

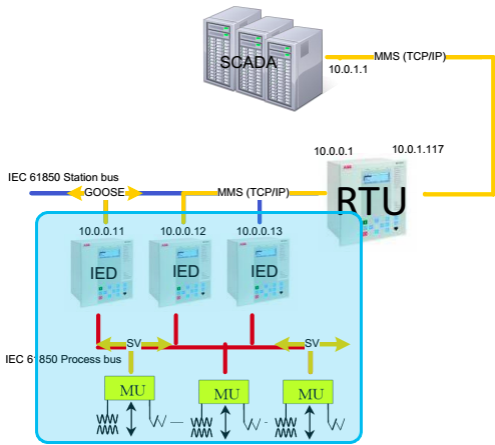
IEC 61850 Sampled Values protocol

Description of the IEC 61850 Sampled Values (SV) protocol implementation in the Typhoon HIL toolchain.

IEC 61850 (*IEC 61850 – Communication Networks and Systems in Substations*) standard defines Sampled Values (SV) protocol as a publisher/subscriber type communication. This protocol is used for information exchange between Merging Units and IEDs (*IED – Intelligent Electronic Device*) in a Substation over the Ethernet.

The "*Implementation Guidance for Digital Interface to Instrument Transformers Using IEC 61850-9-2*", or IEC 61850-9-2LE (LE - Light Edition), guide is used as a reference in the implementation of the SV protocol. The guide can be found at this link: [IEC 61850-9-2LE](#).

Figure 1. SV communication inside the Substation



The concept of SV communication is that the publisher periodically sends messages with exactly defined time intervals. The time interval depends on two factors: measured signal frequency and Samples Per Period (SPP). IEC 61850-9-2LE defines two SPP values of 80 and 256. So, for example, if the measured signal frequency is 50 Hz and SPP is 80, the sending time interval will be $1/50/80$, or 250 μ s.

All messages are published under a topic. The subscriber receives all messages from the system, but filters and parses only the messages sent with the subscribed topic.

Since the SV protocol is publisher/subscriber based, communication is possible only inside the local network (LAN).

The protocol defines the SV message as shown in [Figure 2](#). The field definition is presented in [Table 1](#).

