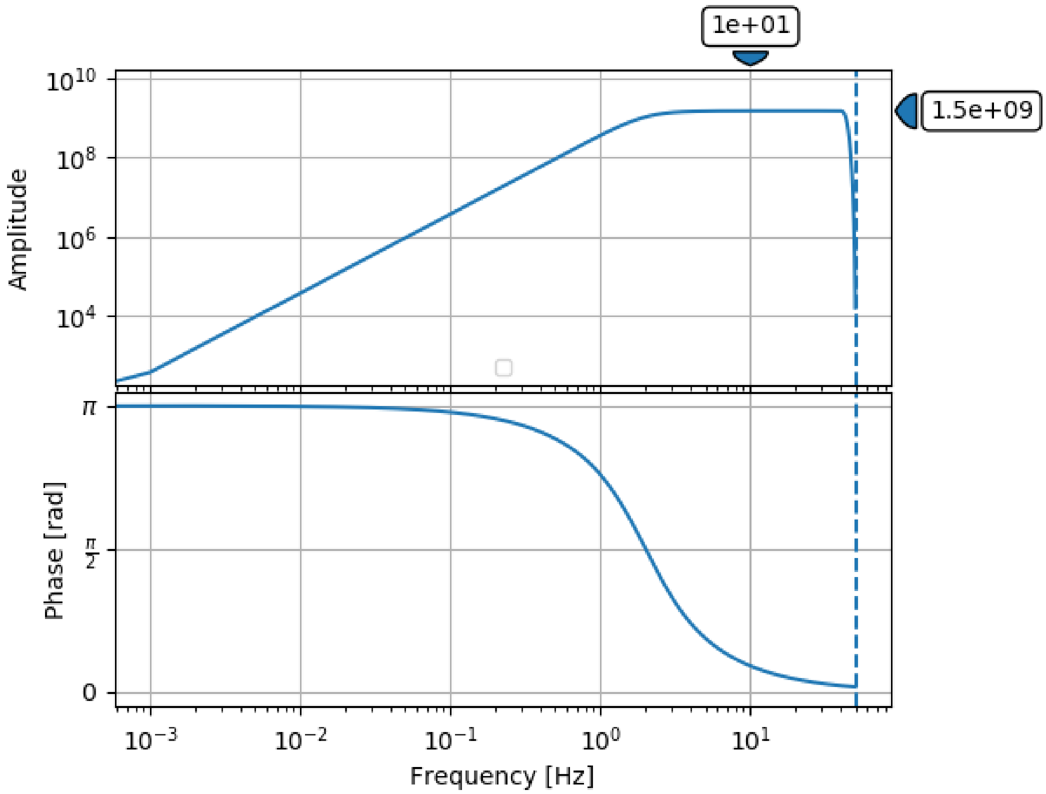

3.2.10 Accelerometer

Kinematics FBA-3 + Kinematics Etna

StationXML **Show/Hide**

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<FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1">
  <Network code=..>
    <Station code=..>
      <Channel code=.. locationCode=..>
        ...
        <SampleRate>200.0</SampleRate>
        <Response>
          <InstrumentSensitivity>
            <Value>213920.152837</Value>
            <Frequency>0.15</Frequency>
            <InputUnits>
              <Name>M/S**2</Name>
              <Description>Acceleration in Meters Per Second Per Second</Description>
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
          </InstrumentSensitivity>
          <Stage number="1">
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            <PolesZeros>
              <InputUnits>
                <Name>M/S**2</Name>
                <Description>Acceleration in Meters Per Second Per Second</
↪Description>
              </InputUnits>
              <OutputUnits>
                <Name>V</Name>
                <Description>Volts</Description>
              </OutputUnits>
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↪PzTransferFunctionType>
              <NormalizationFactor>147985000.0</NormalizationFactor>
              <NormalizationFrequency unit="HERTZ">0.15</NormalizationFrequency>
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                <Imaginary>222.1</Imaginary>
              </Pole>
              <Pole number="1">
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                <Imaginary>-222.1</Imaginary>
              </Pole>
              <Pole number="2">
                <Real>-1500.0</Real>
                <Imaginary>0.0</Imaginary>
              </Pole>
            </PolesZeros>
            <StageGain>
              <Value>0.0637</Value>
              <Frequency>0.15</Frequency>
            </StageGain>
          </Stage>
          <Stage number="2">
            <StageGain>
              <Value>1.0</Value>
              <Frequency>1.0</Frequency>
            </StageGain>
          </Stage>
          <Stage number="3">
            <Coefficients>
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                <Name>V</Name>
                <Description>Volts</Description>
              </InputUnits>
              <OutputUnits>
                <Name>COUNTS</Name>
                <Description>Digital Counts</Description>
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        </Decimation>
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      </Decimation>
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        <OutputUnits>
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          <Description>Digital Counts</Description>
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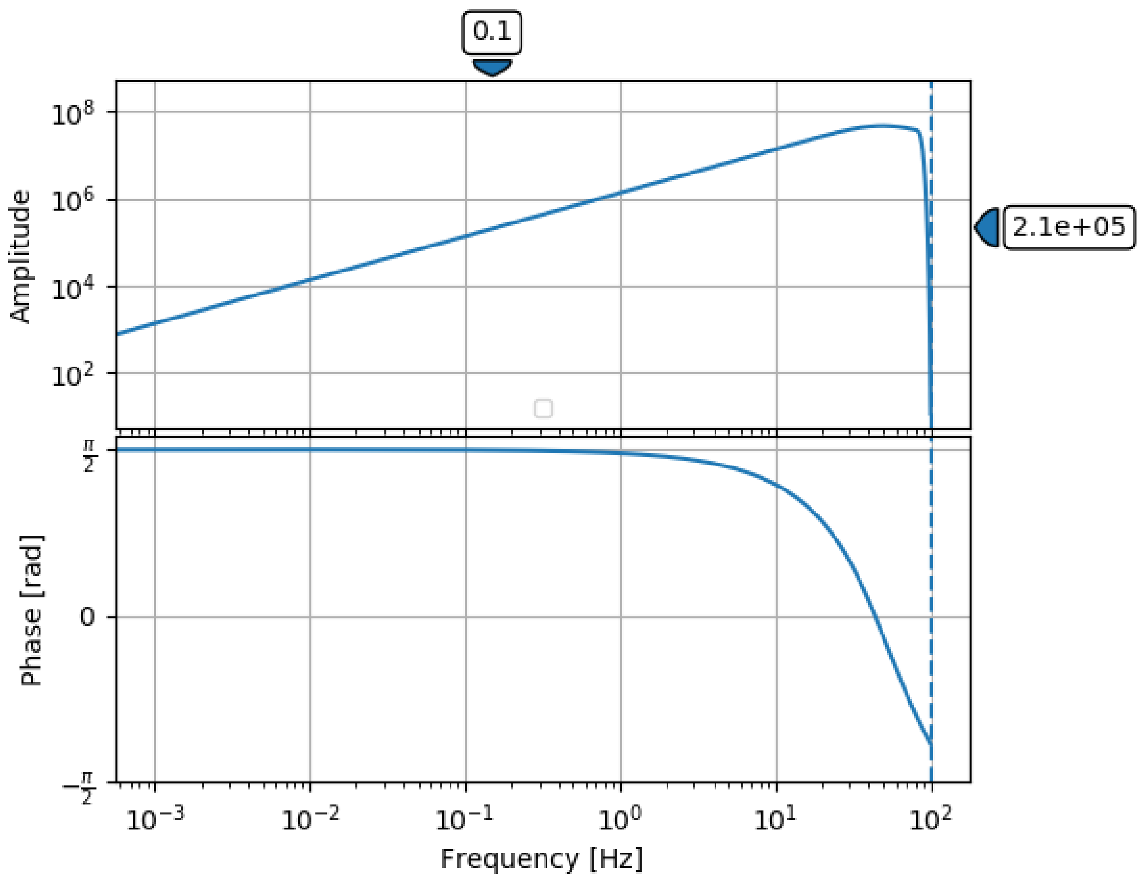

3.2.11 Setra 270

Setra 270 Pressure Transducer

This example was lifted from [62] Response [Polynomial] Blockette section (p.85) of the SEED manual (v.2.4).

The Setra Model 270 Pressure Transducer response is given as a polynomial response with 2 coefficients, valid for input pressure between 600-1100 mbar.

$$Pressure(V) = \sum_{n=0}^{1} a_n V^n$$

where $a_0 = 600$ and $a_1 = 100$

Volts	mbar
0.0	600
1.0	700
2.0	800
3.0	900
4.0	1000
5.0	1100

e.g., over this voltage range (0-5V), the input (mbar of pressure) is a linear function of the output (Volts).

The Response element for the Setra sensor alone consists of a Polynomial stage and an InsrumentPolynomial Stage

Warning

This part is not finished!

