SEED

Standard for the Exchange of Earthquake Data

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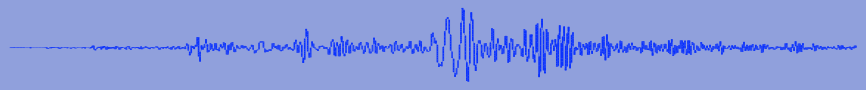


IRIS / ORFEUS Workshop
Understanding and Managing
Information from Seismological Networks

28 Feb – 4 Mar 2005, Palmanova, Italy

Topics:

- what is SEED ?
- general overview of the SEED format
- details on meta-data (headers)
- details on data-records
- system response
- SEED software tools

What is SEED ?

SEED is an international standard format for the exchange of digital seismological data.

1985:	**IASPEI Commision on Practice -> FDSN (working group on digital data exchange)**
1987:	**FDSN draft standard (USGS)**
1988:	**official release (version 2.0) (document by Halbert, Buland and Hutt)**
1990:	**version 2.1 (indexing)**
1991:	**version 2.2 (dataless)**
1992:	**version 2.3 (mini-SEED)**
2004:	**version 2.4 (data quality)**

SEED in practice:

- recording of digital waveform data (dataloggers)
- exchange of waveform data (real-time, archive)
- archiving of digital waveform data (IRIS-DMC, ODC,…)
- storage of meta-data (information about the data, e.g. station information)
- end-user

- not for non-time series data
- not for unequal time-interval sampled data (except Logs)
- not designed for processed or synthetic data, but possible
- parametric data possible (e.g. phase readings)

  IASPEI Seismic Format (ISF)

Standard for the Exchange of Earthquake Data (SEED): structure

control headers

dataless SEED

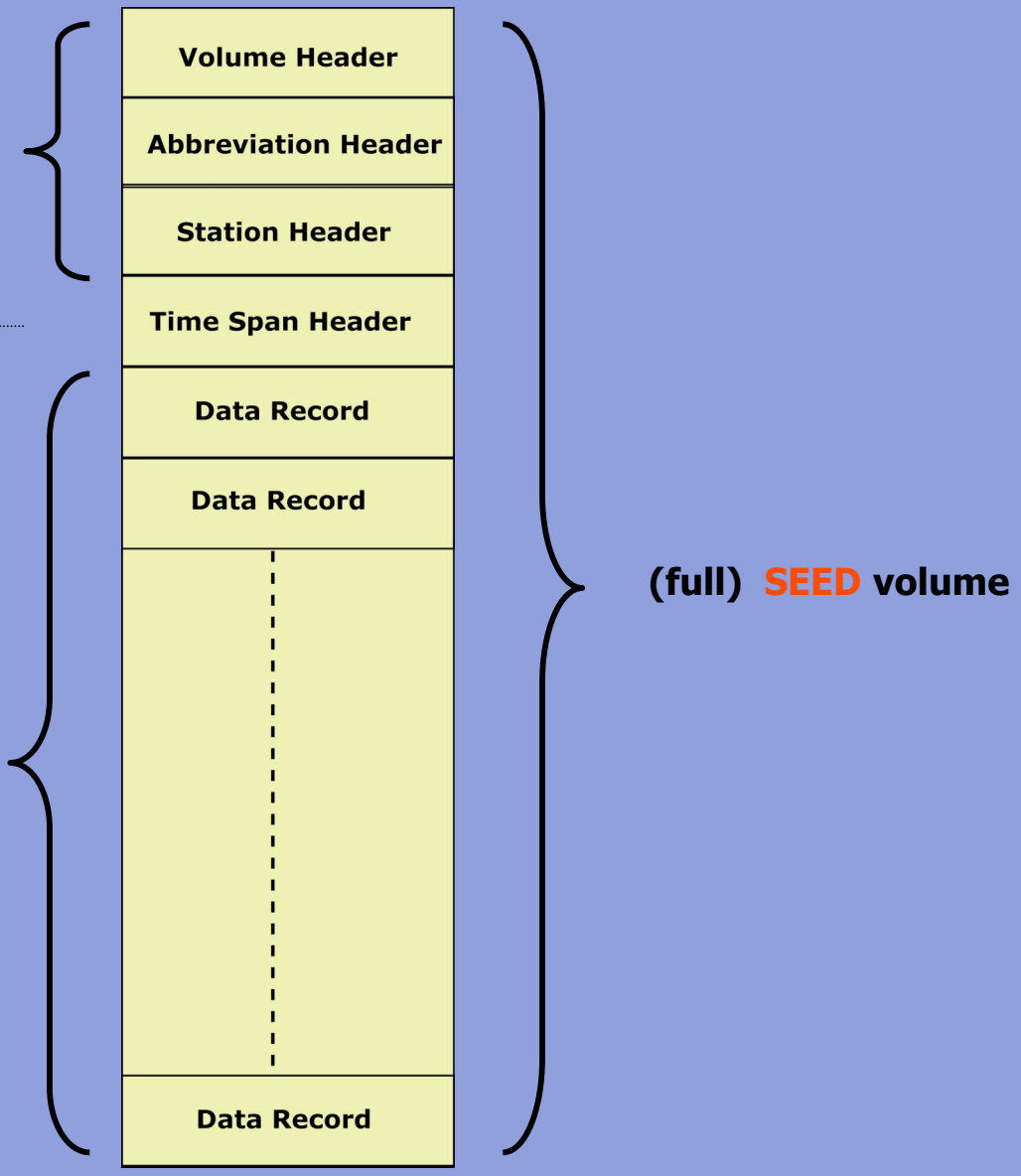
ascii

waveform data

raw data and embedded auxiliary information

mini-SEED

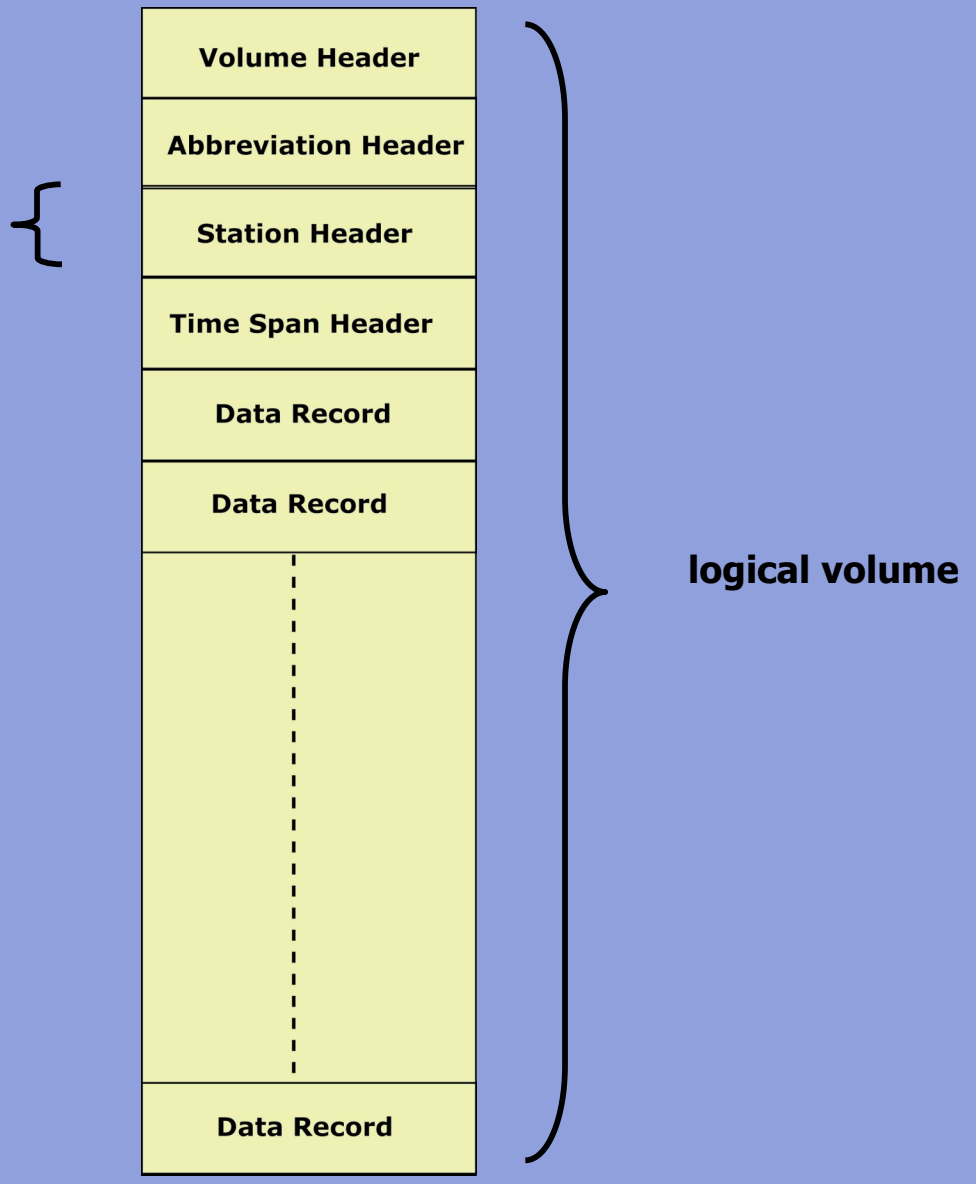
binary (+ ascii)