StationXML **Show/Hide**

```
<?xml version='1.0' encoding='UTF-8'?>
   <FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1">
      <Network code=..>
      <Station code=..>
         <Channel code=.. locationCode=..>
            ...
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            <OutputUnits>
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  </Network>
</FDSNStationXML>
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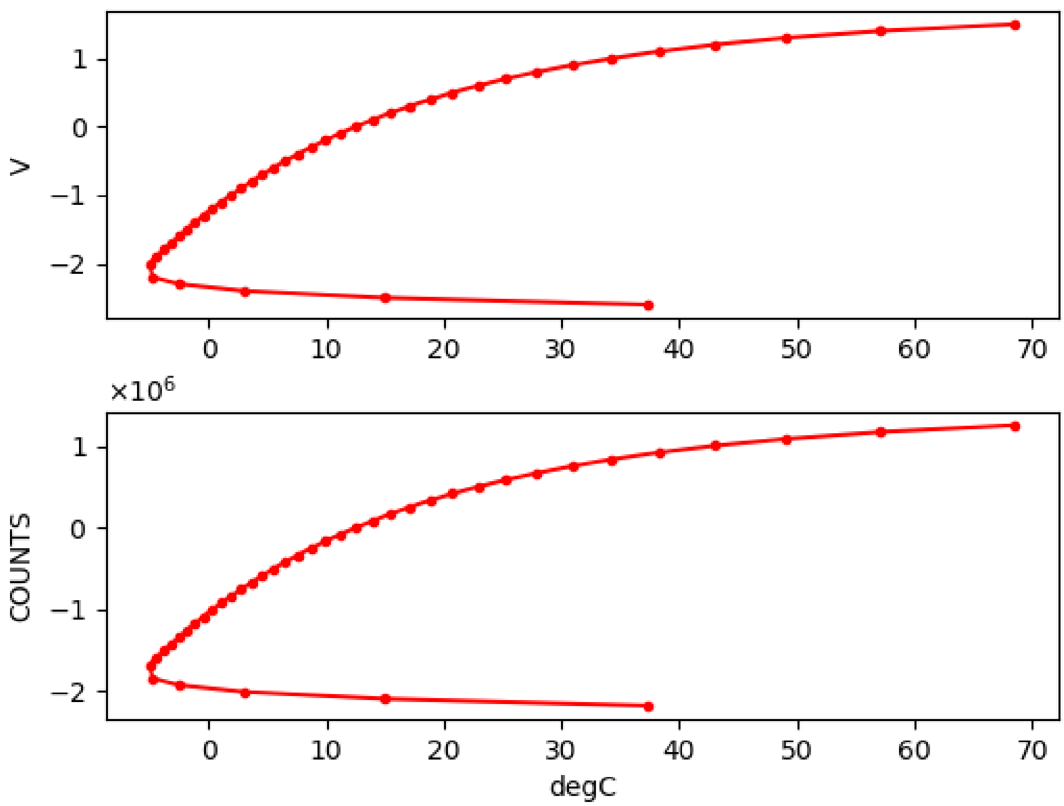

3.2.12 YSI 44031 thermistor

The Berkeley Digital Seismic Network (BDSN) seismometers, use a Yellow Springs Instrument Co. (YSI) 44031 thermistor to monitor the temperature of the seismometer. The thermistor response has been determined by measuring its voltage output as a function of input temperature. It has been calibrated within a range of temperatures from -5C to 68.59C.

The resistance of the thermistor is a non-linear function of the temperature and its response can be described by a polynomial.

In order to model the response within 0.2 degrees C accuracy, a MacLaurin polynomial with 11 coefficients:

$$Temp(V) = \sum_{n=0}^{10} a_n V^n$$

The coefficients are given in Table 1.

a_n	value
a_0	0.12505E+02
a_1	0.13824E+02
a_2	0.41039E+01
a_3	0.12932E+01
a_4	0.18741E+01
a_5	0.17250E+01
a_6	-0.61021E+00
a_7	-0.10540E+01
a_8	0.13974E+00
a_9	0.39061E+00
a_{10}	0.95345E-01

Because this is a *polynomial* response, the corresponding StationXML looks a little different than the usual responses (e.g., for seismometers). Instead of a InstrumentSensitivity element, there is an InstrumentPolynomial element. In addition the analog stage is represented by a Polynomial stage. The Polynomial stage and the InstrumentPolynomial stage both contain all of the MacLaurin coefficients, however, in the InstrumentPolynomial stage, those coefficients have been scaled by the datalogger sensitivity to give units of Counts instead of Volts.

How the InstrumentSensitivity was calculated

Something here about how to find the scalefactor and then scale the coefficients

A complete StationXML Response element is shown below for the YSI-44301 thermistor attached to a Reftek RT130 datalogger sampling at 40Hz.

StationXML **Show/Hide**

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   <FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1">
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      <Station code=..>
         <Channel code=.. locationCode=..>
            ...
            <SampleRate>40.0</SampleRate>

      <Response>
         <InstrumentPolynomial name="InstrumentPolynomial">
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               <Description>Digital Counts</Description>
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              </Decimation>
              <StageGain>
              <Value>1.0</Value>
              <Frequency>0.0</Frequency>
              </StageGain>
           </Stage>
        </Response>
      </Channel>
    </Station>
  </Network>
</FDSNStationXML>
```

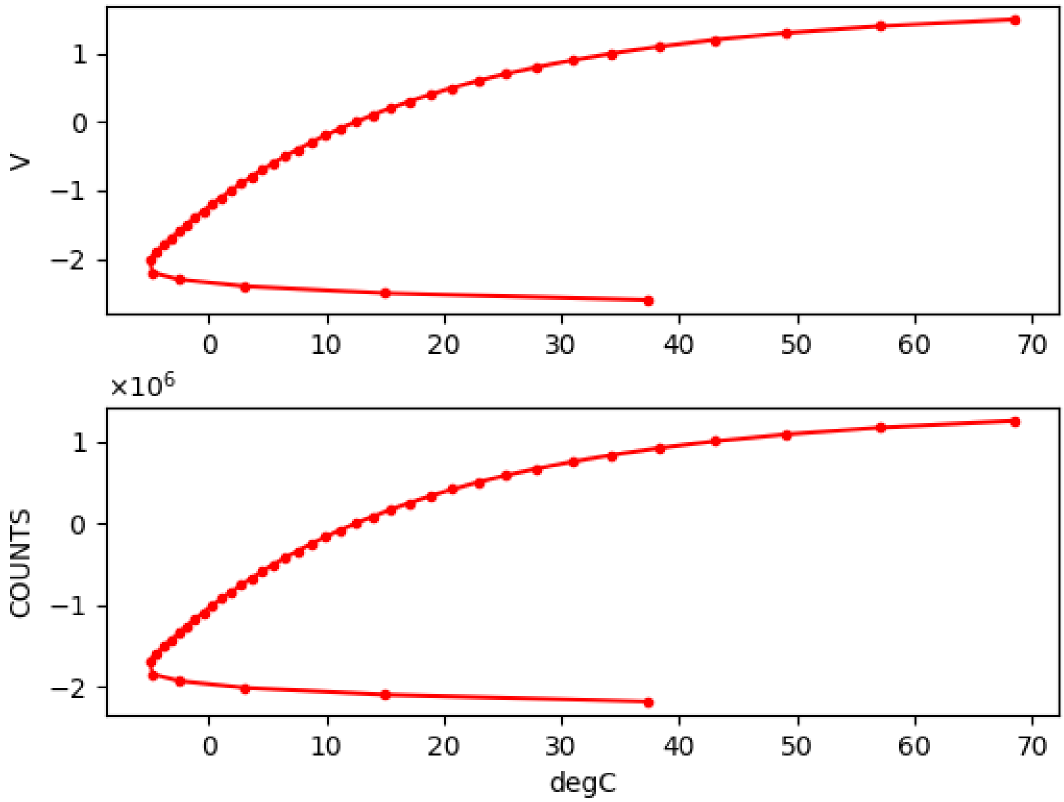

3.3 StationXML Response Examples

3.3.1 Broadband sensor

3rd generation Streckeisen STS-2 sensor + Reftek RT130 datalogger

StationXML **Show/Hide**

```
<?xml version='1.0' encoding='UTF-8'?>
<FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1
↪">
  <Network code=..>
    <Station code=..>
      <Channel code=.. locationCode=..>
        ...
        <SampleRate>40.0</SampleRate>
        <Response>
          <InstrumentSensitivity>
            <Value>941864732.693</Value>
            <Frequency>1.0</Frequency>
            <InputUnits>
              <Name>M/S</Name>
              <Description>Velocity in Meters per Second</Description>
```

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```
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
          </InstrumentSensitivity>
          <Stage number="1">
            <PolesZeros>
              <InputUnits>
                <Name>M/S</Name>
                <Description>Velocity in Meters per Second</Description>
              </InputUnits>
              <OutputUnits>
                <Name>V</Name>
                <Description>Volts</Description>
              </OutputUnits>
              <PzTransferFunctionType>LAPLACE (RADIANS/SECOND)</
↪PzTransferFunctionType>
              <NormalizationFactor>3.4684e+17</NormalizationFactor>
              <NormalizationFrequency unit="HERTZ">1.0</
↪NormalizationFrequency>
              <Zero number="0">
                <Real>0.0</Real>
                <Imaginary>0.0</Imaginary>
              </Zero>
              <Zero number="1">
                <Real>0.0</Real>
                <Imaginary>0.0</Imaginary>
              </Zero>
              <Zero number="2">
                <Real>-15.15</Real>
                <Imaginary>0.0</Imaginary>
              </Zero>
              <Zero number="3">
                <Real>-176.6</Real>
                <Imaginary>0.0</Imaginary>
              </Zero>
              <Zero number="4">
                <Real>-463.1</Real>
                <Imaginary>-430.5</Imaginary>
              </Zero>
              <Zero number="5">
                <Real>-463.1</Real>
                <Imaginary>430.5</Imaginary>
              </Zero>
              <Pole number="0">
                <Real>-0.037</Real>
                <Imaginary>-0.037</Imaginary>
              </Pole>
              <Pole number="1">
                <Real>-0.037</Real>
                <Imaginary>0.037</Imaginary>
              </Pole>
              <Pole number="2">
                <Real>-15.64</Real>
                <Imaginary>0.0</Imaginary>
              </Pole>
```

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```
<Pole number="3">
  <Real>-97.34</Real>
  <Imaginary>-400.7</Imaginary>
</Pole>
<Pole number="4">
  <Real>-97.34</Real>
  <Imaginary>400.7</Imaginary>
</Pole>
<Pole number="5">
  <Real>-374.8</Real>
  <Imaginary>0.0</Imaginary>
</Pole>
<Pole number="6">
  <Real>-520.3</Real>
  <Imaginary>0.0</Imaginary>
</Pole>
<Pole number="7">
  <Real>-10530.0</Real>
  <Imaginary>-10050.0</Imaginary>
</Pole>
<Pole number="8">
  <Real>-10530.0</Real>
  <Imaginary>10050.0</Imaginary>
</Pole>
<Pole number="9">
  <Real>-13300.0</Real>
  <Imaginary>0.0</Imaginary>
</Pole>
<Pole number="10">
  <Real>-255.097</Real>
  <Imaginary>0.0</Imaginary>
</Pole>
</PolesZeros>
<StageGain>
  <Value>1500.0</Value>
  <Frequency>1.0</Frequency>
</StageGain>
</Stage>
<Stage number="2">
  <StageGain>
    <Value>1.0</Value>
    <Frequency>0.05</Frequency>
  </StageGain>
</Stage>
<Stage number="3">
  <Coefficients>
    <InputUnits>
      <Name>V</Name>
      <Description>Volts</Description>
    </InputUnits>
    <OutputUnits>
      <Name>COUNTS</Name>
      <Description>Digital Counts</Description>
    </OutputUnits>
    <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
    <Numerator>1.0</Numerator>
  </Coefficients>
```

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```xml
      <Decimation>
        <InputSampleRate unit="HERTZ">102400.0</InputSampleRate>
        <Factor>1</Factor>
        <Offset>0</Offset>
        <Delay>0.0</Delay>
        <Correction>0.0</Correction>
      </Decimation>
      <StageGain>
        <Value>629129.0</Value>
        <Frequency>0.05</Frequency>
      </StageGain>
    </Stage>
    <Stage number="4">
      <Coefficients>
        <InputUnits>
          <Name>COUNTS</Name>
          <Description>Digital Counts</Description>
        </InputUnits>
        <OutputUnits>
          <Name>COUNTS</Name>
          <Description>Digital Counts</Description>
        </OutputUnits>
        <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
        <Numerator>0.000244141</Numerator>
        <Numerator>0.000976562</Numerator>
        <Numerator>0.00244141</Numerator>
        <Numerator>0.00488281</Numerator>
        <Numerator>0.00854492</Numerator>
        <Numerator>0.0136719</Numerator>
        <Numerator>0.0205078</Numerator>
        <Numerator>0.0292969</Numerator>
        <Numerator>0.0393066</Numerator>
        <Numerator>0.0498047</Numerator>
        <Numerator>0.0600586</Numerator>
        <Numerator>0.0693359</Numerator>
        <Numerator>0.0769043</Numerator>
        <Numerator>0.0820312</Numerator>
        <Numerator>0.0839844</Numerator>
        <Numerator>0.0820312</Numerator>
        <Numerator>0.0769043</Numerator>
        <Numerator>0.0693359</Numerator>
        <Numerator>0.0600586</Numerator>
        <Numerator>0.0498047</Numerator>
        <Numerator>0.0393066</Numerator>
        <Numerator>0.0292969</Numerator>
        <Numerator>0.0205078</Numerator>
        <Numerator>0.0136719</Numerator>
        <Numerator>0.00854492</Numerator>
        <Numerator>0.00488281</Numerator>
        <Numerator>0.00244141</Numerator>
        <Numerator>0.000976562</Numerator>
        <Numerator>0.000244141</Numerator>
      </Coefficients>
      <Decimation>
        <InputSampleRate unit="HERTZ">102400.0</InputSampleRate>
        <Factor>8</Factor>
        <Offset>0</Offset>
```

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```xml
            <Delay>0.00013672</Delay>
            <Correction>0.00013672</Correction>
          </Decimation>
          <StageGain>
            <Value>1.0</Value>
            <Frequency>0.05</Frequency>
          </StageGain>
        </Stage>
        <Stage number="5">
          <Coefficients>
            <InputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
            <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
            <Numerator>0.000244141</Numerator>
            <Numerator>0.00292969</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.0537109</Numerator>
            <Numerator>0.12085</Numerator>
            <Numerator>0.193359</Numerator>
            <Numerator>0.225586</Numerator>
            <Numerator>0.193359</Numerator>
            <Numerator>0.12085</Numerator>
            <Numerator>0.0537109</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.00292969</Numerator>
            <Numerator>0.000244141</Numerator>
          </Coefficients>
          <Decimation>
            <InputSampleRate unit="HERTZ">12800.0</InputSampleRate>
            <Factor>2</Factor>
            <Offset>0</Offset>
            <Delay>0.00046875</Delay>
            <Correction>0.00046875</Correction>
          </Decimation>
          <StageGain>
            <Value>1.0</Value>
            <Frequency>0.05</Frequency>
          </StageGain>
        </Stage>
        <Stage number="6">
          <Coefficients>
            <InputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
            <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
            <Numerator>0.000244141</Numerator>
```


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```
            <Numerator>0.00292969</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.0537109</Numerator>
            <Numerator>0.12085</Numerator>
            <Numerator>0.193359</Numerator>
            <Numerator>0.225586</Numerator>
            <Numerator>0.193359</Numerator>
            <Numerator>0.12085</Numerator>
            <Numerator>0.0537109</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.00292969</Numerator>
            <Numerator>0.000244141</Numerator>
          </Coefficients>
          <Decimation>
            <InputSampleRate unit="HERTZ">6400.0</InputSampleRate>
            <Factor>2</Factor>
            <Offset>0</Offset>
            <Delay>0.0009375</Delay>
            <Correction>0.0009375</Correction>
          </Decimation>
          <StageGain>
            <Value>1.0</Value>
            <Frequency>0.05</Frequency>
          </StageGain>
        </Stage>
        <Stage number="7">
          <Coefficients>
            <InputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
            <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
            <Numerator>0.000244141</Numerator>
            <Numerator>0.00292969</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.0537109</Numerator>
            <Numerator>0.12085</Numerator>
            <Numerator>0.193359</Numerator>
            <Numerator>0.225586</Numerator>
            <Numerator>0.193359</Numerator>
            <Numerator>0.12085</Numerator>
            <Numerator>0.0537109</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.00292969</Numerator>
            <Numerator>0.000244141</Numerator>
          </Coefficients>
          <Decimation>
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            <Factor>2</Factor>
            <Offset>0</Offset>
            <Delay>0.001875</Delay>
            <Correction>0.001875</Correction>
          </Decimation>
```

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```
          <StageGain>
            <Value>1.0</Value>
            <Frequency>0.05</Frequency>
          </StageGain>
        </Stage>
        <Stage number="8">
          <Coefficients>
            <InputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
            <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
            <Numerator>0.000244141</Numerator>
            <Numerator>0.00292969</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.0537109</Numerator>
            <Numerator>0.12085</Numerator>
            <Numerator>0.193359</Numerator>
            <Numerator>0.225586</Numerator>
            <Numerator>0.193359</Numerator>
            <Numerator>0.12085</Numerator>
            <Numerator>0.0537109</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.00292969</Numerator>
            <Numerator>0.000244141</Numerator>
          </Coefficients>
          <Decimation>
            <InputSampleRate unit="HERTZ">1600.0</InputSampleRate>
            <Factor>2</Factor>
            <Offset>0</Offset>
            <Delay>0.00375</Delay>
            <Correction>0.00375</Correction>
          </Decimation>
          <StageGain>
            <Value>1.0</Value>
            <Frequency>0.05</Frequency>
          </StageGain>
        </Stage>
        <Stage number="9">
          <Coefficients>
            <InputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
            <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
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            <Numerator>0.00292969</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.0537109</Numerator>
```

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```
            <Numerator>0.12085</Numerator>
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            <Numerator>0.193359</Numerator>
            <Numerator>0.12085</Numerator>
            <Numerator>0.0537109</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.00292969</Numerator>
            <Numerator>0.000244141</Numerator>
          </Coefficients>
          <Decimation>
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            <Factor>2</Factor>
            <Offset>0</Offset>
            <Delay>0.0075</Delay>
            <Correction>0.0075</Correction>
          </Decimation>
          <StageGain>
            <Value>1.0</Value>
            <Frequency>0.05</Frequency>
          </StageGain>
        </Stage>
        <Stage number="10">
          <Coefficients>
            <InputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
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            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
            <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
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            <Numerator>-5.60109e-06</Numerator>
            <Numerator>-2.62179e-06</Numerator>
            <Numerator>-4.31403e-05</Numerator>
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            <Numerator>1.43006e-06</Numerator>
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            <Numerator>-0.00264288</Numerator>
            <Numerator>-0.00720121</Numerator>
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```
                <Numerator>-0.000644006</Numerator>
                <Numerator>0.009184</Numerator>
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                <Numerator>-0.0209407</Numerator>
                <Numerator>-0.0181629</Numerator>
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                <Numerator>-0.000644006</Numerator>
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              <Numerator>-0.00127621</Numerator>
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            <Decimation>
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              <Offset>0</Offset>
              <Delay>0.125</Delay>
              <Correction>0.125</Correction>
            </Decimation>
            <StageGain>
              <Value>1.0</Value>
              <Frequency>0.05</Frequency>
            </StageGain>
          </Stage>
          <Stage number="11">
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                <Description>Digital Counts</Description>
              </InputUnits>
              <OutputUnits>
                <Name>COUNTS</Name>
                <Description>Digital Counts</Description>
              </OutputUnits>
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              <Numerator>-3.29668e-05</Numerator>
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              <Numerator>-4.79522e-05</Numerator>
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                    <Numerator>0.000104895</Numerator>
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                    <Numerator>-0.0013037</Numerator>
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```


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            <Numerator>-0.00016084</Numerator>
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            <Numerator>-1.99798e-05</Numerator>
            <Numerator>-1.09889e-05</Numerator>
          </Coefficients>
          <Decimation>
            <InputSampleRate unit="HERTZ">200.0</InputSampleRate>
            <Factor>5</Factor>
            <Offset>0</Offset>
            <Delay>0.585</Delay>
```

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              </Decimation>
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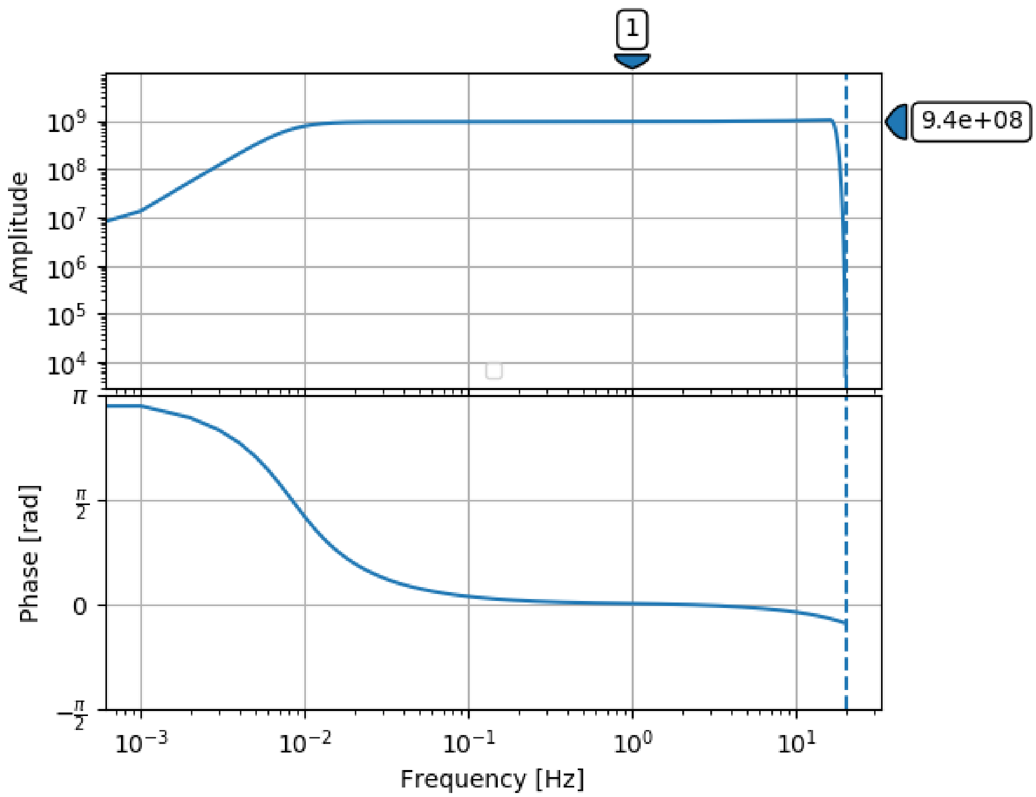
                <Frequency>0.05</Frequency>
              </StageGain>
            </Stage>
          </Response>
        </Channel>
      </Station>
    </Network>
</FDSNStationXML>
```

3.3.2 Broadband sensor

Streckeisen STS-1 sensor (360 s) + Quanterra Qx80 datalogger (80)