Standard for the Exchange of Earthquake Data (SEED): organization

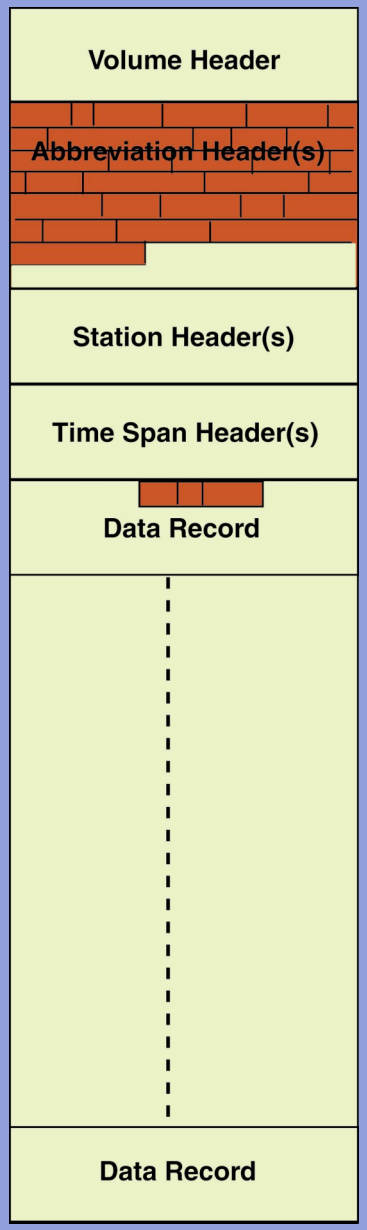
logical record

size in bytes:
256
512
1024
2048
4096
8192
16384
32768



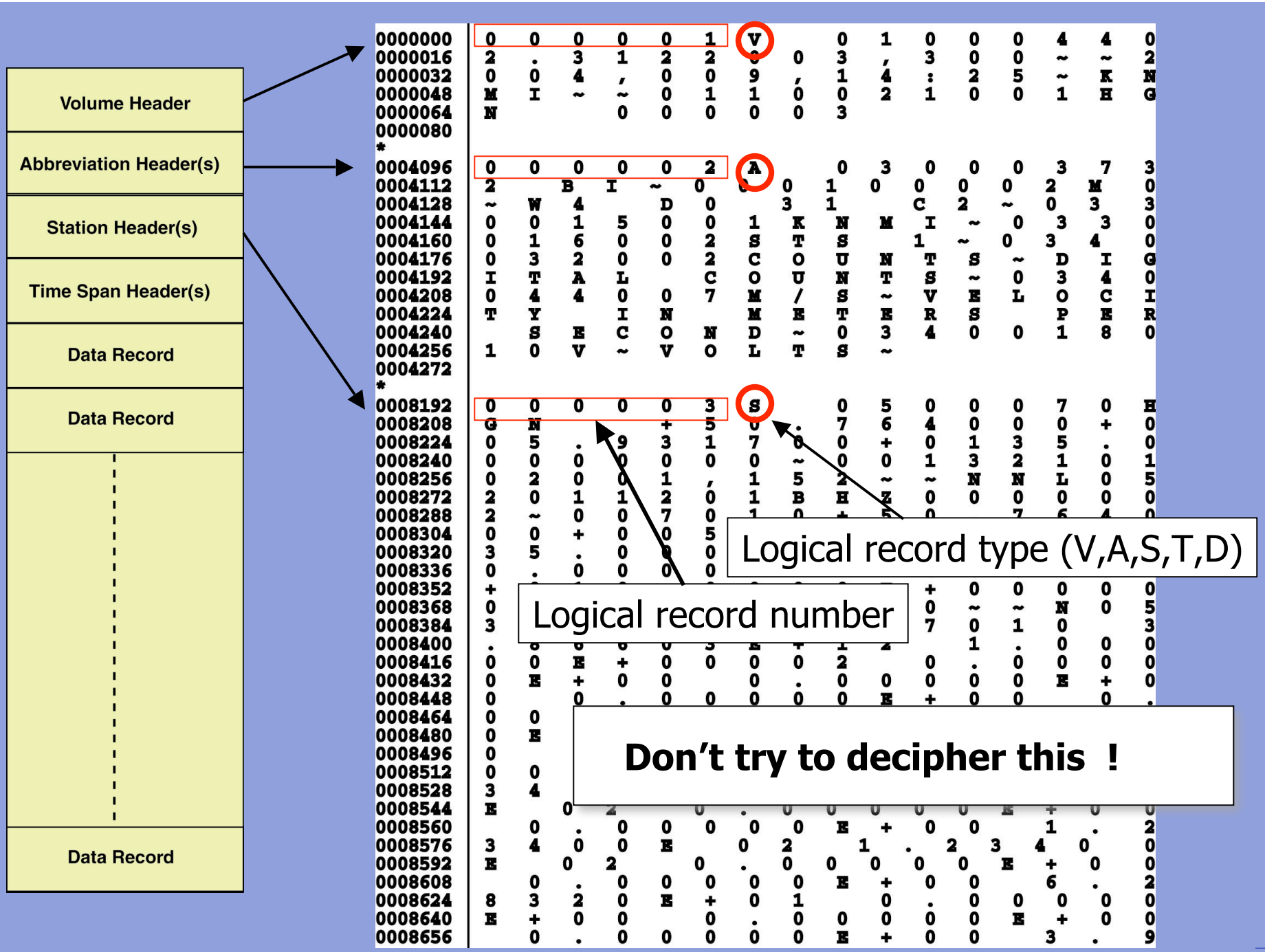
A control header may use a number of logical records

Standard for the Exchange of Earthquake Data (SEED): blockettes



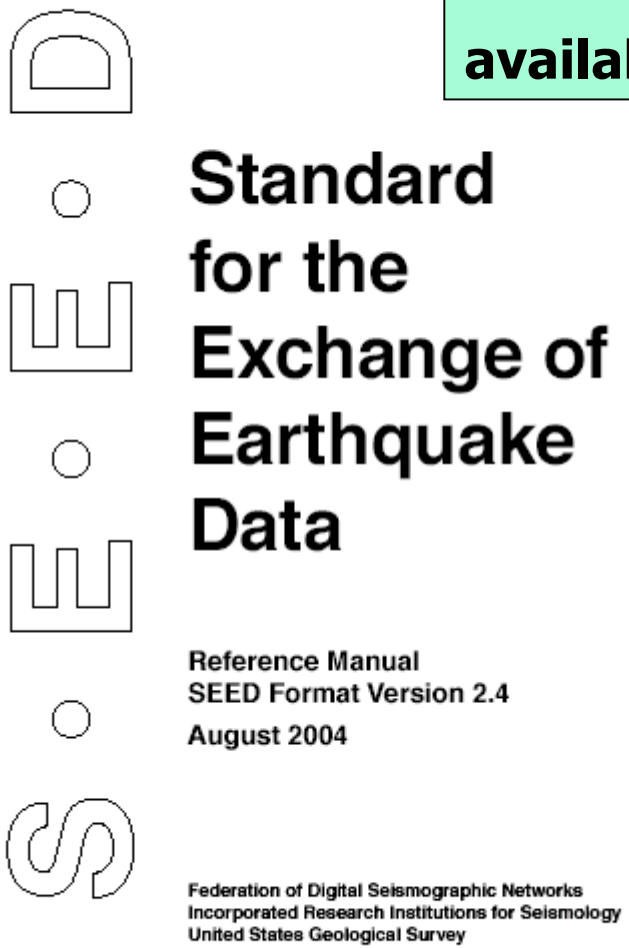
blockettes:

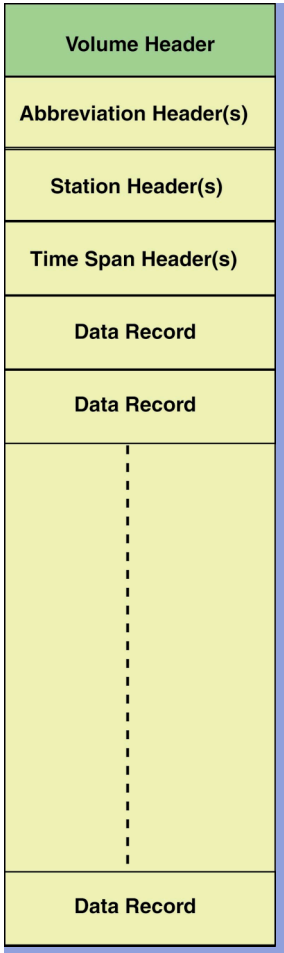
- building blocks of (control) headers
- defined data structures
- different and variable length
- not restricted to logical record boundaries
- ascii (in control headers) or binary (in data records)


Volume Header
Abbreviation Header(s)
Station Header(s)
Time Span Header(s)
Data Record
Data Record
Data Record
Logical record type (V,A,S,T,D)
Logical record number
Don’t try to decipher this !

SEED Reference Manual

available from IRIS: www.iris.edu





Use of blockette

Blockette fields

Notes for blockette fields

[10] Volume Identifier Blockette

Name: Volume Identifier Blockette
Blockette Type: 010
Control Header: Volume Index
Field Station Volume: Not Applicable
Station Oriented Network Volume: Required
Event Oriented Network Volume: Required

This is the normal header blockette for station or event oriented network volumes. Include it once at the begin logical volume or sub-volume.

Sample:

```
010009502.1121992,001,00:00:00.0000~1992,002,00:00:00.0
000~1993,029~IRIS_DMC~Data for 1992,001~
```

Field type
Field length
Field format

	Note	Field name	Type	Length	Mask or Flags
	1	Blockette type 010	D	3	"###"
	2	Length of blockette	D	4	"####"
	3	Version of format	D	4	"##.#"
	4	Logical record length	D	2	"##"
	5	Beginning time	V	1—22	TIME
	6	End time	V	1—22	TIME
V2.3 -	7	Volume Time	V	1—22	TIME
V2.3 -	8	Originating Organization	V	1—80	
V2.3 -	9	Label	V	1-- 80	

Notes for fields:

1 Standard blockette type identification number.

2 Length of the entire blockette, including the 7 bytes in fields 1 and 2.

3 Version number of the format, currently "V2.4."

4 Volume logical record length, expressed as a power of 2. A 4096 byte logical record would have "12" in this field. Logical record lengths can be from 256 bytes to 32,768 bytes. 4096 bytes is preferred.

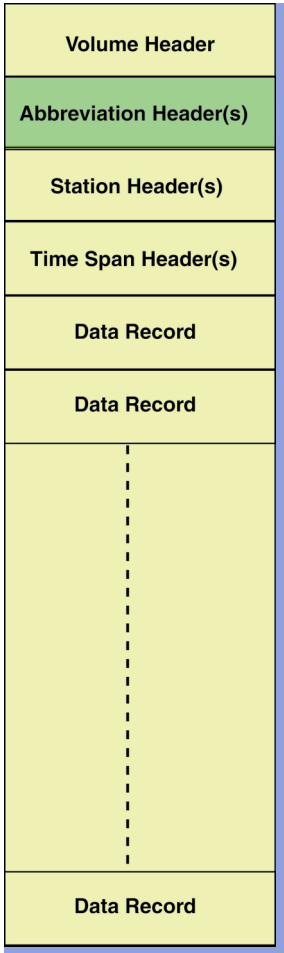
5 The earliest time seen in the time span list for this logical volume.

6 The latest time on the logical volume.

7 The actual date and time that the volume was written.

8 The organization writing the SEED volume.

9 An optional label that can be used to identify this SEED volume. For instance a label such as "Loma Prieta Earthquake" could be designated. If there is no label a ~ must be inserted.



[34] Units Abbreviations Blockette

Name:	**Units Abbreviations Blockette**
Blockette Type:	**034**
Control Header:	**Abbreviation Dictionaries**
Field Station Volume:	**Required**
Station Oriented Network Volume:	**Required**
Event Oriented Network Volume:	**Required**

This blockette defines the units of measurement in a standard, repeatable way. Mention each unit of measurement only once.

Sample:

```
0340044001M/S~VelocityΔinΔMetersΔPerΔSecond~
```

Note	Field name	Type	Length	Mask or Flags
1	Blockette type — 034	D	3	"###"
2	Length of blockette	D	4	"####"
3	Unit lookup code	D	3	"###"
4	Unit name	V	1—20	[UNP]
5	Unit description	V	0—50	[UNLPS]

Notes for fields:

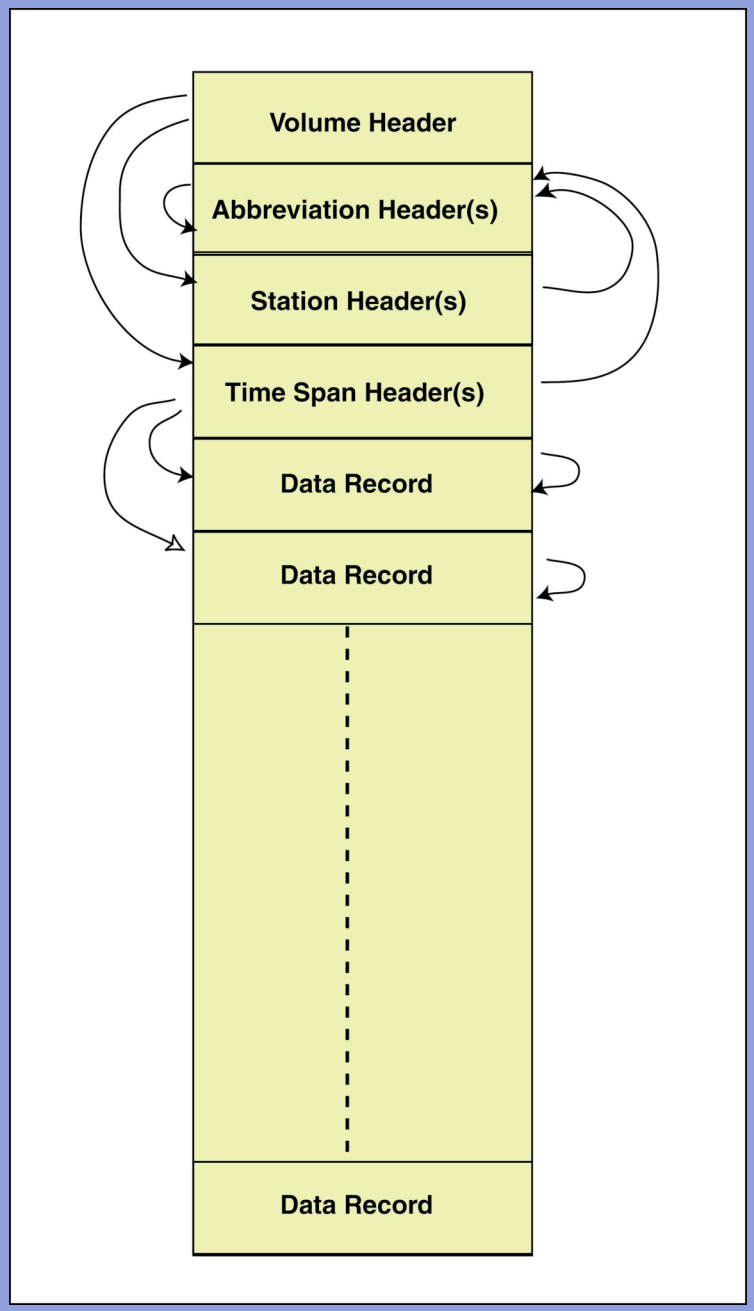
1 Standard blockette type identification number.

2 Length of the entire blockette, including the 7 bytes of fields 1 and 2.

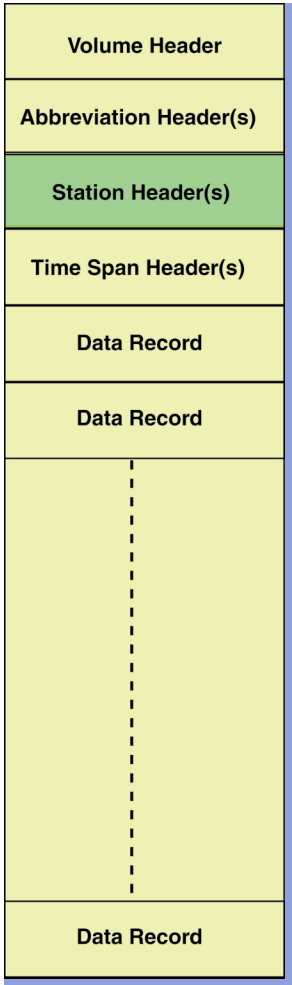
3 A unit lookup code, used in later blockettes to indicate this particular dictionary entry. As of this manual's publication, the following fields and blockettes refer to this code:

- field 6 of the Comment Description Dictionary Blockette [31]
- field 6 of the Response (Poles & Zeros) Dictionary Blockette [43]
- field 7 of the Response (Poles & Zeros) Dictionary Blockette [43]
- field 6 of the Response (Coefficients) Blockette [44]
- field 7 of the Response (Coefficients) Blockette [44]
- field 5 of the Response List Blockette [45]

Cross references →



Cross references and pointers



[50] Station Identifier Blockette

Name:	Station Identifier Blockette
Blockette Type:	050
Control Header:	Station
Field Station Volume:	Required
Station Oriented Network Volume:	Required
Event Oriented Network Volume:	Required

NEIC registered

http://neic.usgs.gov

:00-106.456700+1740.00006001Albuquerque,ΔNewMexico,ΔUSA~0013210101989,241~~

	Note	Field name	Type	Length	Mask or Flags
	1	Blockette type — 050	D	3	"###"
	2	Length of blockette	D	4	"####"
	3	Station call letters	A	5	[UN]
	4	Latitude (degrees)	D	10	"-##.######"
	5	Longitude (degrees)	D	11	"-###.######"
	6	Elevation (m)	D	7	"-####.#"
	7	Number of channels	D	4	"####"
	8	Number of station comments	D	3	"###"
	9	Site name	V	1—60	[UNLPS]
	10	Network identifier code	D	3	"###"
	11	32 bit word order	D	4	"####"
	12	16 bit word order	D	2	"##"
	13	Start effective date	V	1—22	TIME
	14	End effective date	V	0—22	TIME
	15	Update flag	A	1	
V2.3-	16	Network Code	A	2	[ULN]

FDSN network code

http://www.fdsn.org

Volume Header

Abbreviation Header(s)

Station Header(s)

Time Span Header(s)

Data Record

Data Record

Data Record

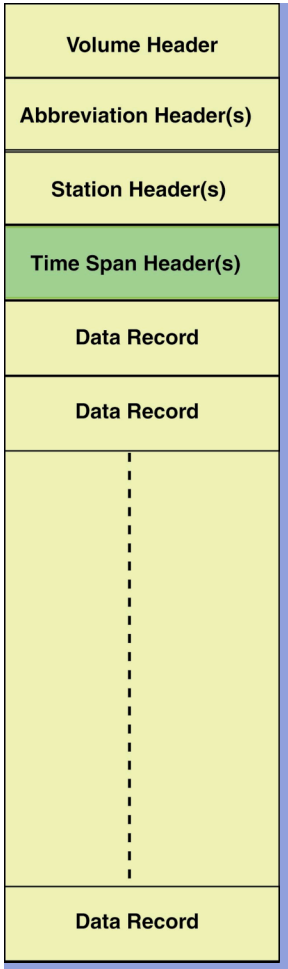
[53] Response (Poles & Zeros) Blockette

Name:	**Response (Poles & Zeros) Blockette**
Blockette Type:	**053**
Control Header:	**Station**
Field Station Volume:	**Some Response Required**
Station Oriented Network Volume:	**Some Response Required**
Event Oriented Network Volume:	**Some Response Required**

usually b53 - 58

Use this blockette for the analog stages of filter systems and for infinite impulse response (IIR) digital filters. Digital filters usually have a Decimation Blockette [57] following, and most stages have a Sensitivity/Gain Blockette [58] following. The stage sequence takes into account the fact that newer seismic systems will contain combinations of analog and digital filtering, allowing different deconvolution algorithms to be run sequentially (in cascade). SEED reserves the composite function to describe analog instruments with digital feedback circuitry. Stage order is the same as the original convolution order. Use the original earth units for the input units of stage 1. Use digital counts for the output units on the last stage. (See Appendix C for more information.)

Note	Field name	Type	Length	Mask or Flags
1	Blockette type — 053	D	3	"###"
2	Length of blockette	D	4	"####"
3	Transfer function type	A	1	[U]
4	Stage sequence number	D	2	"##"
5	Stage signal input units	D	3	"###"
6	Stage signal output units	D	3	"###"
7	AO normalization factor (1.0 if none)	F	12	"-#.#####E-##"
8	Normalization frequency fn(Hz)	F	12	"-#.#####E-##"
9	Number of complex zeros	D	3	"###"
	REPEAT fields 10 — 13 for the Number of complex zeros:			
10	Real zero	F	12	"-#.#####E-##"
11	Imaginary zero	F	12	"-#.#####E-##"
12	Real zero error	F	12	"-#.#####E-##"
13	Imaginary zero error	F	12	"-#.#####E-##"
14	Number of complex poles	D	3	"###"
	REPEAT fields 15 — 18 for the Number of complex poles:			
15	Real pole	F	12	"-#.#####E-##"
16	Imaginary pole	F	12	"-#.#####E-##"
17	Real pole error	F	12	"-#.#####E-##"
18	Imaginary pole error	F	12	"-#.#####E-##"



[74] Time Series Index Blockette

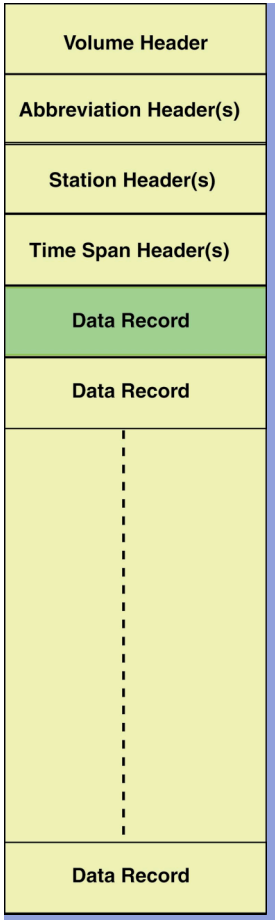
Name:	**Time Series Index Blockette**
Blockette Type:	**074**
Control Header:	**Time Span**
Field Station Volume:	**Not Applicable**
Station Oriented Network Volume:	**Required**
Event Oriented Network Volume:	**Required**

This blockette replaces the Time Span Data Start Index Blockette [73], and allows version 2.1 and later of SEED to correctly document time tears, events, and time indexes. There should be one Time Series Index Blockette [74] for each continuous time series and/or each station/ channel combination in the time span. This blockette provides indices and times of both the beginning and end of the time series described. Writing programs can also provide indices and times of intervening records to speed direct access — particularly useful for compressed data.

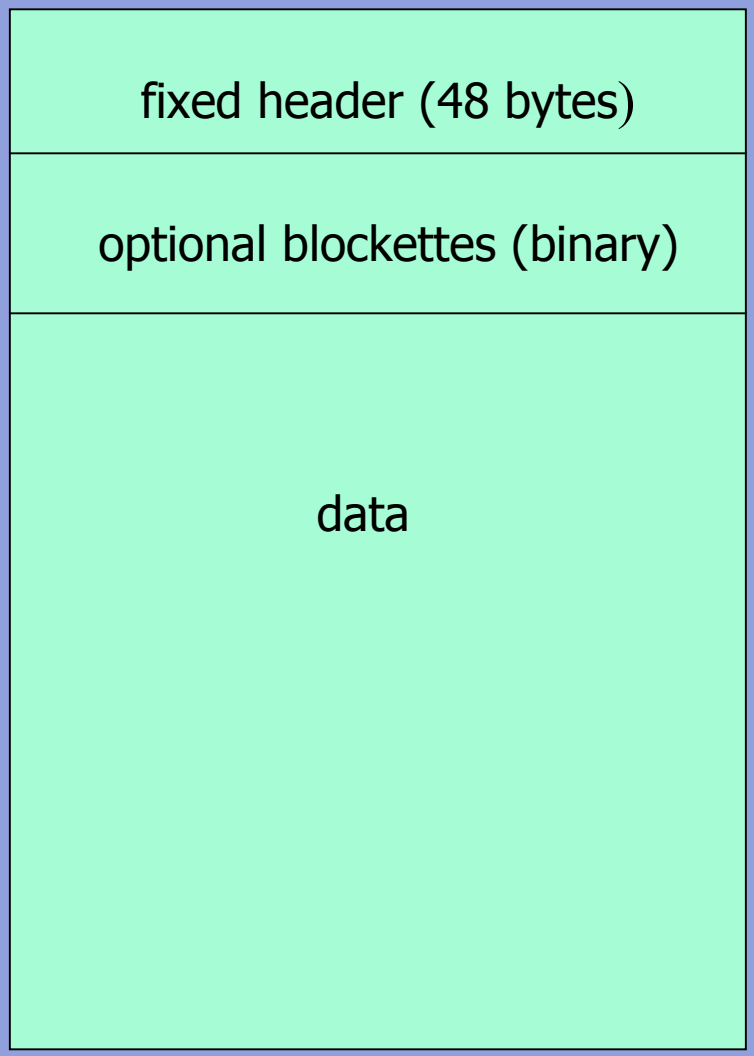
Sample:

```
0740084BJIΔΔΔΔBHZ1992,001,20:18:54.5700~003217011992,001,20:29:36.7200~00322301000CD
```

	Note	Field name	Type	Length	Mask or Flags
	1	Blockette type — 074	D	3	"###"
	2	Length of blockette	D	4	"####"
	3	Station identifier	A	5	[UN]
	4	Location identifier	A	2	[UN]
	5	Channel identifier	A	3	[UN]
	6	Series start time	V	1—22	TIME
	7	Sequence number of first data	D	6	"######"
	8	Sub-sequence number	D	2	"##"
	9	Series end time	V	1—22	TIME
	10	Sequence number of last record	D	6	"######"
	11	Sub-sequence number	D	2	"##"
	12	Number of accelerator repeats	D	3	"###"
	REPEAT fields 13 — 15 for the Number of accelerator repeats:				
	13	Record start time	V	1—22	TIME
	14	Sequence number of record	D	6	"######"
	15	Sub-sequence number	D	2	"##"
V2.3 -	16	Network Code	A	2	[ULN]

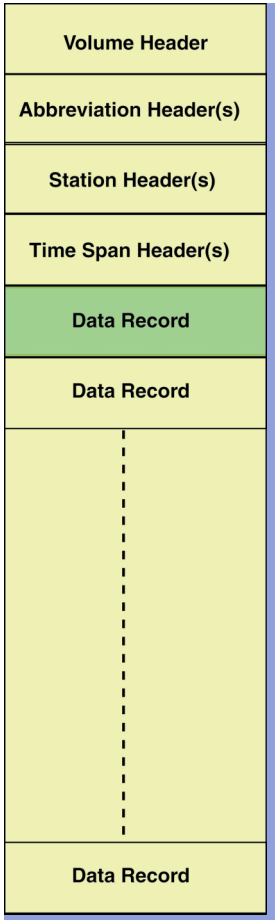


Data record:



e.g. b100 sample rate

b1000 encoding key



Fixed Section of Data Header (48 bytes)

The data record header starts at the first byte. The next eight bytes follow the same structure as the control headers. Byte seven contains an ASCII "D," indicating it is a data record. (The eighth byte, or third field, is always an ASCII space — shown here as a "Δ"). The next ten bytes contain the station, location, and channel identity of the record. The rest of the header section is binary.

	Note	Field name	Type	Length	Mask or Flags
	1	Sequence number	A	6	"######"
V2.4 -	2	Data header/quality indicator ("D"|"R"|"Q")	A	1	
	3	Reserved byte ("Δ")	A	1	
	4	Station identifier code	A	5	[UN]
	5	Location identifier	A	2	[UN]
	6	Channel identifier	A	3	[UN]
V2.3 -	7	Network Code	A	2	[ULN]
	8	Record start time	B	10	
	9	Number of samples	B	2	
	10	Sample rate factor	B	2	
	11	Sample rate multiplier			
	12	Activity flags			
	13	I/O and clock flags			
	14	Data quality flags	B	1	
	15	Number of blockettes that follow	B	1	
	16	Time correction	B	4	
	17	Beginning of data	B	2	
	18	First blockette	B	2	

e.g. time correction applied

Notes for fields: * indicates mandatory information

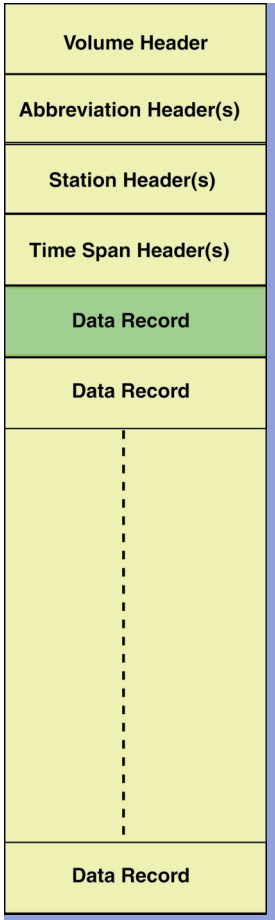
1 * Data record sequence number (Format "######").