StationXML **Show/Hide**


```
<?xml version='1.0' encoding='UTF-8'?>
<FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1
↪">
  <Source>isti</Source>
  <Module>ObsPy 1.2.0rc8.post0+9.gfdab3d4f94.dirty.obspy.master</Module>
  <ModuleURI>https://www.obspy.org</ModuleURI>
  <Created>2020-06-06T01:19:15.736834Z</Created>
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  <Network code="BK">
    <Station code="ANMO">
      <Latitude unit="DEGREES">34.945911</Latitude>
      <Longitude unit="DEGREES">-106.457199</Longitude>
      <Elevation unit="METERS">1820.0</Elevation>
      <Site>
        <Name>Albuquerque, New Mexico, USA</Name>
      </Site>
      <CreationDate>1970-01-01T00:00:00.000000Z</CreationDate>
      <Channel code="BHZ" locationCode="10">
        <Latitude unit="DEGREES">34.945911</Latitude>
        <Longitude unit="DEGREES">-106.457199</Longitude>
        <Elevation unit="METERS">1820.0</Elevation>
        <Depth unit="METERS">0.0</Depth>
        <SampleRate>80.0</SampleRate>
        <Response>
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            <Value>966938797.852</Value>
            <Frequency>0.02</Frequency>
            <InputUnits>
              <Name>M/S</Name>
              <Description>Velocity in Meters per Second</Description>
            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
          </InstrumentSensitivity>
          <Stage number="1">
            <PolesZeros>
              <InputUnits>
                <Name>M/S</Name>
                <Description>Velocity in Meters per Second</Description>
              </InputUnits>
              <OutputUnits>
                <Name>V</Name>
                <Description>Volts</Description>
              </OutputUnits>
              <PzTransferFunctionType>LAPLACE (RADIANS/SECOND)</
↪PzTransferFunctionType>
              <NormalizationFactor>3948.58</NormalizationFactor>
              <NormalizationFrequency unit="HERTZ">0.02</
↪NormalizationFrequency>
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                <Imaginary>0.0</Imaginary>
              </Zero>
              <Zero number="1">
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                <Imaginary>0.0</Imaginary>
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  <Imaginary>49.12</Imaginary>
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</StageGain>
</Stage>
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  <StageGain>
    <Value>1.0</Value>
    <Frequency>0.05</Frequency>
  </StageGain>
</Stage>
<Stage number="3">
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      <Name>V</Name>
      <Description>Volts</Description>
    </InputUnits>
    <OutputUnits>
      <Name>COUNTS</Name>
      <Description>Digital Counts</Description>
    </OutputUnits>
    <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
    <Numerator>1.0</Numerator>
  </Coefficients>
  <Decimation>
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    <Factor>1</Factor>
    <Offset>0</Offset>
    <Delay>0.0</Delay>
    <Correction>0.0</Correction>
  </Decimation>
  <StageGain>
    <Value>400000.0</Value>
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  </StageGain>
</Stage>
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  <Coefficients>
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      <Name>COUNTS</Name>
      <Description>Digital Counts</Description>
    </InputUnits>
    <OutputUnits>
      <Name>COUNTS</Name>
      <Description>Digital Counts</Description>
    </OutputUnits>
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            <Correction>0.006</Correction>
          </Decimation>
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            <Frequency>0.05</Frequency>
          </StageGain>
        </Stage>
        <Stage number="5">
          <Coefficients>
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              <Description>Digital Counts</Description>
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            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
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<Numerator>0.000442949</Numerator>
<Numerator>0.000305924</Numerator>
<Numerator>0.000150487</Numerator>
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<Delay>0.1109375</Delay>
<Correction>0.083</Correction>
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            </Stage>
          </Response>
        </Channel>
      </Station>
    </Network>
</FDSNStationXML>
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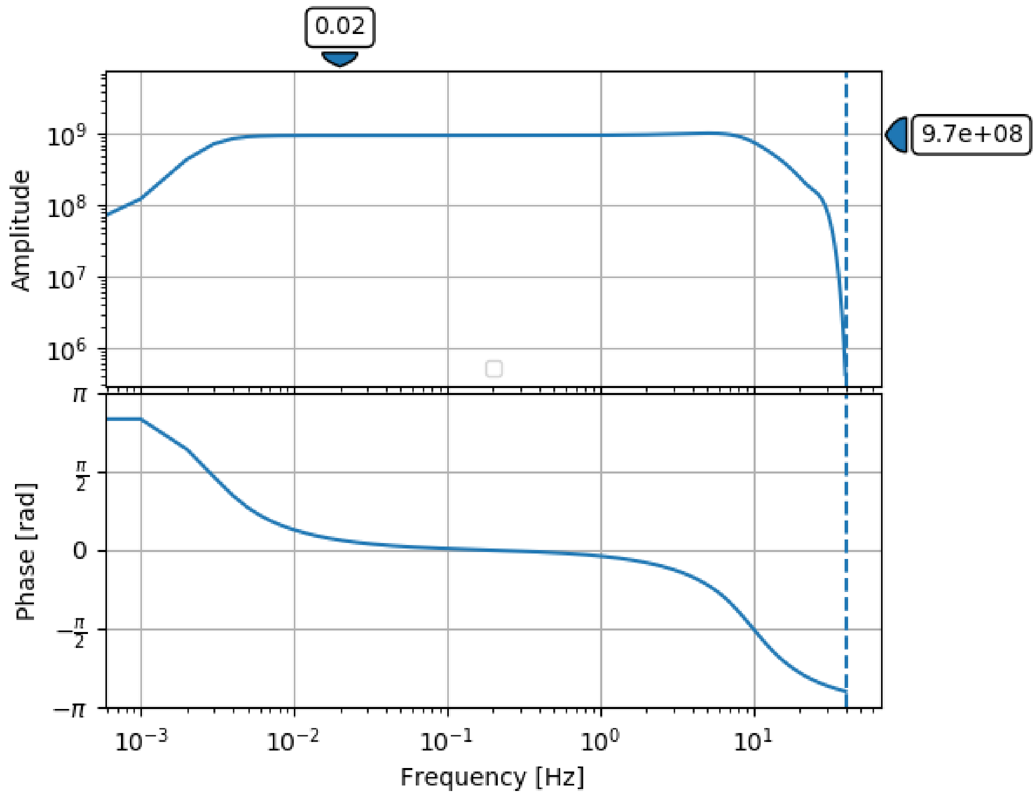

3.3.3 Short-period sensor

Geotech GS-13 short-period sensor + Quanterra Quanterra Qx80 datalogger

StationXML **Show/Hide**

```
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<FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1
↪">
  <Network code=..>
    <Station code=..>
      <Channel code=.. locationCode=..>
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        <Response>
          <InstrumentSensitivity>
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            <Frequency>5.0</Frequency>
```

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            </InputUnits>
            <OutputUnits>
              <Name>COUNTS</Name>
              <Description>Digital Counts</Description>
            </OutputUnits>
          </InstrumentSensitivity>
          <Stage number="1">
            <PolesZeros>
              <InputUnits>
                <Name>M/S</Name>
                <Description>Velocity in Meters per Second</Description>
              </InputUnits>
              <OutputUnits>
                <Name>V</Name>
                <Description>Volts</Description>
              </OutputUnits>
              <PzTransferFunctionType>LAPLACE (RADIANS/SECOND)</
↪PzTransferFunctionType>
              <NormalizationFactor>1.0</NormalizationFactor>
              <NormalizationFrequency unit="HERTZ">5.0</
↪NormalizationFrequency>
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              <Zero number="1">
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              </Zero>
              <Pole number="0">
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              </Pole>
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              </Pole>
            </PolesZeros>
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            </StageGain>
          </Stage>
          <Stage number="2">
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              <Frequency>0.05</Frequency>
            </StageGain>
          </Stage>
          <Stage number="3">
            <Coefficients>
              <InputUnits>
                <Name>V</Name>
                <Description>Volts</Description>
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```
              </InputUnits>
              <OutputUnits>
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                <Description>Digital Counts</Description>
              </OutputUnits>
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            </StageGain>
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          <Stage number="4">
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              <OutputUnits>
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      <Stage number="5">
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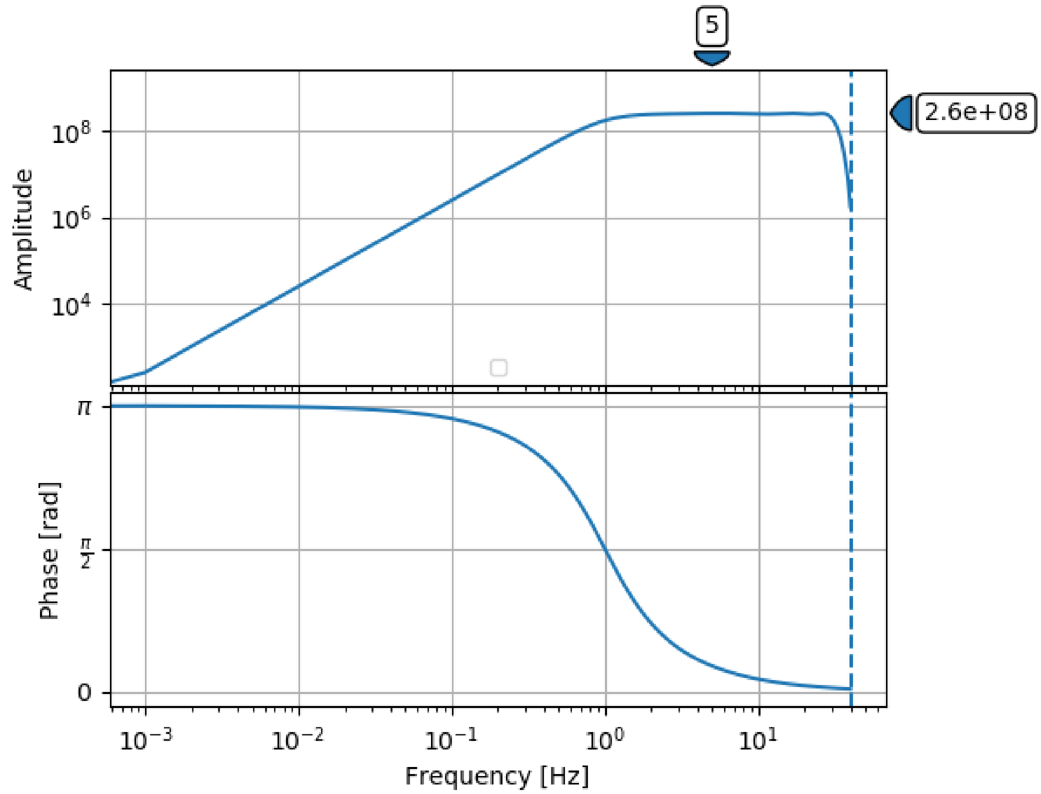

3.3.4 Short-period sensor

Sercel L-22D short-period sensor (Rc=5470 Ohms, Rs=20000 Ohms) + Reftek RT72A-08 24-bit datalogger, 1 stream, 100 Hz, gain 32

StationXML **Show/Hide**