2 * "D" or "R" or "Q" — Data header/quality indicator. Previously, this field was only allowed to be "D" and was only used to indicate that this is a data header. As of SEED version 2.4 the meaning of this field has been extended to also indicate the level of quality control that has been applied to the record.

D —The state of quality control of the data is indeterminate.

R — Raw Waveform Data with no Quality Control

Q — Quality Controlled Data, some processes have been applied to the data.



Decoding data records:

data encoding information by Data Description Language ("DDL"):

The data description language or DDL used with SEED lets the data producer use the native data format by describing it in an unambiguous language that will ultimately drive a data parser and disassembler. The data producer may then place data directly into the SEED format with much less processing and manipulation.

The actual language is composed of several records, called keys. Each key describes some aspect of the language for that family. Each family has its own arrangement and interpretation of keys. A key is made up of different fields that contain the actual parser information. A field is typically a single letter code, followed by numeric parameters

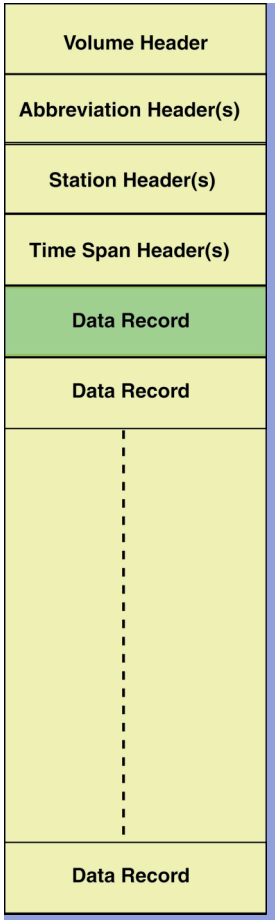
SEED: blockette 52, field 16, refers to set of DDL keys (blockette 30)

mini-SEED: blockette 1000, field 3

CODES 10 - 29	FDSN Networks
10	STEIM (1) Compression
11	STEIM (2) Compression
12	GEOSCOPE Multiplexed Format 24 bit integer
13	GEOSCOPE Multiplexed Format 16 bit gain ranged, 3 bit exponent
14	GEOSCOPE Multiplexed Format 16 bit gain ranged, 4 bit exponent
15	US National Network compression
16	CDSN 16 bit gain ranged
17	Graefenberg 16 bit gain ranged
18	IPG - Strasbourg 16 bit gain ranged
19	STEIM (3) Compression

The Steim 1 data format was originally described this way:

Key 1: F1 P4 W4 D0-31 C2 R1 P8 W4 D0-31 C2
Key 2: P0 W4 N15 S2,0,1
Key 3: T0 X N0 W4 D0-31 C2
Key 4: T1 N0 W1 D0-7 C2 N1 W1 D0-7 C2 N2 W1 D0-7 C2 N3 W1 D0-7 C2
Key 5: T2 N0 W2 D0-15 C2 N1 W2 D0-15 C2
Key 6: T3 N0 W4 D0-31 C2



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SEED: blockette 52, field 16, refers to set of DDL keys (blockette 30)

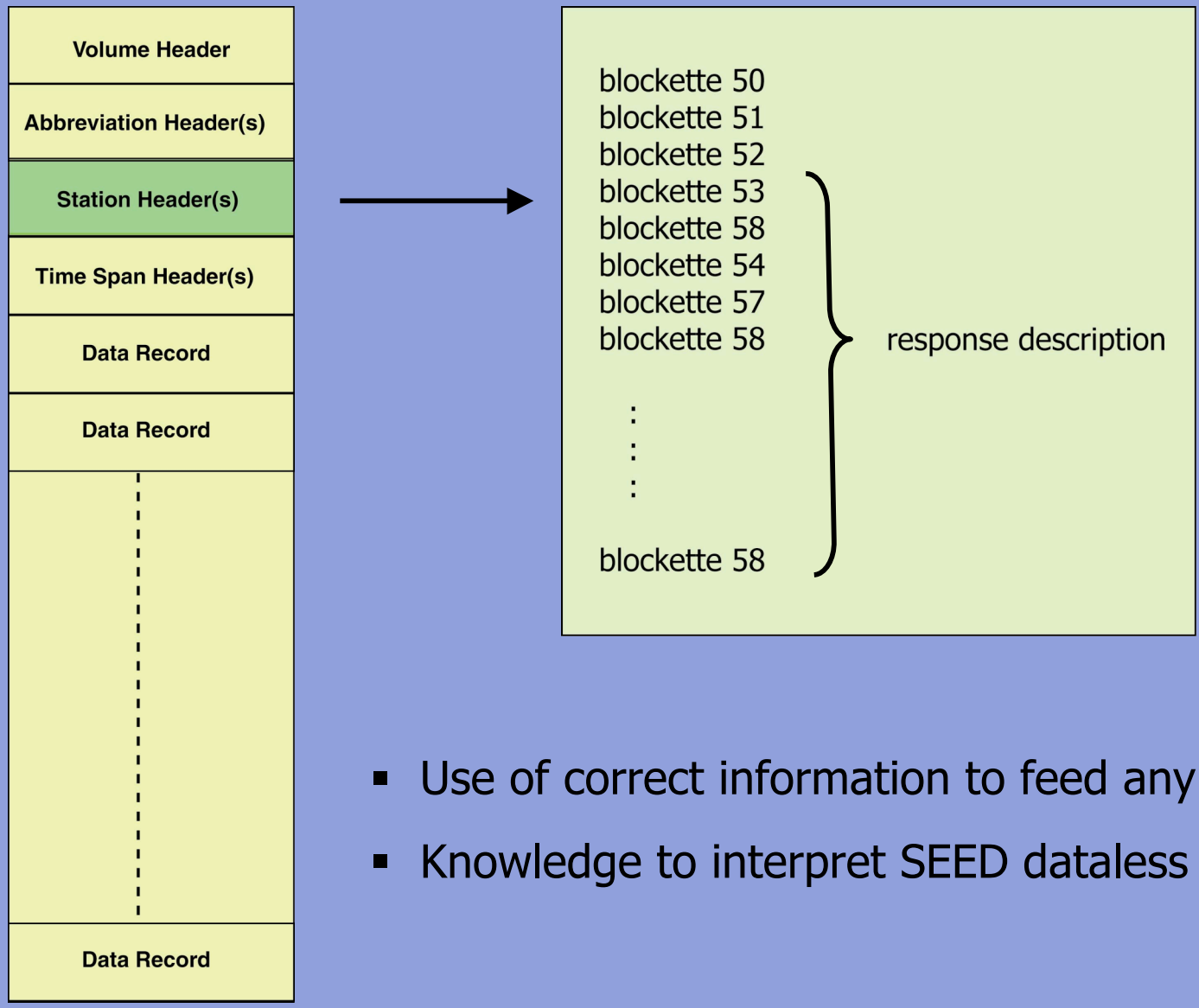
mini-SEED: blockette 1000, field 3

Practice: "Steim-1" (code 10)

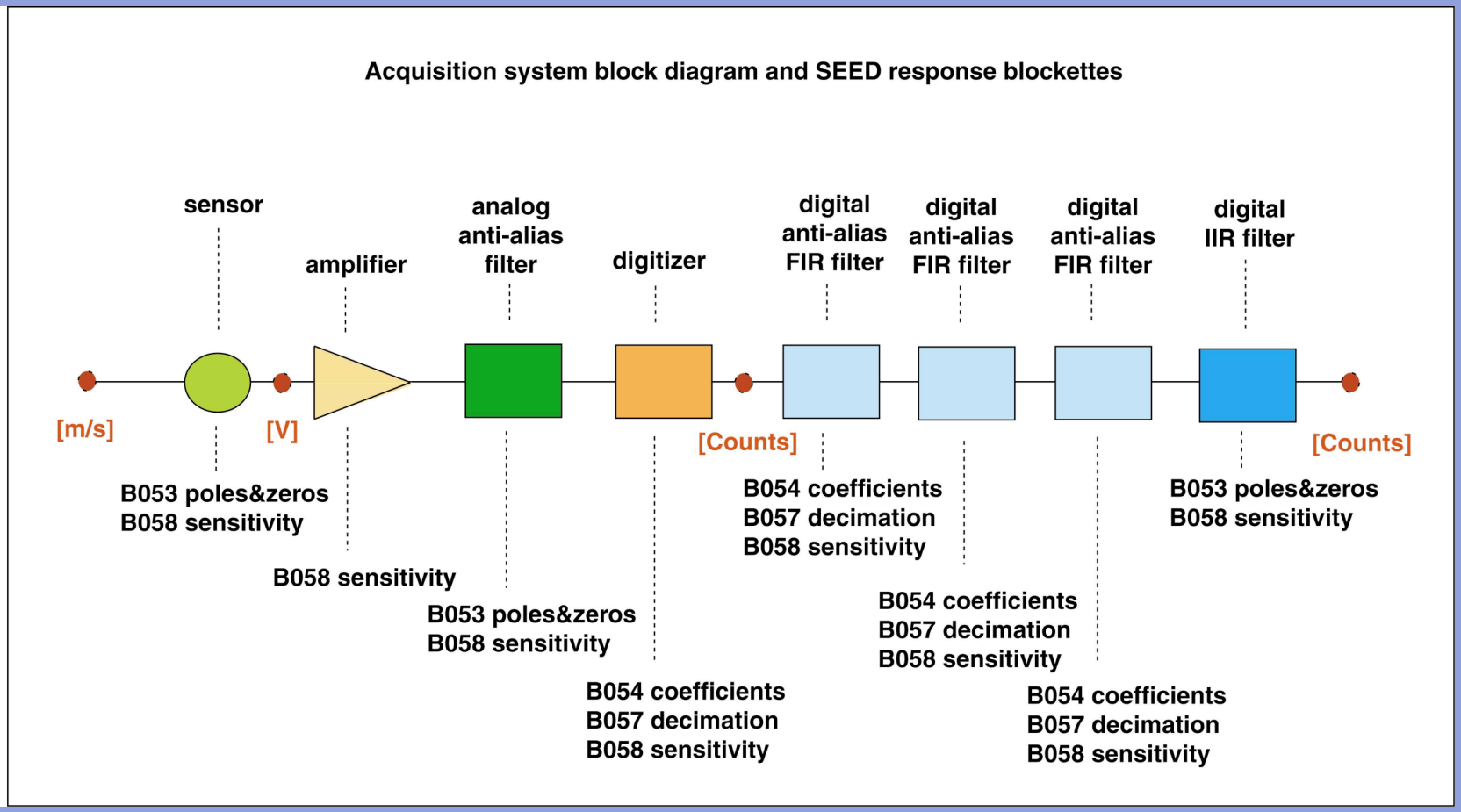
"Steim-2" (code 11)

"24-bit" (code 2)

SEED concept of system response



- Use of correct information to feed any SEED writer
- Knowledge to interpret SEED dataless correctly


Acquisition system block diagram and SEED response blockettes
sensor
amplifier
analog anti-alias filter
digitizer
digital anti-alias FIR filter
digital anti-alias FIR filter
digital anti-alias FIR filter
digital IIR filter
[m/s]
[V]
[Counts]
[Counts]
B053 poles&zeros
B058 sensitivity
B058 sensitivity
B053 poles&zeros
B058 sensitivity
B054 coefficients
B057 decimation
B058 sensitivity
B054 coefficients
B057 decimation
B058 sensitivity
B054 coefficients
B057 decimation
B058 sensitivity
B053 poles&zeros
B058 sensitivity