```
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      <Channel code=.. locationCode=..>
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            <OutputUnits>
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              <Description>Digital Counts</Description>
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                <Description>Velocity in Meters per Second</Description>
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                <Imaginary>0.0</Imaginary>
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                <Imaginary>0.0</Imaginary>
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                <Numerator>-0.000186167</Numerator>
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              <StageGain>
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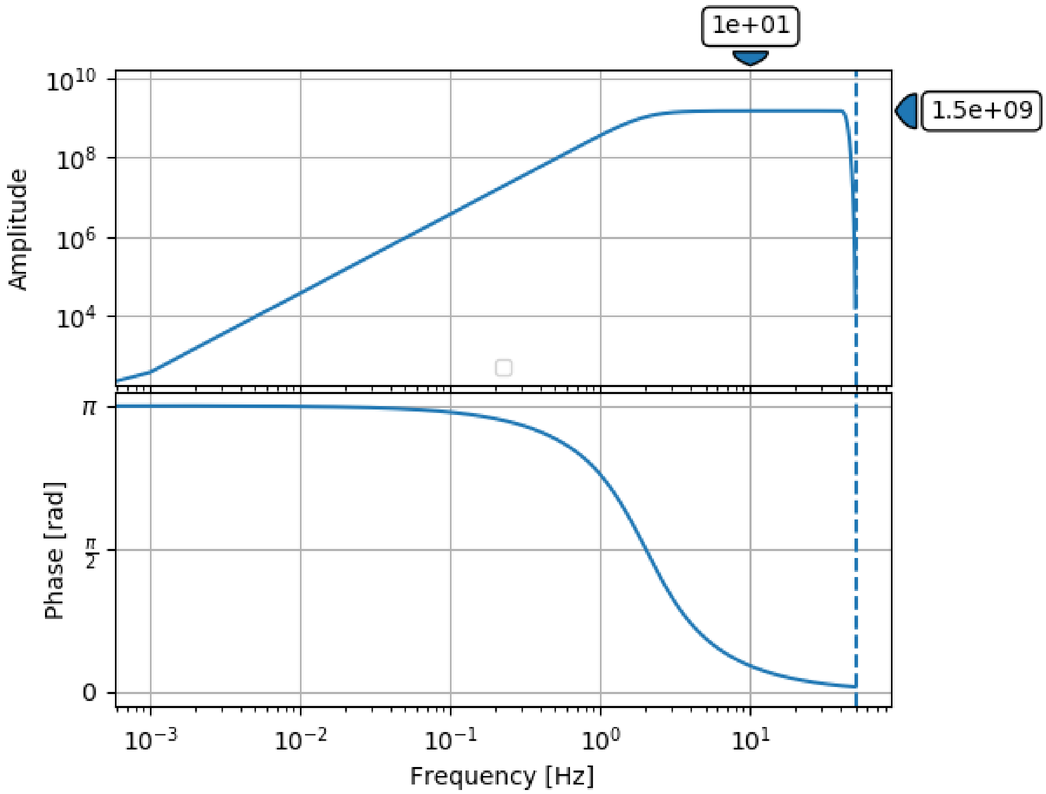

3.3.5 Accelerometer

Kinemetrics FBA-3 + Kinemetrics Etna

StationXML **Show/Hide**

```
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    <Station code=..>
      <Channel code=.. locationCode=..>
        ...
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              <Description>Acceleration in Meters Per Second Per Second</Description>
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```

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↪Description>
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      </Channel>
    </Station>
  </Network>
</FDSNStationXML>
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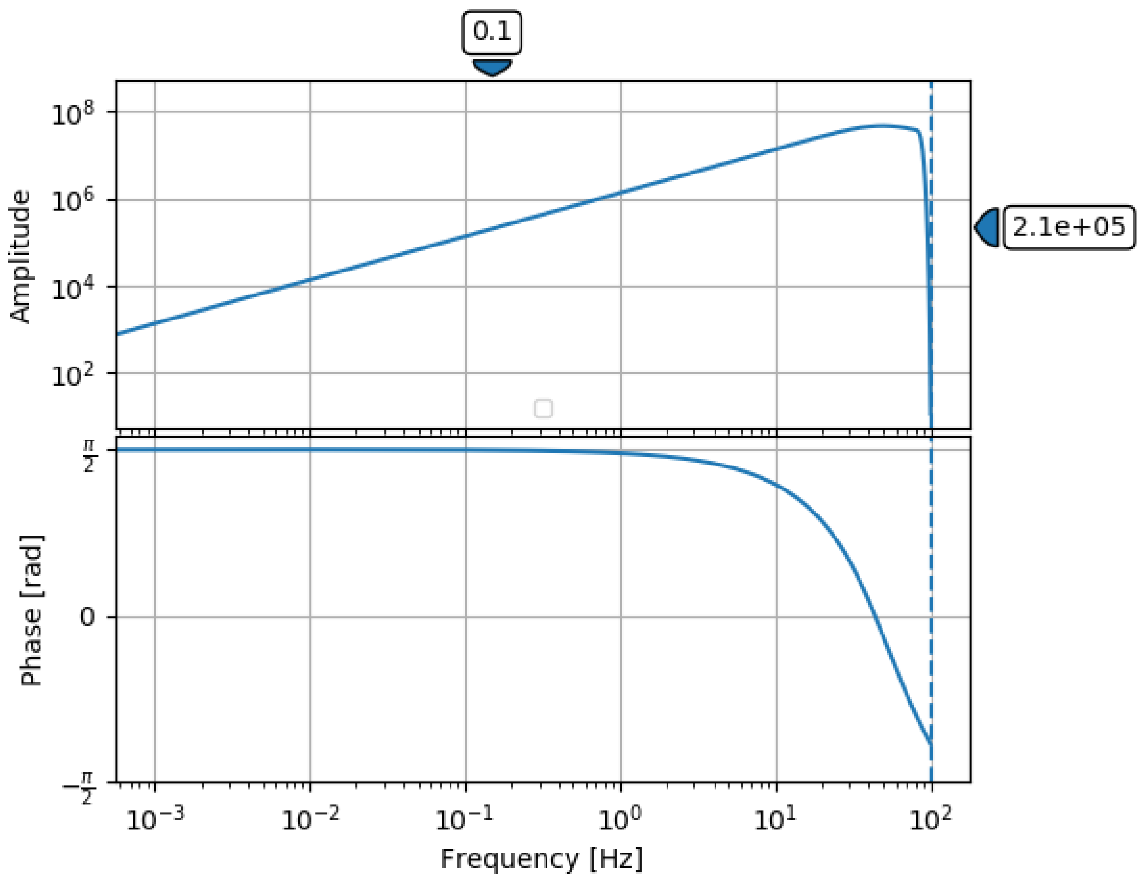

3.3.6 Setra 270

Setra 270 Pressure Transducer

This example was lifted from [62] Response [Polynomial] Blockette section (p.85) of the SEED manual (v.2.4).

The Setra Model 270 Pressure Transducer response is given as a polynomial response with 2 coefficients, valid for input pressure between 600-1100 mbar.

$$Pressure(V) = \sum_{n=0}^{1} a_n V^n$$

where $a_0 = 600$ and $a_1 = 100$

Volts	mbar
0.0	600
1.0	700
2.0	800
3.0	900
4.0	1000
5.0	1100

e.g., over this voltage range (0-5V), the input (mbar of pressure) is a linear function of the output (Volts).

The Response element for the Setra sensor alone consists of a Polynomial stage and an InsrumentPolynomial Stage

Warning

This part is not finished!

StationXML **Show/Hide**

```
<?xml version='1.0' encoding='UTF-8'?>
   <FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.1">
      <Network code=..>
      <Station code=..>
         <Channel code=.. locationCode=..>
            ...
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            <InputUnits>
            <Name>degC</Name>
            <Description>TEMPERATURE in Celsius</Description>
            </InputUnits>
            <OutputUnits>
            <Name>COUNTS</Name>
            <Description>Digital Counts</Description>
            </OutputUnits>
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            <ApproximationLowerBound>-5.02</ApproximationLowerBound>
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```

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               <Description>TEMPERATURE in Celsius</Description>
            </InputUnits>
            <OutputUnits>
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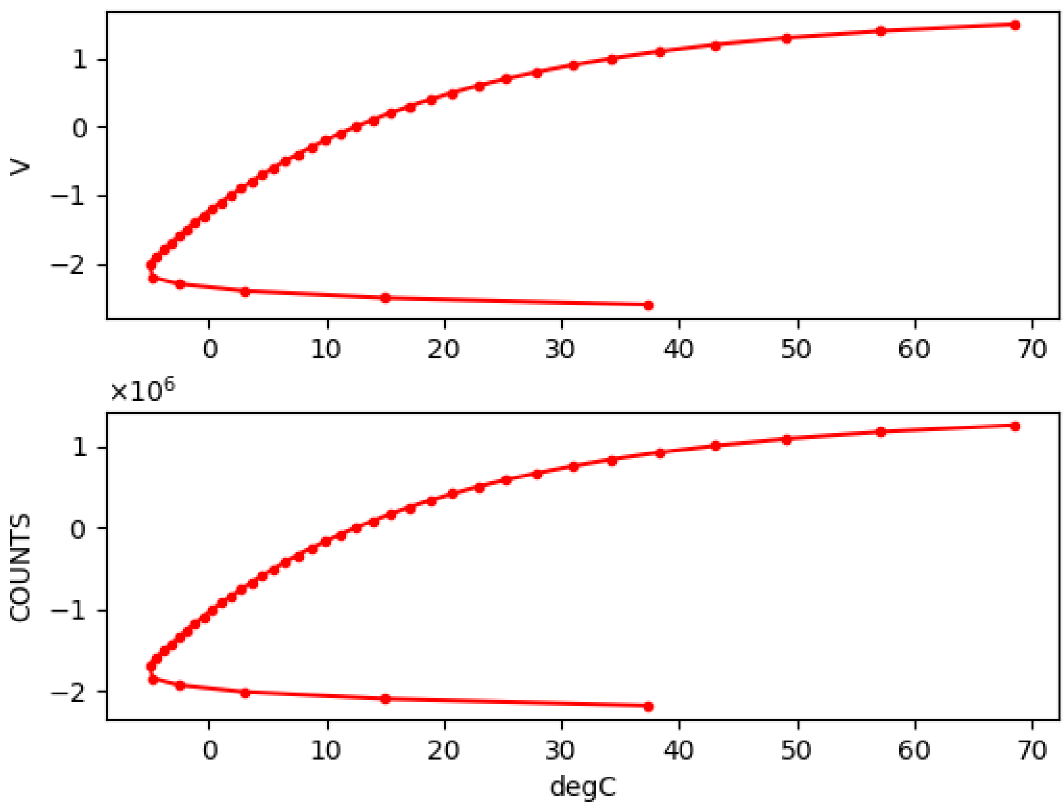

3.3.7 YSI 44031 thermistor

The Berkeley Digital Seismic Network (BDSN) seismometers, use a Yellow Springs Instrument Co. (YSI) 44031 thermistor to monitor the temperature of the seismometer. The thermistor response has been determined by measuring its voltage output as a function of input temperature. It has been calibrated within a range of temperatures from -5C to 68.59C.

The resistance of the thermistor is a non-linear function of the temperature and its response can be described by a polynomial.

In order to model the response within 0.2 degrees C accuracy, a MacLaurin polynomial with 11 coefficients:

$$Temp(V) = \sum_{n=0}^{10} a_n V^n$$

The coefficients are given in Table 1.

a_n	value
a_0	0.12505E+02
a_1	0.13824E+02
a_2	0.41039E+01
a_3	0.12932E+01
a_4	0.18741E+01
a_5	0.17250E+01
a_6	-0.61021E+00
a_7	-0.10540E+01
a_8	0.13974E+00
a_9	0.39061E+00
a_{10}	0.95345E-01

Because this is a *polynomial* response, the corresponding StationXML looks a little different than the usual responses (e.g., for seismometers). Instead of a InstrumentSensitivity element, there is an InstrumentPolynomial element. In addition the analog stage is represented by a Polynomial stage. The Polynomial stage and the InstrumentPolynomial stage both contain all of the MacLaurin coefficients, however, in the InstrumentPolynomial stage, those coefficients have been scaled by the datalogger sensitivity to give units of Counts instead of Volts.

How the InstrumentSensitivity was calculated

Something here about how to find the scalefactor and then scale the coefficients

A complete StationXML Response element is shown below for the YSI-44301 thermistor attached to a Reftek RT130 datalogger sampling at 40Hz.

StationXML **Show/Hide**

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        ...
        <SampleRate>40.0</SampleRate>

    <Response>
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```xml
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              <Numerator>-4.79522e-05</Numerator>
              <Numerator>-4.39561e-05</Numerator>
              <Numerator>-3.29668e-05</Numerator>
              <Numerator>-1.99798e-05</Numerator>
              <Numerator>-1.09889e-05</Numerator>
              </Coefficients>
              <Decimation>
              <InputSampleRate unit="HERTZ">200.0</InputSampleRate>
              <Factor>5</Factor>
              <Offset>0</Offset>
              <Delay>0.0</Delay>
              <Correction>0.0</Correction>
              </Decimation>
              <StageGain>
              <Value>1.0</Value>
              <Frequency>0.0</Frequency>
              </StageGain>
           </Stage>
        </Response>
      </Channel>
    </Station>
  </Network>
</FDSNStationXML>
```
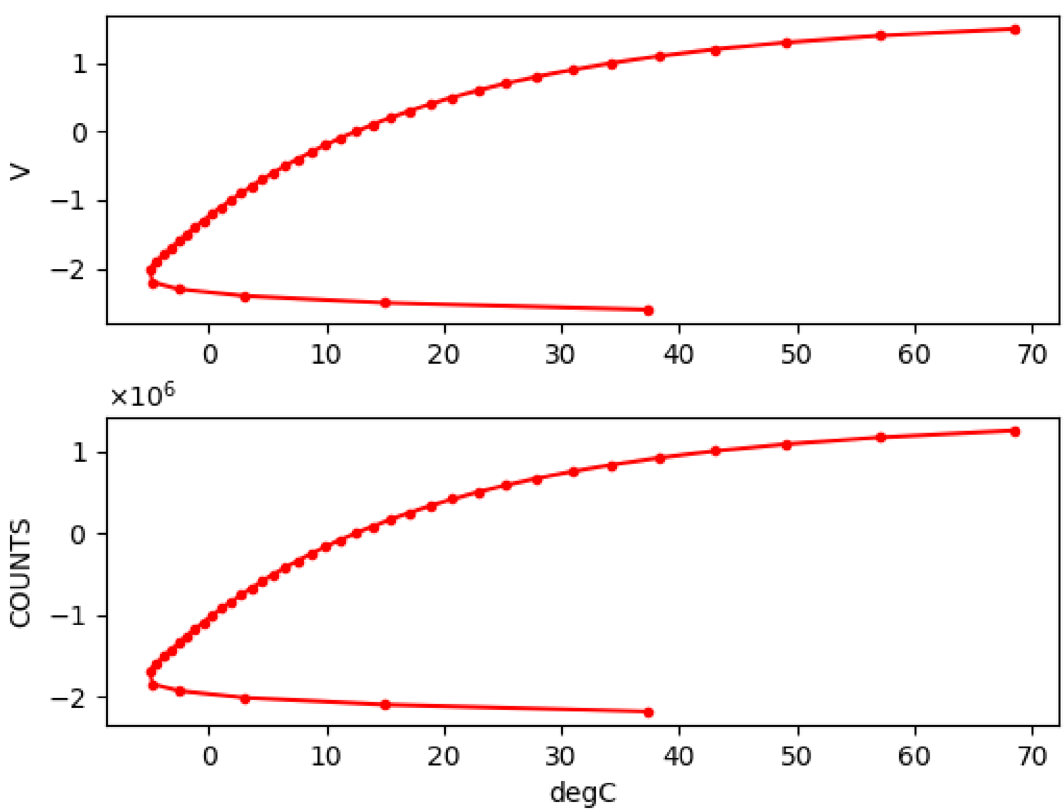


V
COUNTS
×10^6
degC

CHAPTER FOUR

STATIONXML TOOLS

As stationxml files are ordinary ascii files, they may be editted with any text editor (e.g., vi/VIM, TextWrangler, Notepad/Wordpad, etc)

However, stationxml files can become very large and unwieldly as more stations and channels are added. For instance a regional seismic network can generate a stationxml file of size > 30Mb on disk (>400,000 lines).

Fortunately, several tools exist that allow creation and editting of stationxml files.

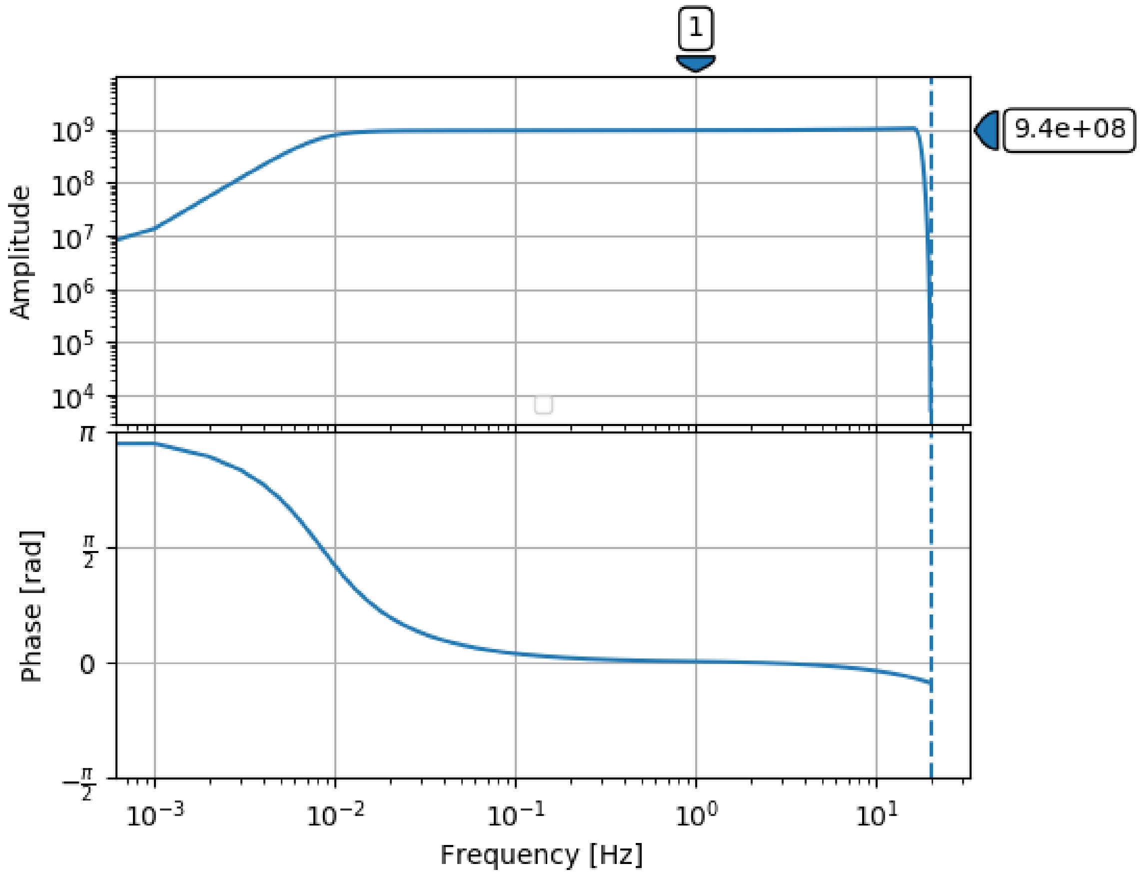
4.1 obspy + NRL

ObsPy contains a number of very useful modules for working with stationxml. In particular, ObsPy contain a module able to connect to the IRIS Nominal Resource Library (NRL) and download full responses (sensor + datalogger) for various combinations of sensor + datalogger contained within the NRL.

The excerpts below provide examples of how to work with ObsPy and the NRL.

```
from obspy.clients.nrl import NRL

from lib.valid import stationxml_validator

def main():

   nrl = NRL('http://ds.iris.edu/NRL/')
   datalogger_keys = ['REF TEK', 'RT 130 & 130-SMA', '1', '40']
   sensor_keys = ['Streckeisen', 'STS-2', '1500', '3 - installed 04/97 to␣
↪present']

   response = nrl.get_response(sensor_keys=sensor_keys, datalogger_
↪keys=datalogger_keys)

   response.plot(min_freq=.001)

   for stage in response.response_stages:
      print(stage)
```

The resulting response plot looks like



Output for the response stages **Show/Hide Stages**

```
<?xml version='1.0' encoding='UTF-8'?>

Response type: PolesZerosResponseStage, Stage Sequence Number: 1
	From M/S (Velocity in Meters per Second) to V (Volts)
	Stage gain: 1500.0, defined at 1.00 Hz
	Transfer function type: LAPLACE (RADIANS/SECOND)
	Normalization factor: 3.4684e+17, Normalization frequency: 1.00 Hz
	Poles: (-0.037-0.037j), (-0.037+0.037j), (-15.64+0j), (-97.34-400.7j), (-97.
↪34+400.7j), (-374.8+0j), (-520.3+0j), (-10530-10050j), (-10530+10050j), (-13300+0j),
↪ (-255.097+0j)
	Zeros: 0j, 0j, (-15.15+0j), (-176.6+0j), (-463.1-430.5j), (-463.1+430.5j)
Response type: ResponseStage, Stage Sequence Number: 2
	From V to V
	Stage gain: 1.0, defined at 0.05 Hz
Response type: CoefficientsTypeResponseStage, Stage Sequence Number: 3
	From V (Volts) to COUNTS (Digital Counts)
	Stage gain: 629129.0, defined at 0.05 Hz
	Decimation:
		Input Sample Rate: 102400.00 Hz
		Decimation Factor: 1
		Decimation Offset: 0
		Decimation Delay: 0.00
		Decimation Correction: 0.00
	Transfer function type: DIGITAL
```

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```
      Contains 1 numerators and 0 denominators
Response type: CoefficientsTypeResponseStage, Stage Sequence Number: 4
      From COUNTS (Digital Counts) to COUNTS (Digital Counts)
      Stage gain: 1.0, defined at 0.05 Hz
      Decimation:
              Input Sample Rate: 102400.00 Hz
              Decimation Factor: 8
              Decimation Offset: 0
              Decimation Delay: 0.00
              Decimation Correction: 0.00
      Transfer function type: DIGITAL
      Contains 29 numerators and 0 denominators
Response type: CoefficientsTypeResponseStage, Stage Sequence Number: 5
      From COUNTS (Digital Counts) to COUNTS (Digital Counts)
      Stage gain: 1.0, defined at 0.05 Hz
      Decimation:
              Input Sample Rate: 12800.00 Hz
              Decimation Factor: 2
              Decimation Offset: 0
              Decimation Delay: 0.00
              Decimation Correction: 0.00
      Transfer function type: DIGITAL
      Contains 13 numerators and 0 denominators
Response type: CoefficientsTypeResponseStage, Stage Sequence Number: 6
      From COUNTS (Digital Counts) to COUNTS (Digital Counts)
      Stage gain: 1.0, defined at 0.05 Hz
      Decimation:
              Input Sample Rate: 6400.00 Hz
              Decimation Factor: 2
              Decimation Offset: 0
              Decimation Delay: 0.00
              Decimation Correction: 0.00
      Transfer function type: DIGITAL
      Contains 13 numerators and 0 denominators
Response type: CoefficientsTypeResponseStage, Stage Sequence Number: 7
      From COUNTS (Digital Counts) to COUNTS (Digital Counts)
      Stage gain: 1.0, defined at 0.05 Hz
      Decimation:
              Input Sample Rate: 3200.00 Hz
              Decimation Factor: 2
              Decimation Offset: 0
              Decimation Delay: 0.00
              Decimation Correction: 0.00
      Transfer function type: DIGITAL
      Contains 13 numerators and 0 denominators
Response type: CoefficientsTypeResponseStage, Stage Sequence Number: 8
      From COUNTS (Digital Counts) to COUNTS (Digital Counts)
      Stage gain: 1.0, defined at 0.05 Hz
      Decimation:
              Input Sample Rate: 1600.00 Hz
              Decimation Factor: 2
              Decimation Offset: 0
              Decimation Delay: 0.00
              Decimation Correction: 0.00
      Transfer function type: DIGITAL
      Contains 13 numerators and 0 denominators
Response type: CoefficientsTypeResponseStage, Stage Sequence Number: 9
```