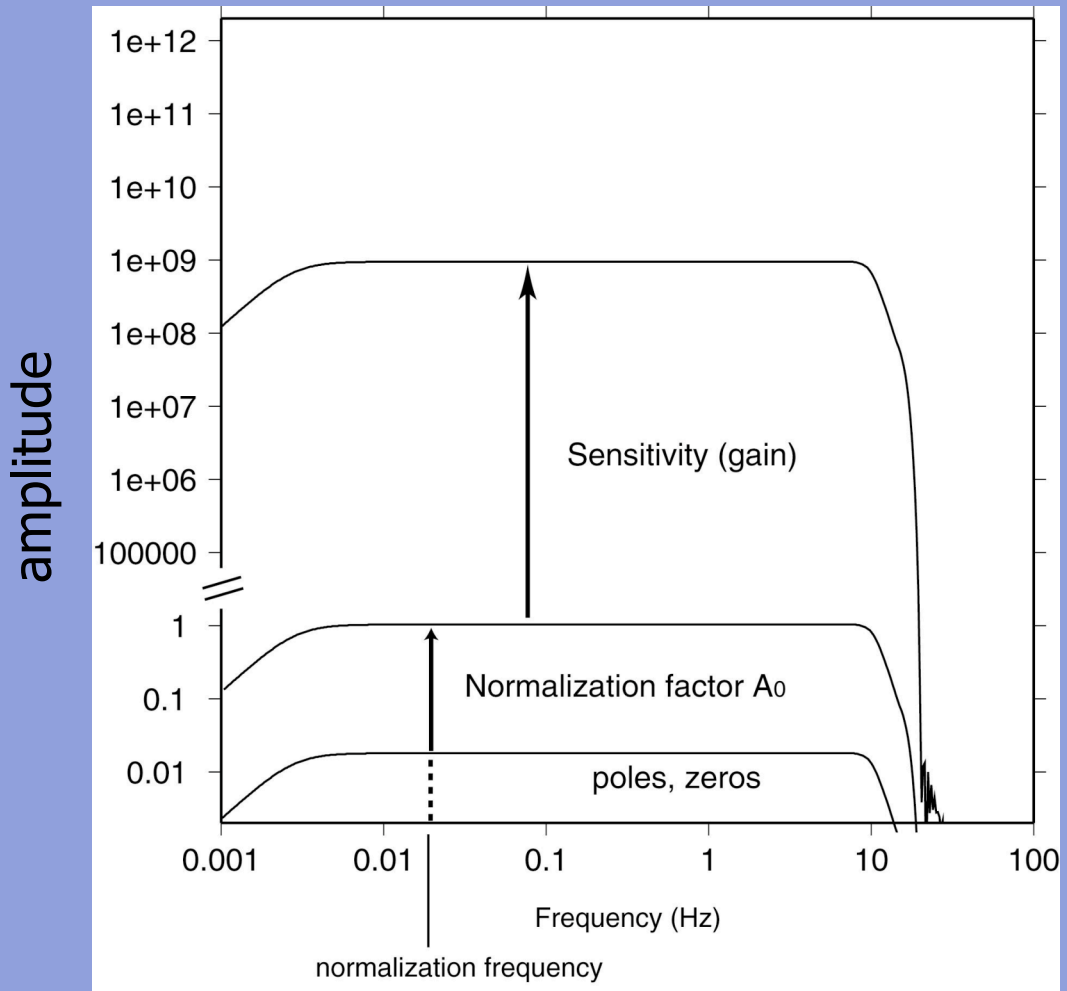
Mathematical description of system response

Sensor

poles and zeros in Hz or rad/sec **(b53)**

normalization constant (at f_n) **(b53)**

sensitivity (V/m/s) or (V/m) at f_n **(b58)**



Example calibration sheet Guralp CMG-3T

CMG-3T CALIBRATION SHEET

WORKS ORDER:	**1246**	**DATE:**	**13.01.97**
SERIAL NUMBER:	**T3442**	**TESTED BY:**	**SDG**

	Velocity Output V/m/s (Differential)	Mass Position Output (Acceleration output) $V/m/s^2$	Feedback Coil Constant $Amp/m/s^2$
VERTICAL	**2 x 1993.7**	**1163**	**0.02475**
NORTH/SOUTH	**2 x 1983.8**	**1366**	**0.02906**
EAST/WEST	**2 x 2005.6**	**1637**	**0.03483**

Single ended digitizer

Differential ended digitizer

caldoc@guralp.com

Example calibration sheet Guralp CMG-3T

b54, field 3:

A - rad/s

B - Hz

D - digital

POLES AND ZERO TABLE

WORKS ORDER NUMBER: 1246

SENSOR SERIAL NOS: T3442

Velocity response output, Vertical Sensor:

POLES (HZ)	**ZEROS HZ**
$-35.35 \times 10^{-3} \pm j\ 35.35 \times 10^{-3}$	122.4 ± 116
- 149	0
- 88	0

Normalizing factor at 1 Hz: A = 0.464

Sensor Sensitivity: See Calibration Sheet.

Velocity response output, Horizontal Sensors:

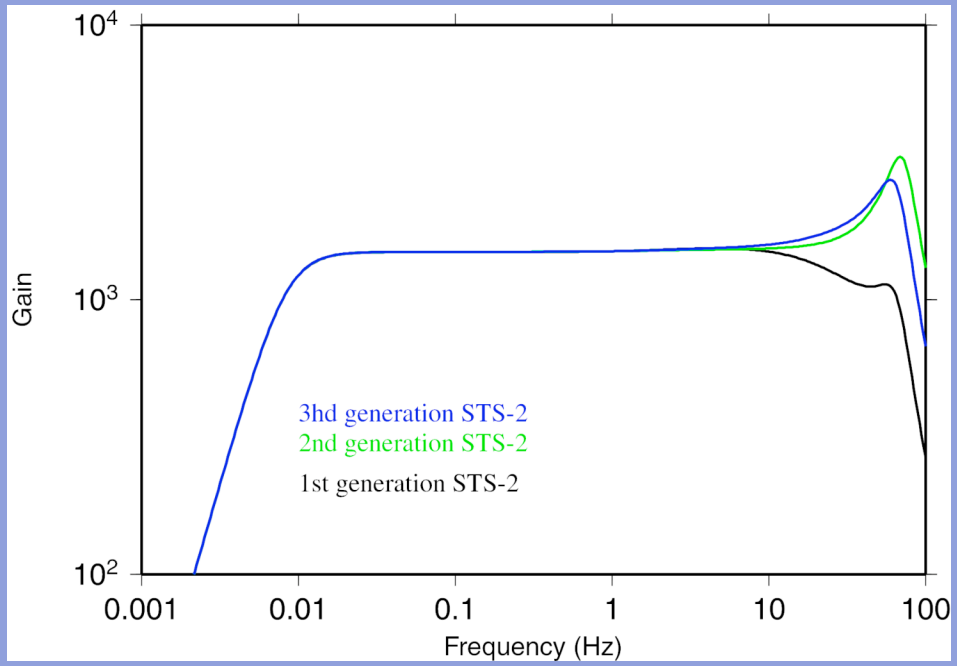
POLES (HZ)	**ZEROS (HZ)**
$-35.35 \times 10^{-3} \pm j\ 35.35 \times 10^{-3}$	122.4 ± 116
- 149	0
- 88	0

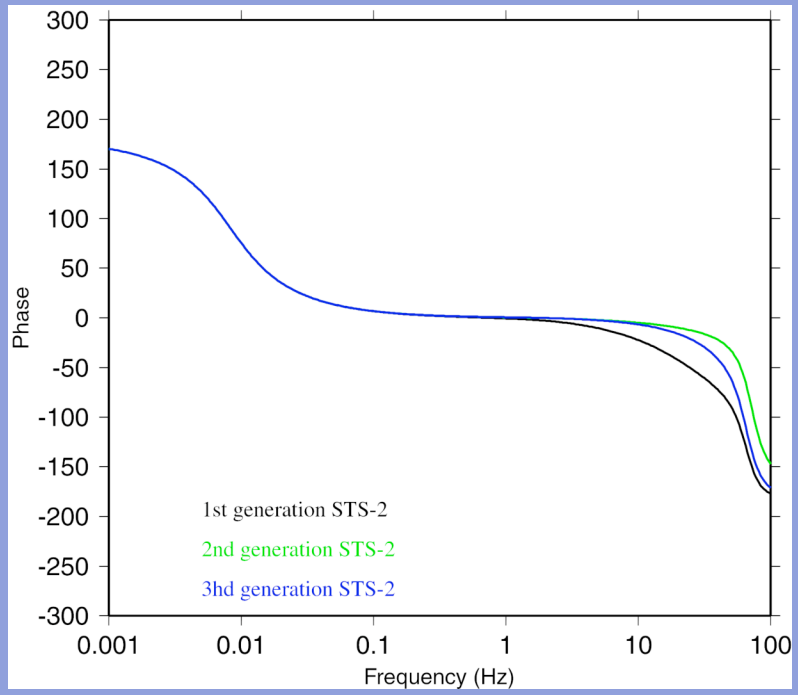
Normalizing factor at 1 Hz: A = 0.464

Response of the STS-2 sensor for 3 generations

each generation has its own sets of poles and zeros

S/N ⇒ generation type

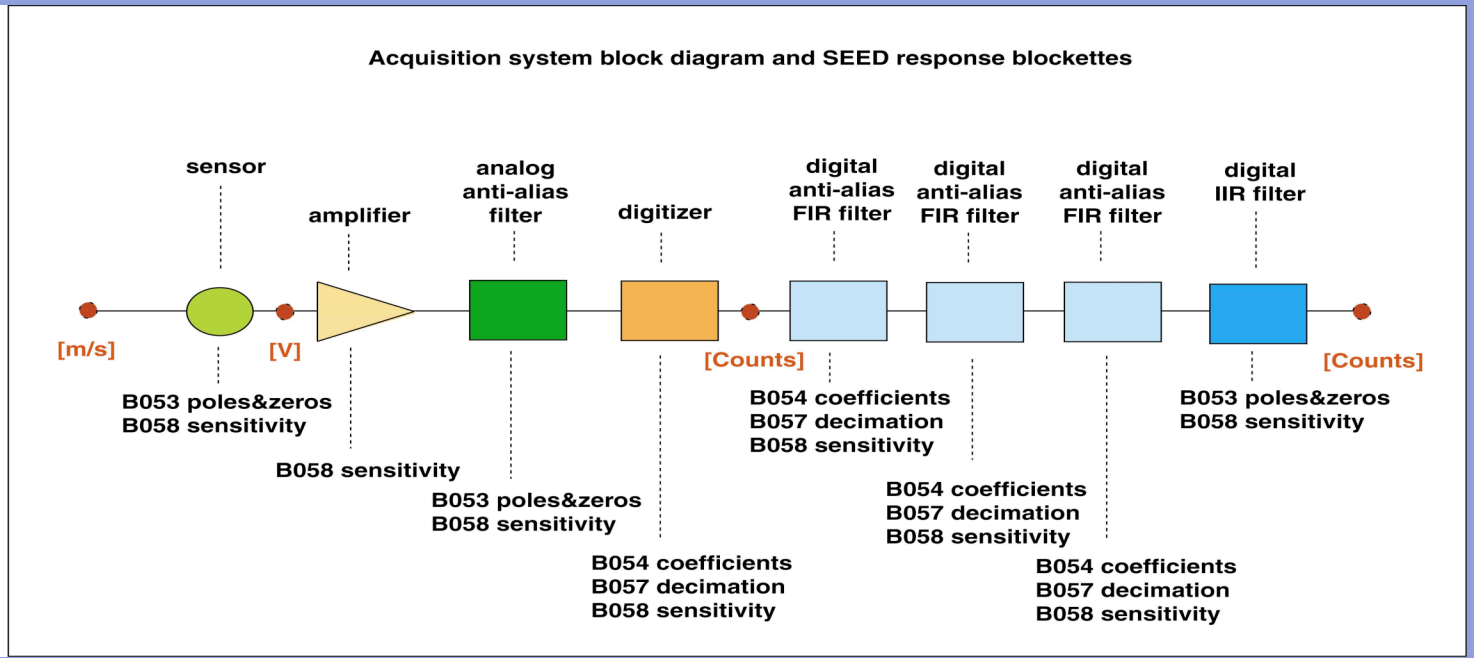




⇒ Also include high frequency poles and zeros in your response file !