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```
      From COUNTS (Digital Counts) to COUNTS (Digital Counts)
      Stage gain: 1.0, defined at 0.05 Hz
      Decimation:
               Input Sample Rate: 800.00 Hz
               Decimation Factor: 2
               Decimation Offset: 0
               Decimation Delay: 0.01
               Decimation Correction: 0.01
      Transfer function type: DIGITAL
      Contains 13 numerators and 0 denominators
Response type: CoefficientsTypeResponseStage, Stage Sequence Number: 10
      From COUNTS (Digital Counts) to COUNTS (Digital Counts)
      Stage gain: 1.0, defined at 0.05 Hz
      Decimation:
               Input Sample Rate: 400.00 Hz
               Decimation Factor: 2
               Decimation Offset: 0
               Decimation Delay: 0.12
               Decimation Correction: 0.12
      Transfer function type: DIGITAL
      Contains 101 numerators and 0 denominators
Response type: CoefficientsTypeResponseStage, Stage Sequence Number: 11
      From COUNTS (Digital Counts) to COUNTS (Digital Counts)
      Stage gain: 1.0, defined at 0.05 Hz
      Decimation:
               Input Sample Rate: 200.00 Hz
               Decimation Factor: 5
               Decimation Offset: 0
               Decimation Delay: 0.58
               Decimation Correction: 0.58
      Transfer function type: DIGITAL
      Contains 235 numerators and 0 denominators
```

Up until now we've been examining the response in ObsPy format, that is, as an instance of type obspy.core.inventory.response.Response.

We can also examine this as part of a stationxml file, however, stationxml does not allow children to exist without parents. Thus, a response must be contained within a <Channel> element, which itself must be contained within a <Station> element, which must be contained within a <Network> element, etc.

The excerpt below creates a generic structure to contain our Response object, exports this to stationxml, and validates it against the stationxml schema.

```
from obspy.clients.nrl import NRL

   ...

   inventory = Inventory(networks=[], source="demo")
   network = Network(code='US')
   station = Station(code='ANMO',
                     latitude=34.945911,
                     longitude=-106.457199,
                     elevation=1820.0,
                     creation_date=UTCDateTime(1970, 1, 1),           #␣
↪required
                     site=Site(name='Albuquerque, New Mexico, USA')   #␣
↪required
```

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```
                        )

    channel = Channel(code='BHZ',
                        location_code='10',       # required
                        latitude=34.945911,       # required
                        longitude=-106.457199,    # required
                        elevation=1820.0,         # required
                        depth=0.,                 # required
                        )

    channel.response = response

    inventory.write("Test.xml", format="stationxml", validate=False)
```

The output stationxml file looks like:


```
<?xml version='1.0' encoding='UTF-8'?>

Response type: PolesZerosResponseStage, Stage Sequence Number: 1


<?xml version='1.0' encoding='UTF-8'?>
<FDSNStationXML xmlns="http://www.fdsn.org/xml/station/1" schemaVersion="1.0">
<Source>demo</Source>
<Module>ObsPy 1.1.0</Module>
<ModuleURI>https://www.obspy.org</ModuleURI>
<Created>2020-02-07T22:26:54.123236</Created>
<Network code="US">
   <Station code="ANMO">
      <Latitude unit="DEGREES">34.945911</Latitude>
      <Longitude unit="DEGREES">-106.457199</Longitude>
      <Elevation unit="METERS">1820.0</Elevation>
      <Site>
      <Name>Albuquerque, New Mexico, USA</Name>
      </Site>
      <CreationDate>1970-01-01T00:00:00</CreationDate>
      <Channel code="BHZ" locationCode="10">
      <Latitude unit="DEGREES">34.945911</Latitude>
      <Longitude unit="DEGREES">-106.457199</Longitude>
      <Elevation unit="METERS">1820.0</Elevation>
      <Depth unit="METERS">0.0</Depth>
      <Response>
         <InstrumentSensitivity>
            <Value>941864732.6931986</Value>
            <Frequency>1.0</Frequency>
            <InputUnits>
            <Name>M/S</Name>
            <Description>Velocity in Meters per Second</Description>
            </InputUnits>
            <OutputUnits>
            <Name>COUNTS</Name>
            <Description>Digital Counts</Description>
            </OutputUnits>
         </InstrumentSensitivity>
         <Stage number="1">
            <PolesZeros>
            <InputUnits>
```


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```
            <Name>M/S</Name>
            <Description>Velocity in Meters per Second</Description>
         </InputUnits>
         <OutputUnits>
            <Name>V</Name>
            <Description>Volts</Description>
         </OutputUnits>
         <PzTransferFunctionType>LAPLACE (RADIANS/SECOND)</PzTransferFunctionType>
         <NormalizationFactor>3.4684e+17</NormalizationFactor>
         <NormalizationFrequency unit="HERTZ">1.0</NormalizationFrequency>
         <Zero number="0">
            <Real minusError="0.0" plusError="0.0">0.0</Real>
            <Imaginary minusError="0.0" plusError="0.0">0.0</Imaginary>
         </Zero>
         <Zero number="1">
            <Real minusError="0.0" plusError="0.0">0.0</Real>
            <Imaginary minusError="0.0" plusError="0.0">0.0</Imaginary>
         </Zero>
         <Zero number="2">
            <Real minusError="-15.15" plusError="-15.15">-15.15</Real>
            <Imaginary minusError="0.0" plusError="0.0">0.0</Imaginary>
         </Zero>
         <Zero number="3">
            <Real minusError="-176.6" plusError="-176.6">-176.6</Real>
            <Imaginary minusError="0.0" plusError="0.0">0.0</Imaginary>
         </Zero>
         <Zero number="4">
            <Real minusError="-463.1" plusError="-463.1">-463.1</Real>
            <Imaginary minusError="-430.5" plusError="-430.5">-430.5</Imaginary>
         </Zero>
         <Zero number="5">
            <Real minusError="-463.1" plusError="-463.1">-463.1</Real>
            <Imaginary minusError="430.5" plusError="430.5">430.5</Imaginary>
         </Zero>
         <Pole number="0">
            <Real minusError="-0.037" plusError="-0.037">-0.037</Real>
            <Imaginary minusError="-0.037" plusError="-0.037">-0.037</Imaginary>
         </Pole>
         <Pole number="1">
            <Real minusError="-0.037" plusError="-0.037">-0.037</Real>
            <Imaginary minusError="0.037" plusError="0.037">0.037</Imaginary>
         </Pole>
         <Pole number="2">
            <Real minusError="-15.64" plusError="-15.64">-15.64</Real>
            <Imaginary minusError="0.0" plusError="0.0">0.0</Imaginary>
         </Pole>
         <Pole number="3">
            <Real minusError="-97.34" plusError="-97.34">-97.34</Real>
            <Imaginary minusError="-400.7" plusError="-400.7">-400.7</Imaginary>
         </Pole>
         <Pole number="4">
            <Real minusError="-97.34" plusError="-97.34">-97.34</Real>
            <Imaginary minusError="400.7" plusError="400.7">400.7</Imaginary>
         </Pole>
         <Pole number="5">
            <Real minusError="-374.8" plusError="-374.8">-374.8</Real>
            <Imaginary minusError="0.0" plusError="0.0">0.0</Imaginary>
```

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```
            </Pole>
            <Pole number="6">
               <Real minusError="-520.3" plusError="-520.3">-520.3</Real>
               <Imaginary minusError="0.0" plusError="0.0">0.0</Imaginary>
            </Pole>
            <Pole number="7">
               <Real minusError="-10530.0" plusError="-10530.0">-10530.0</Real>
               <Imaginary minusError="-10050.0" plusError="-10050.0">-10050.0</
↪Imaginary>
            </Pole>
            <Pole number="8">
               <Real minusError="-10530.0" plusError="-10530.0">-10530.0</Real>
               <Imaginary minusError="10050.0" plusError="10050.0">10050.0</Imaginary>
            </Pole>
            <Pole number="9">
               <Real minusError="-13300.0" plusError="-13300.0">-13300.0</Real>
               <Imaginary minusError="0.0" plusError="0.0">0.0</Imaginary>
            </Pole>
            <Pole number="10">
               <Real minusError="-255.097" plusError="-255.097">-255.097</Real>
               <Imaginary minusError="0.0" plusError="0.0">0.0</Imaginary>
            </Pole>
            </PolesZeros>
            <StageGain>
            <Value>1500.0</Value>
            <Frequency>1.0</Frequency>
            </StageGain>
         </Stage>
         <Stage number="2">
            <StageGain>
            <Value>1.0</Value>
            <Frequency>0.05</Frequency>
            </StageGain>
         </Stage>
         <Stage number="3">
            <Coefficients>
            <InputUnits>
               <Name>V</Name>
               <Description>Volts</Description>
            </InputUnits>
            <OutputUnits>
               <Name>COUNTS</Name>
               <Description>Digital Counts</Description>
            </OutputUnits>
            <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
            <Numerator>1.0</Numerator>
            </Coefficients>
            <Decimation>
            <InputSampleRate unit="HERTZ">102400.0</InputSampleRate>
            <Factor>1</Factor>
            <Offset>0</Offset>
            <Delay>0.0</Delay>
            <Correction>0.0</Correction>
            </Decimation>
            <StageGain>
            <Value>629129.0</Value>
            <Frequency>0.05</Frequency>
```


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```
            </StageGain>
         </Stage>
         <Stage number="4">
            <Coefficients>
            <InputUnits>
               <Name>COUNTS</Name>
               <Description>Digital Counts</Description>
            </InputUnits>
            <OutputUnits>
               <Name>COUNTS</Name>
               <Description>Digital Counts</Description>
            </OutputUnits>
            <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
            <Numerator>0.000244141</Numerator>
            <Numerator>0.000976562</Numerator>
            <Numerator>0.00244141</Numerator>
            <Numerator>0.00488281</Numerator>
            <Numerator>0.00854492</Numerator>
            <Numerator>0.0136719</Numerator>
            <Numerator>0.0205078</Numerator>
            <Numerator>0.0292969</Numerator>
            <Numerator>0.0393066</Numerator>
            <Numerator>0.0498047</Numerator>
            <Numerator>0.0600586</Numerator>
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            <Numerator>0.0205078</Numerator>
            <Numerator>0.0136719</Numerator>
            <Numerator>0.00854492</Numerator>
            <Numerator>0.00488281</Numerator>
            <Numerator>0.00244141</Numerator>
            <Numerator>0.000976562</Numerator>
            <Numerator>0.000244141</Numerator>
            </Coefficients>
            <Decimation>
            <InputSampleRate unit="HERTZ">102400.0</InputSampleRate>
            <Factor>8</Factor>
            <Offset>0</Offset>
            <Delay>0.00013672</Delay>
            <Correction>0.00013672</Correction>
            </Decimation>
            <StageGain>
            <Value>1.0</Value>
            <Frequency>0.05</Frequency>
            </StageGain>
         </Stage>
         <Stage number="5">
            <Coefficients>
```

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```
            <InputUnits>
               <Name>COUNTS</Name>
               <Description>Digital Counts</Description>
            </InputUnits>
            <OutputUnits>
               <Name>COUNTS</Name>
               <Description>Digital Counts</Description>
            </OutputUnits>
            <CfTransferFunctionType>DIGITAL</CfTransferFunctionType>
            <Numerator>0.000244141</Numerator>
            <Numerator>0.00292969</Numerator>
            <Numerator>0.0161133</Numerator>
            <Numerator>0.0537109</Numerator>
            <Numerator>0.12085</Numerator>
            <Numerator>0.193359</Numerator>
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            <Correction>0.585</Correction>
            </Decimation>
            <StageGain>
            <Value>1.0</Value>
            <Frequency>0.05</Frequency>
            </StageGain>
         </Stage>
      </Response>
      </Channel>
   </Station>
```

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```
</Network>
</FDSNStationXML>
```

4.2 IRIS SEED-stationXML Converter

IRIS maintains a java tool that can convert between dataless SEED and stationxml formats at:

https://github.com/iris-edu/stationxml-seed-converter

CHAPTER

FIVE

APPENDICES

5.1 Mapping SEED blockettes to StationXML

5.1.1 B34 Units Abbreviations

Field	Field Name	StationXML Element	Attribute	Dictionary Field(s)
B034F03	Unit Lookup Code	Multiple Mappings		
B034F04	Unit Name	Multiple Mappings		• B053F05, B053F06 • B055F04, B055F05 • B061F06, B055F07 • B062F05, B062F06
B034F05	Unit Description	Multiple Mappings		

5.1.2 B50 Station Identifier

Field	Field Name	StationXML Element	Attribute	Dictionary Field(s)
B050F03	Station Call Letters	Station	• code	
B050F04	Station Latitude	Station/Latitude		
B050F05	Station Longitude	Station/Longitude		
B050F06	Station Elevation	Station/Elevation		
B050F07	Number Of Channels	Station/TotalNumberChannels		
B050F08	Number Of Station Comments	Station/Comments		
B050F09	Site Name	Station/Site/Name		
B050F10	Network Identifier Code	No Mapping		
B050F11	32-bit Word Order	No Mapping		
B050F12	16-bit Word Order	No Mapping		
B050F13	Start Effective Date	Station	• startDate	
B050F14	End Effective Date	Station	• endDate	
B050F15	Update Flag	No Mapping		
B050F16	Network Code	Network	• code	

5.1.3 B52 Channel Identifier

Field	Field Name	StationXML Element	Attribute	Dictionary Field(s)
B052F03	Location Identifier	Channel	• locationCode	
B052F04	Channel Identifier	Channel	• code	
B052F05	Subchannel Identifier	No Mapping		
B052F06	Instrument Identifier	No Mapping		
B052F07	Optional Comment	Channel		
B052F08	Units Of Signal Response	No Mapping		
B052F09	Units Of Calibration Input	Channel/CalibrationUnits/Name		
B052F10	Latitude	Channel/Latitude		
B052F11	Longitude	Channel/Longitude		
B052F12	Elevation	Channel/Elevation		
B052F13	Local Depth	Channel/Depth		
B052F14	Azimuth	Channel/Azimuth		
B052F15	Dip	Channel/Dip		
B052F16	Data Format Identifier Code	No Mapping		
B052F17	Data Record Length	No Mapping		
B052F18	Sample Rate	Channel/SampleRate		
B052F19	Max Clock Drift	Channel/ClockDrift		
B052F20	Number Of Comments	No Mapping		
B052F21	Channel Flags	No Mapping		
B052F22	Start Date	Channel	• startDate	
B052F23	End Date	Channel	• endDate	
B052F24	Update Flags	No Mapping		

5.1.4 B53 Response Poles & Zeros

Field	Field Name	StationXML Element	Attribute	Dictionary Field(s)
B053F03	Transfer Function Type	Response/Stage/PolesZeros/PzTransferFunctionType		
B053F04	Stage Sequence Number	Response/Stage/PolesZeros	• number	
B053F05	Stage Signal Input Units	Response/Stage/PolesZeros/InputUnits/Name		B034F04, B043F06
B053F06	Stage Signal Output Units	Response/Stage/PolesZeros/OutputUnits/Name		B034F04, B043F07
B053F07	A0 Normalization Factor	Response/Stage/PolesZeros/NormalizationFactor		
B053F08	Normalization Frequency	Response/Stage/PolesZeros/NormalizationFrequency		
B053F09	Number Of Complex Zeros	No Mapping		
B053F10	Real Zero	Response/Stage/PolesZeros/Zero/Real		
B053F11	Imaginary Zero	Response/Stage/PolesZeros/Zero/Imaginary		
B053F12	Real Zero Error	Response/Stage/PolesZeros/Zero/Real	• minusError • plusError	
B053F13	Imaginary Zero Error	Response/Stage/PolesZeros/Zero/Imaginary	• minusError • plusError	
B053F14	Number Of Complex Poles	No Mapping		
B053F15	Real Pole	Response/Stage/PolesZeros/Pole/Real		
B053F16	Imaginary Pole	Response/Stage/PolesZeros/Pole/Imaginary		
B053F17	Real Pole Error	Response/Stage/PolesZeros/Pole/Real	• minusError • plusError	
B053F18	Imaginary Pole Error	Response/Stage/PolesZeros/Pole/Imaginary	• minusError • plusError	

5.1.5 B55 Response List

Field	Field Name	StationXML Element	Attribute	Dictionary Field(s)
B055F03	Stage Sequence Number	Response/Stage/ResponseList	• name	
B055F04	Signal Input Units	Response/Stage/ResponseList/InputUnits/Name		B034F04, B045F05
B055F05	Signal Output Units	Response/Stage/ResponseList/OutputUnits/Name		B034F04, B045F06
B055F06	Number Of Responses Listed	No Mapping		
B055F07	Frequency	Response/Stage/ResponseList/ResponseListElement/Frequency		
B055F08	Amplitude	Response/Stage/ResponseList/ResponseListElement/Amplitude		
B055F09	Amplitude Error	Response/Stage/ResponseList/ResponseListElement/Amplitude	• minusError • plusError	
B055F10	Phase Angle	Response/Stage/ResponseList/ResponseListElement/Phase		
B055F11	Phase Angle Error	Response/Stage/ResponseList/ResponseListElement/Phase	• minusError • plusError	

5.1.6 B57 Decimation

Field	Field Name	StationXML Element	Attribute	Dictionary Field(s)
B057F03	Stage Sequence Number	Response/Stage/Decimation	• number	
B057F04	Input Sample Rate	Response/Stage/Decimation/InputSampleRate		
B057F05	Decimation Factor	Response/Stage/Decimation/Factor		
B057F06	Decimation Offset	Response/Stage/Decimation/Offset		
B057F07	Estimated Delay	Response/Stage/Decimation/Delay		
B057F08	Correction Applied	Response/Stage/Decimation/Correction		

5.1.7 B58 Channel Sensitivity/Gain

Field	Field Name	StationXML Element	Attribute	Dictionary Field(s)
B058F03	Stage Sequence Number	No Mapping		
B058F04	Sensitivity/Gain	Response/InstrumentSensitivity/Value		
B058F05	Frequency	Response/InstrumentSensitivity/Frequency		
B058F06	Number Of History Values	No Mapping		
B058F07	Sensitivity For Calibration	No Mapping		
B058F08	Frequency Of Calibration	No Mapping		
B058F09	Time Of Calibration	No Mapping		

5.1.8 B61 FIR Response

Field	Field Name	StationXML Element	Attribute	Dictionary Field(s)
B061F03	Stage Sequence Number	Response/Stage/FIR	• number	
B061F04	Response Name	Response/Stage/FIR	• name	
B061F05	Symmetry	Response/Stage/FIR/Symmetry		
B061F06	Signal In Units	Response/Stage/FIR/InputUnits/Name		B034F04, B041F06
B061F07	Signal Out Units	Response/Stage/FIR/OutputUnits/Name		B034F04, B041F07
B061F08	Number of Coefficients	No Mapping		
B061F09	FIR Coefficient	Response/Stage/FIR/NumeratorCoefficient		

5.1.9 B62 Response Polynomial

Field	Field Name	StationXML Element	Attribute	Dictionary Field(s)
B062F03	Transfer Function Type	No Mapping		
B062F04	Stage Sequence Number	Response/Stage/Polynomial	• number	
B062F05	Stage Signal Input Units	Response/Stage/Polynomial/InputUnits/Name		B034F04, B042F06
B062F06	Stage Signal Output Units	Response/Stage/Polynomial/OutputUnits/Name		B034F04, B042F07
B062F07	Polynomial Approximation Type	Response/Stage/Polynomial/ApproximationType		
B062F08	Valid Frequency Units	No Mapping		
B062F09	Lower Valid Frequency Bound	Response/Stage/Polynomial/FrequencyLowerBound		
B062F10	Upper Valid Frequency Bound	Response/Stage/Polynomial/FrequencyUpperBound		
B062F11	Lower Bound Of Approximation	Response/Stage/Polynomial/ApproximationLowerBound		
B062F12	Upper Bound Of Approximation	Response/Stage/Polynomial/ApproximationUpperBound		
B062F13	Maximum Absolute Error	Response/Stage/Polynomial/MaximumError		
B062F14	Number Of Polynomial Coefficients	No Mapping		
B062F15	Polynomial Coefficient Error	Response/Stage/Polynomial/Coefficient	• minusError • plusError	

5.2 Channel Naming Conventions

For information on Network, Station and Channel naming conventions and recommendations, see:

https://iris-edu.github.io/xFDSN-source-identifiers/

5.3 Type Glossary

Type	Type Details	Examples
anyURI	Represents a Uniform Resource Identifier Reference, which often describes URLs and file paths.	• http://some/path • http://usgs.gov
CounterType	Integers greater than or equal to 0.	• 0 • 12345
dateTime	Integer values used to represent the year, day, hours, minutes. Decimals represent seconds, a boolean represents the timezone.	
decimal	The subset of real numbers	• -123.45 • 53.7
double	A number between 2.23 × 10^-308 and 8.98 × 10^307 (rounded), along with positive and negative infinity and NaN.	• 12.78e-2 • -32
integer	A decimal number without the period and numbers following it.	. . . -2,-1,0,1, 2, . . .
RestrictedStatusType	an NMTOKEN that is either “open”, “closed,” or “partial.””	• open • closed
string	A finite sequence of characters.	foo bar
NMTOKEN	a combination of name characters, which include letters, digits, periods, hyphens, underscores, colons.	• ANMO • a1.-_:

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