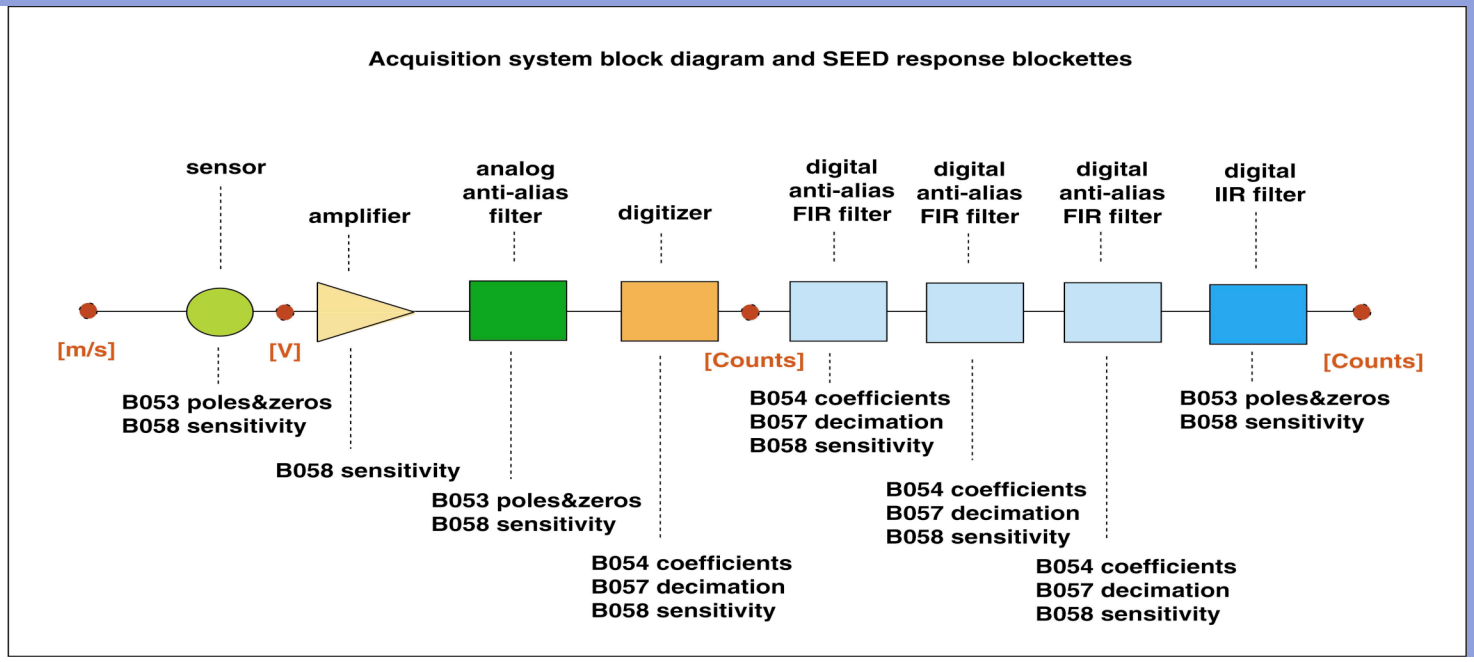
Mathematical description of system response

Sensor	**poles and zeros in Hz or rad/sec**	**(b53)**
	normalization constant (at f_n)	**(b53)**
	sensitivity (V/m/s) or (V/m) at f_n	**(b58)**
Amplifier	**sensitivity**	**(b58)**
Analog anti-alias filter:	**poles and zeros in Hz or rad/sec**	**(b53)**
	gain at f_n	**(b58)**



Mathematical description of system response

Sensor	**poles and zeros in Hz or rad/sec**	**(b53)**
	normalization constant (at f_n)	**(b53)**
	sensitivity (V/m/s) or (V/m) at f_n	**(b58)**
Amplifier	**sensitivity**	**(b58)**
Analog anti-alias filter:	**poles and zeros in Hz or rad/sec**	**(b53)**
	gain at f_n	**(b58)**
Digitizer:	**A/D sampling rate, sensitivity (C/V)**	**(b54, 57, 58)**



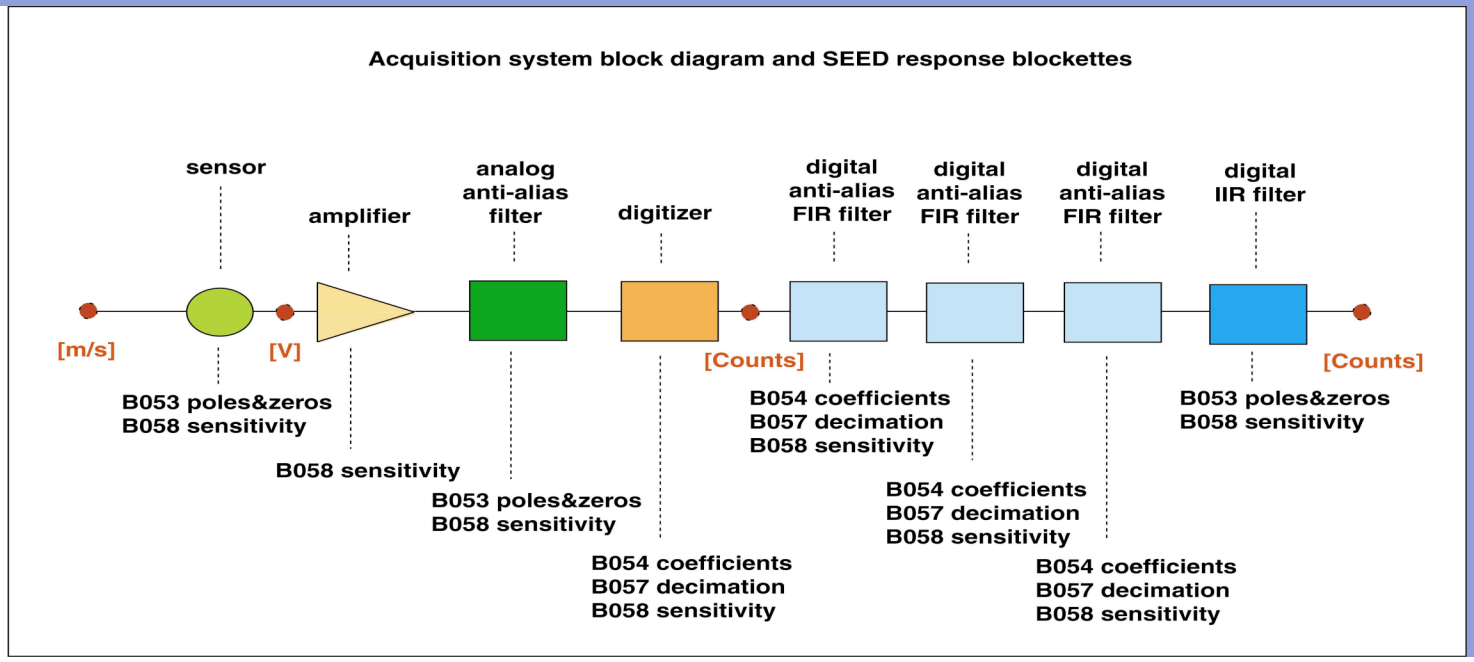
Digitizers: every datalogger different

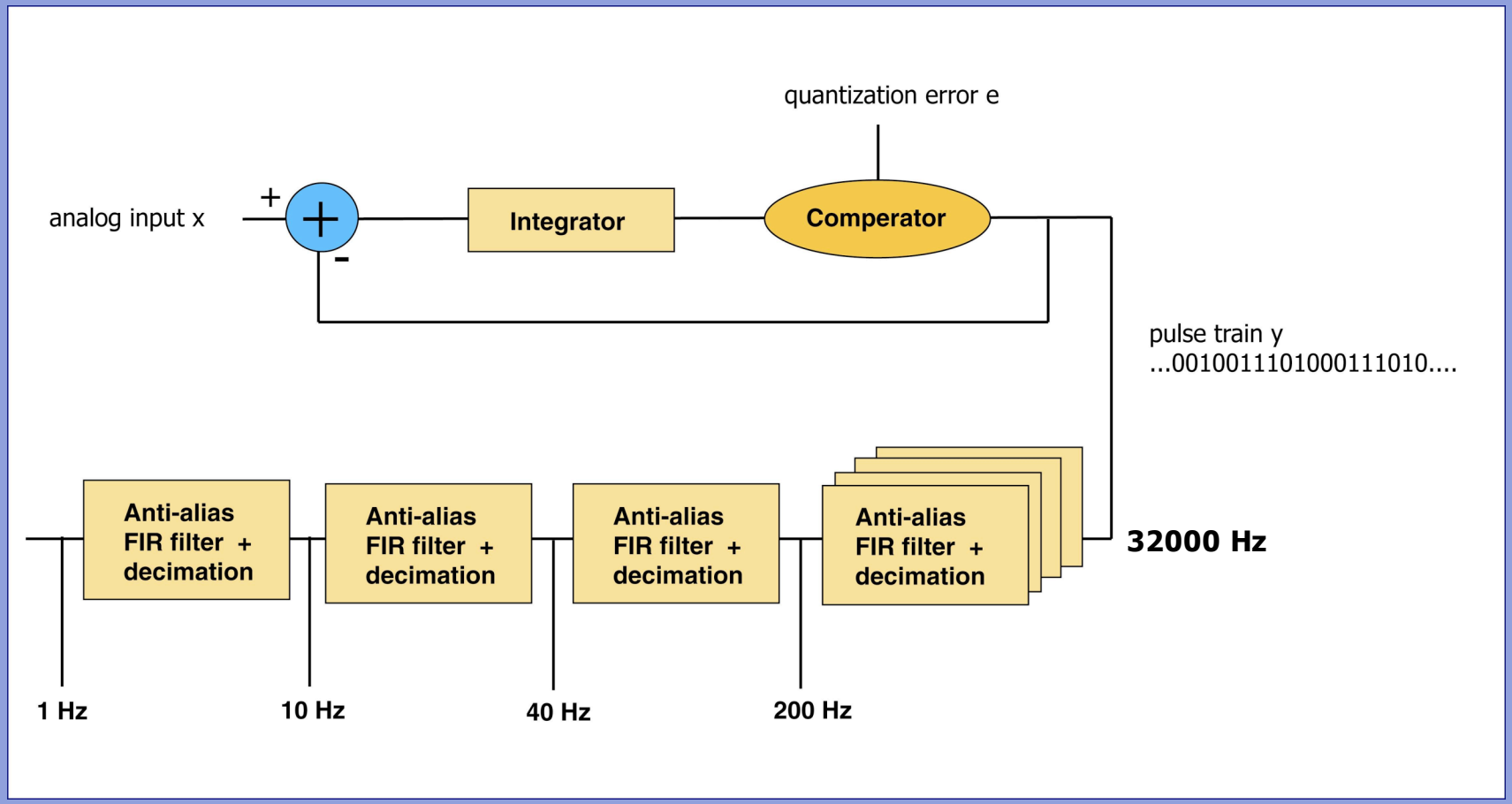
(gain, FIR filters, dynamic range, self-noise)

- Quanterra
  - Variable A/D constants by channel
    - Q680, Q4120, Q730
  - Home brewed filters allowed
    - Q680, Q4120, Q730
  - Q330 default
    - Causal to 100 sps
    - Acausal below
  - FIR coeffs distributed in reverse time order
- Guralp
  - Differential or Single ended inputs; user selected FIR filters
- Nanometrics
  - Variable A/D gains
  - FIR Filters

Mathematical description of system response

Sensor	**poles and zeros in Hz or rad/sec**	**(b53)**
	normalization constant (at f_n)	**(b53)**
	sensitivity (V/m/s) or (V/m) at f_n	**(b58)**
Amplifier	**sensitivity**	**(b58)**
Analog anti-alias filter:	**poles and zeros in Hz or rad/sec**	**(b53)**
	gain at f_n	**(b58)**
Digitizer:	**A/D sampling rate, sensitivity (C/V)**	**(b54, 57, 58)**
FIR filter	**coefficients, decimation, gain**	**(b54, 57, 58)**
IIR filter	**poles and zeros in Z-domain, gain**	**(b53, 58)**
Overall gain		**(b58)**



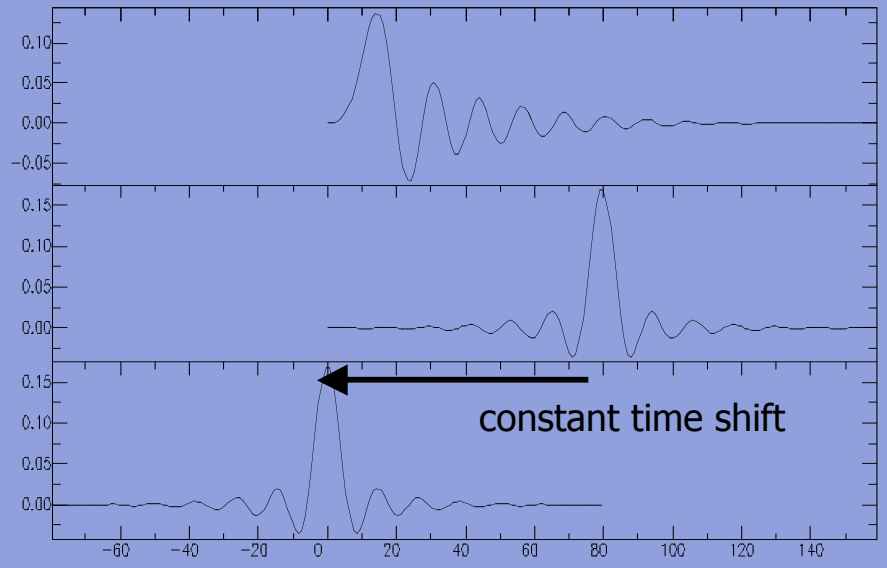

quantization error e
analog input x
+
-
Integrator
Comperator
pulse train y
...0010011101000111010....
Anti-alias FIR filter + decimation
Anti-alias FIR filter + decimation
Anti-alias FIR filter + decimation
Anti-alias FIR filter + decimation
32000 Hz
1 Hz
10 Hz
40 Hz
200 Hz

FIR filters

- Weighted average over some number of data
- Steep cut-off at their corner frequency
- Usually linear-phase (symmetric)
- Quanterra: minimum phase for onset picking

$$y_k = \sum_{m=0}^{M} a_m \cdot x_{k-m}$$

coefficients (b57)



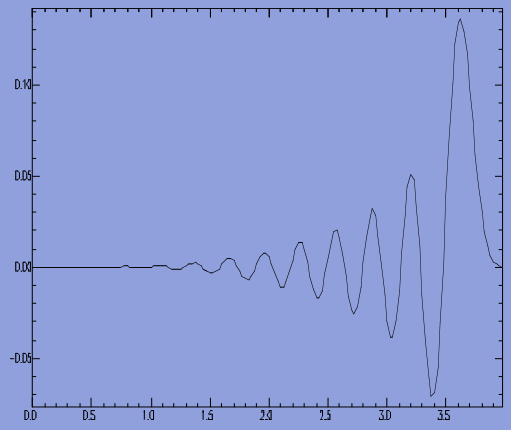
Minimum phase, causal

Linear phase, acausal

Zero phase, acausal

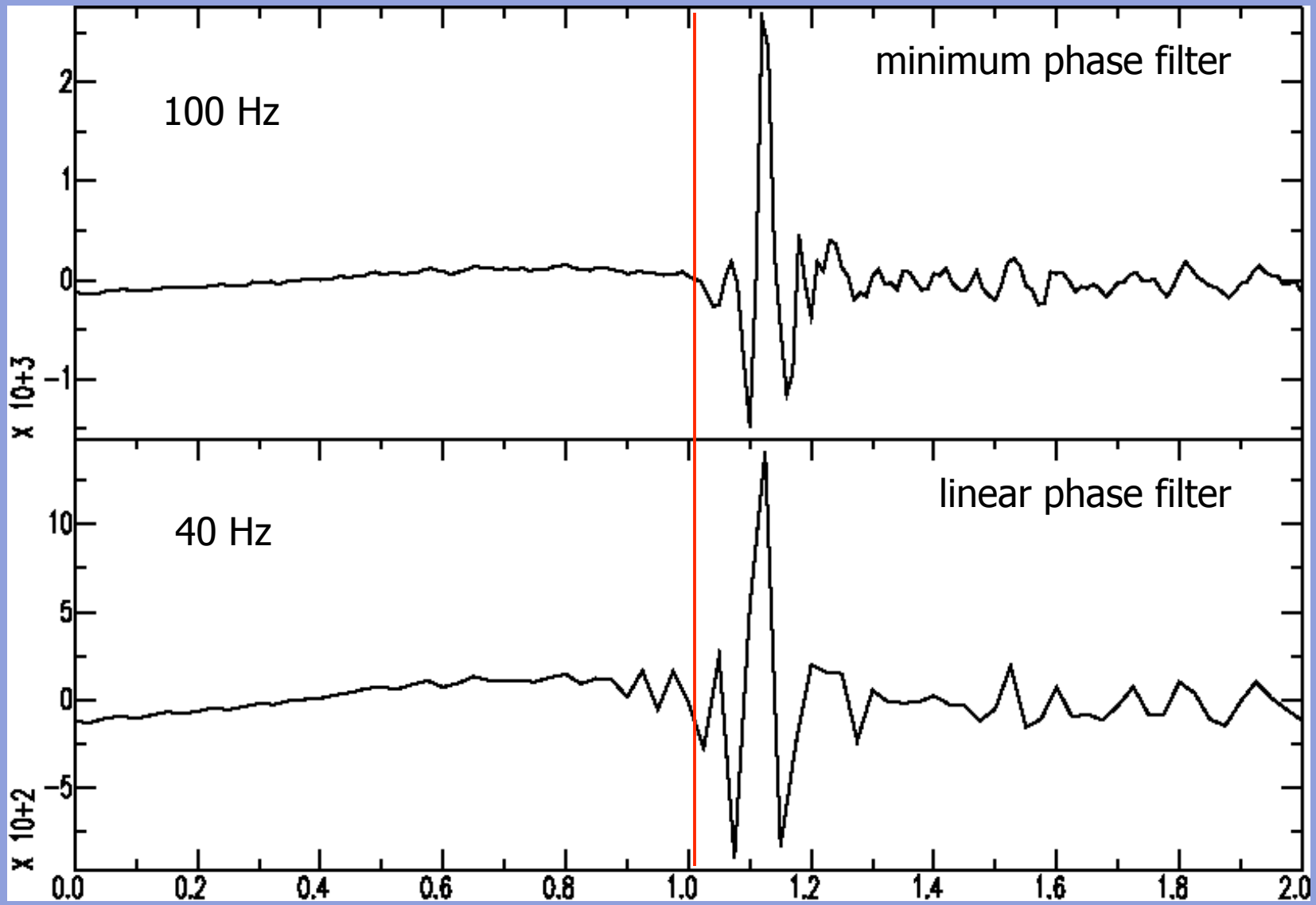
Quanterra: Default FIR filter configuration (Q680, Q4120, Q730)

STAGE=1,2000,0.001663,>>234678		
STAGE=2,400,FS2D5M,<1,>>234678	# output: 400 Hz	(minimum phase !)
STAGE=3,200,F96CM,<2,>>234678	# output: 200 Hz	(minimum phase !)
STAGE=4,100,F96CM,<3,>234678,>>234678	# output: 100 Hz	(minimum phase !)
STAGE=5,40,FS2D5,<3,>234678	# output: 40 Hz	
STAGE=6,20,FS2D5,<4,>234678,>>234678	# output: 20 Hz	
STAGE=7,10,F96C,<6,>>234678	# output: 10 Hz	
STAGE=9,1,F260,<7,>234678	# output: 1 Hz	



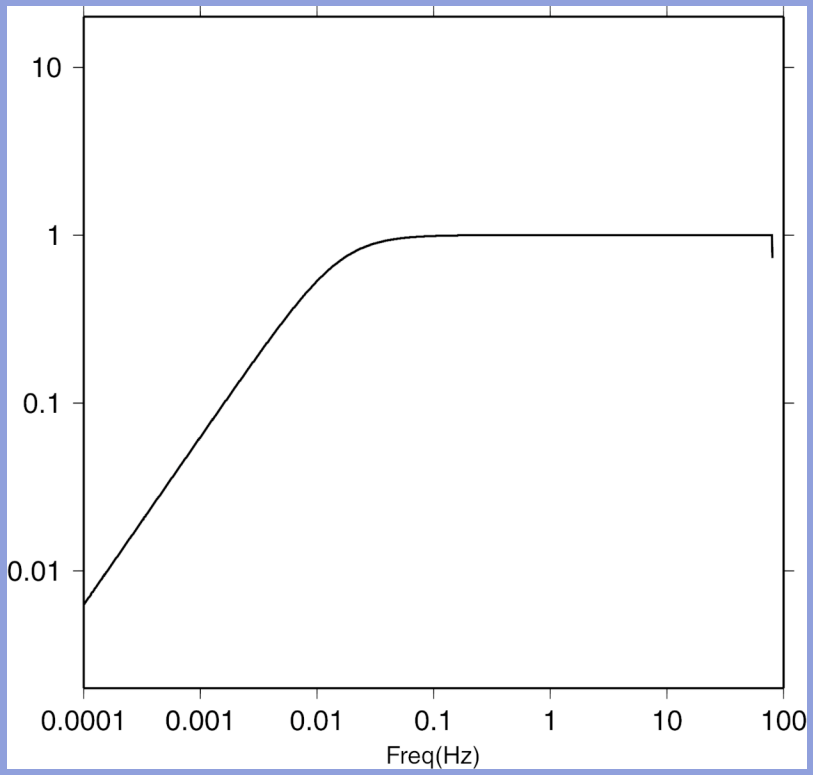
FIR FILTER COEFFICIENTS ARE STORED IN REVERSE ORDER (maximum phase) ON QUANTERRA

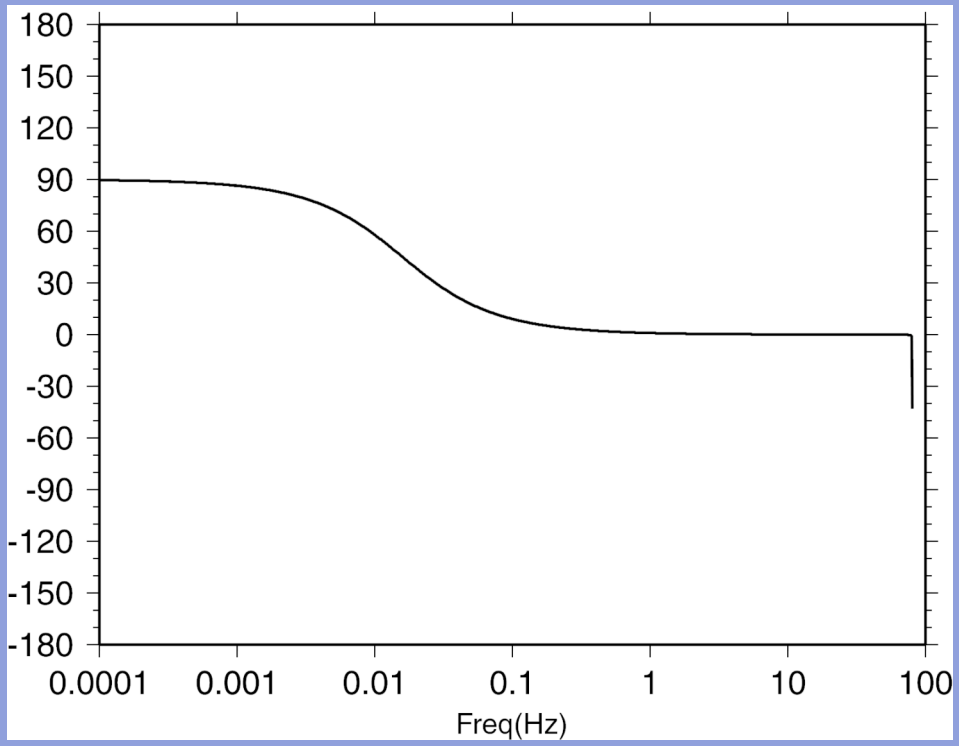
FIR FILTER COEFFICIENTS SHOULD BE STORED IN CORRECT ORDER (minimum phase) IN SEED HEADER


minimum phase filter
100 Hz
2
1
0
−1
x 10+3
linear phase filter
40 Hz
10
5
0
−5
x 10+2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0

Response of an IIR filter (DC removal)

Nanometrics





Nanometrics: IIR filter specified with coefficients (b54)

SEED prefers IIR filter expressed by poles and zeros (b53)

IIR filter: relation between coefficients and poles/zeros

$$y_k = \sum_{m=0}^{M} a_m \cdot x_{k-m}$$

time domain

a_m : filter coefficients

$$Y(z) = \sum_{m=0}^{M} a_m \cdot z^{-m} \cdot X(z)$$

z-domain

complex variable: $z = e^{s \cdot T}$

Numerator coefficients

$$H(z) = \frac{Y(z)}{X(z)} = \frac{\sum_{m=0}^{M} a_m \cdot z^{-m}}{\sum_{k=0}^{K} b_k \cdot z^{-k}} = \frac{a_0 \cdot \prod_{m=1}^{M} \left(1 - c_m \cdot z^{-1}\right)}{b_0 \cdot \prod_{k=1}^{K} \left(1 - d_k \cdot z^{-1}\right)}$$

Denominator coefficients

c_m : Roots of polynomial (zeros)

d_m : Roots of polynomial (poles)

SEED software conversion tools for waveform data

waveform data	Archive	SeedLink Real-Time
mini-SEED	✓	✓
other	Conversion (e.g): • gse2seed (ORFEUS) • codeco (ETH) • segy2mseed IRIS) • ref2mseed (IRIS) • css2mseed (IRIS) • customized (ORFEUS) • … http :// **orfeus.knm.nl**	Plugin (e.g.): • Quanterra (680, 4120, 730, 330) • EarthData PS2400 • Lennartz M24 • Guralp DM24 • SCREAM • GeoTech DR24 • NAQS (Nanometrics) • SEISAN (data files) http://**www.gfz-potsdam.de**

SEED software tools for meta-data

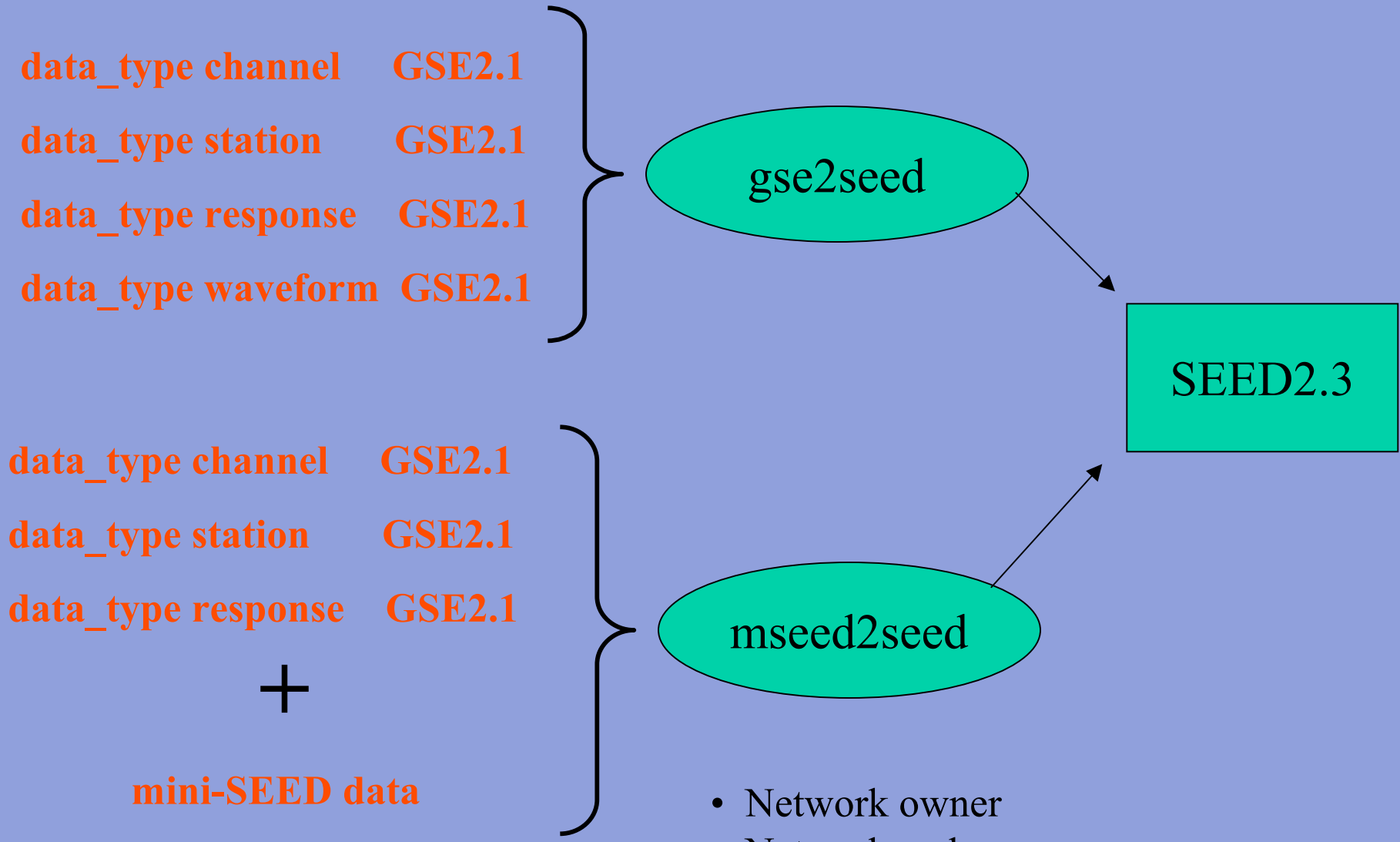
• gse2seed	converts GSE2.0 to dataless SEED	ORFEUS
• PDCC	manages dataless SEED database	IRIS
• SHAPE	converts RESP files to dataless SEED	ISTI/ORFEUS
• make_dlsv	generates 'generic' dataless SEED (now also as web request tool)	GEOFON
• wseed	generates 'generic' dataless SEED	Toulouse

GEOFON web request tool for meta-data demo

http://www.gfz-potsdam.de/cgi-bin/geofon/request?mode=xdlsv

- based on make_dlsv (Geophone)
- insrument generic information
- combination of instrument information (Hanka, Fels, Vernon)

gse2seed, mseed2seed



GSE header:

```
DATA_TYPE STATION GSE2.0
Sta   Type  Latitude  Longitude    Elev   On Date   Off Date
MUD   3C   +55.68      12.43      0.012 1999/01/01

DATA_TYPE channel GSE2.0
Sta  Chan Aux   Latitude  Longitude    Elev  Depth   Hang  Vang Sample_Rate Inst Ondate  Offdate
MUD   HHZ       56.46       9.17      0.012  0.008   -1.0   0.0  100.000000 STS-2
MUD   HHN       56.46       9.17      0.012  0.000    0.0  90.0  100.000000 STS-2
MUD   HHE       56.46       9.17      0.012  0.000   90.0  90.0  100.000000 STS-2

DATA_TYPE response GSE2.0
CAL2 MUD   HHZ      STS-2  252.97E-03  001.000 0000.01000 1999/01/01 00:00:00 2500/01/01 00:00:00
PAZ2 01 V 88.79820000E+00                005 003 Laplace transform sensor
 -0.03685E+00    -0.03696E+00
 -0.03685E+00    +0.03696E+00
 -2.51300E+02    00.00000E+00
 -1.31000E+02    -4.67300E+02
 -1.31000E+02    +4.67300E+02
 00.00000E+00    00.00000E+00
 00.00000E+00    00.00000E+00
 00.00000E+00    00.00000E+00
```

```
PAZ2 02 V 008.4661900E+20                005 000 Laplace transform anti-alias filter
 -1.30543E+04    -6.78678E+03
 -1.30543E+04    +6.78678E+03
 -9.05344E+03    +1.39072E+04
 -9.05344E+03    -1.39072E+04
 -1.42022E+04    00.00000E+00
DIG2 03 419463.0872E+00 30000.00000 Nanometrics HRD24 digitizer
FIR2 04 1.0000E+00 0005 0000.000 C 0034 FIR filter stage 1 coefficients
 +3.788775e-05   +1.997269e-04   +5.912768e-04   +1.198337e-03  +1.677196e-03
 +1.234444e-03   -1.158774e-03   -6.071729e-03   -1.261023e-02  -1.766685e-02
 -1.615370e-02   -2.631810e-03   +2.601663e-02   +6.805387e-02  +1.159861e-01
 +1.582344e-01   +1.830499e-01
FIR2 05 1.0000E+00 0003 0000.000 C 0030 FIR filter stage 2 coefficients
 +6.587914e-05   +1.899969e-04   -4.827186e-05   -1.216777e-03  -2.457607e-03
 -5.687041e-04    6.495283e-03    1.294971e-02    5.449010e-03  -2.159296e-02
 -4.696462e-02   -2.711075e-02    6.566507e-02    2.029431e-01   3.061833e-01
FIR2 06 1.0000E+00 0002 0000.000 C 0118 FIR filter stage 3  coefficients
  1.518937e-003  -2.042215e-002  -9.579908e-003   2.209426e-002  2.060824e-002
 -2.067742e-002  -3.521951e-002   1.417054e-002   5.525585e-002  1.904586e-003
 -8.790202e-002  -4.504146e-002   1.822970e-001   4.105864e-001
PAZ2  7  C  1.0000e+00  1   0.0   1  1  IIR DC removal (poles and zeros)
 +9.994811e-01    0.00000e+00
 +1.000000e+00    0.00000e+00

DATA_TYPE response GSE2.0
WID2 1999/08/15 20:10:00.010 MUD   HHZ      INT    24502  100.000000   0.00E+00
DAT2
517 519 522 517 …… (data sample values)
CHK2    34487
```

Pitfalls in preparing GSE response file:

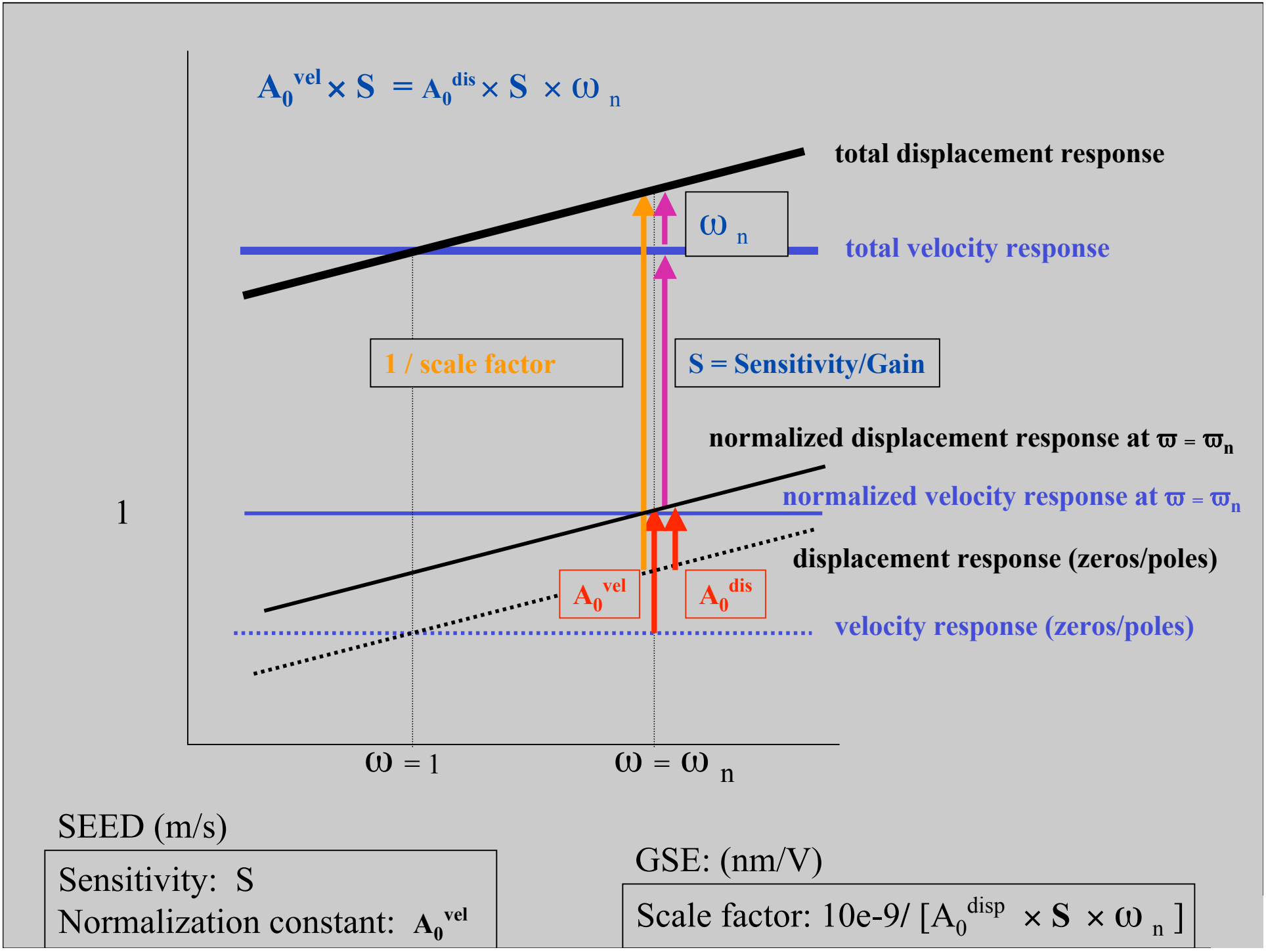
- **PAZ2: poles and zeros in Laplace (rad/sec) for displacement !!**
- **PAZ2: scale factor definition**

Scale factor: $10e\text{-}9 / [A_0^{vel} \times \mathbf{S}]$

in nm/V !!

- **FIR2: minimum phase filters (Quanterra) order of coefficients**
- **IIR filters: poles and zeros in Z-domain, not the coefficients**
- **Guralp systems: $A_0 < 0$?**

$$a_0 = \frac{1}{|H(z)|}$$



SEED (m/s)

Sensitivity: S
Normalization constant: A_0^{vel}

GSE: (nm/V)

Scale factor: 10e-9/ [$A_0^{disp} \times S \times \omega_n$]