Figure 2. SV message content

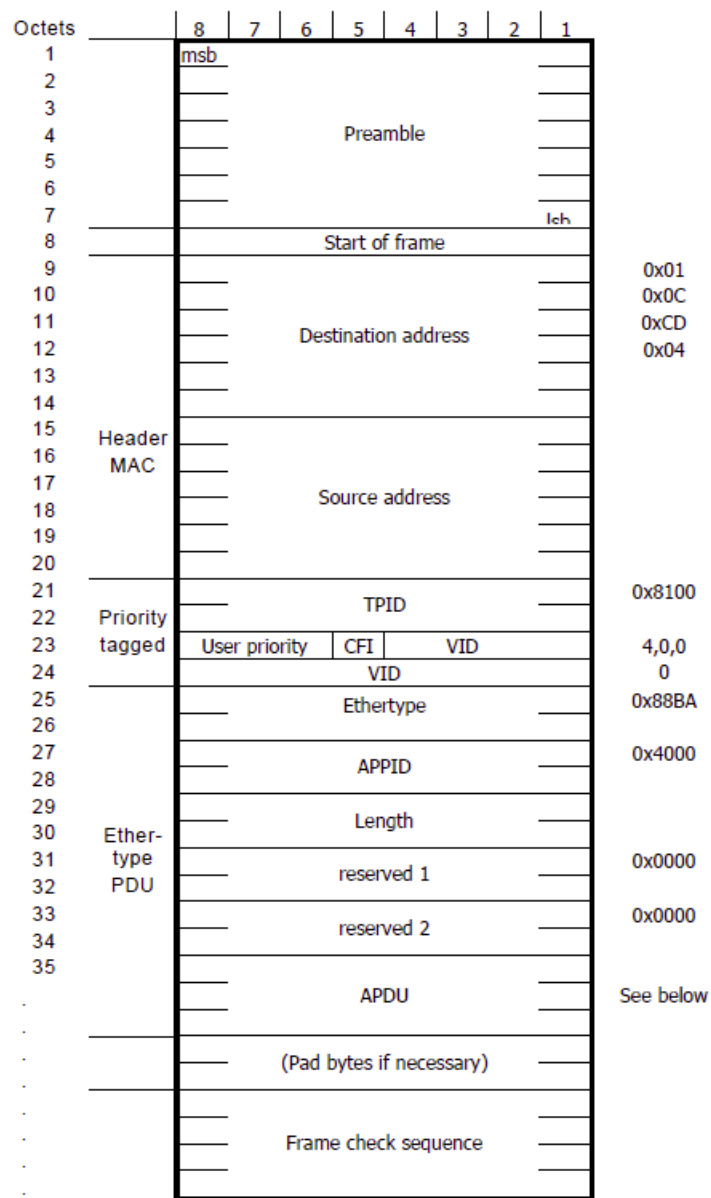


Table 1. SV message field description

Field name			Value	Description
Destination address 01:0c:cd:04:xx:xx			00:00 - 01:ff	Destination MAC address
Source address			Defined by the sending device	Source MAC address
Priority tagged	TPID		0x8100	Defines the 802.1Q protocol
	TCI	User priority	1 - 7	SV message priority: 4-7 is high priority; 1-3 is low priority
		CFI	0	
		VID	0 - 4095	Virtual LAN ID
Ethertype			0x8ba	Defines the SV protocol
APPID			0x4000 - 0x7FFF	Application ID
Length				Message length
Reserved 1			0x0000	Reserved field
Reserved 2			0x0000	Reserved field
APDU				Application Protocol Data Unit

The structure of Reserved 1 is defined in [Figure 3](#).

Figure 3. Reserved 1

Octets	8	7	6	5	4	3	2	1
0	S	R			Reserved Security			
1	Reserved Security							

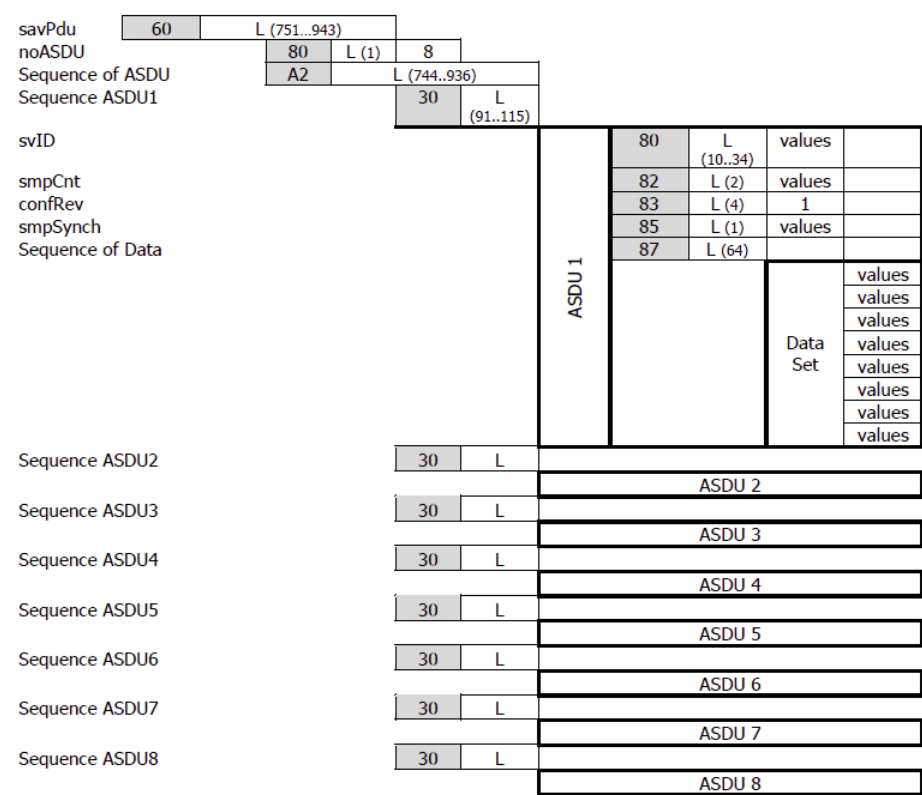
S: Simulate. This flag indicates that the SV message is sent by a test device. This flag helps the Subscriber to distinguish whether the received values are real Voltage and Current values coming from the Merging Units or simulated test values.

R: Reserved. These bits are reserved for future use and are set to 0 by default.

Reserved Security: these four bits and the Reserved 2 field form a 28 bit word defined by the security standard IEC/TS 62351-6. It is used as defined when an SV message with security is transmitted, otherwise it is set to 0.

The APDU field contains the payload of the SV messages. Every APDU contains up to 8 ASDU (Application Specific Data Unit), where each ASDU contains one three phase current and voltage measurements and each ASDU has a unique SV identification value. The content of an APDU can be found on [Figure 4](#).

Figure 4. APDU field content

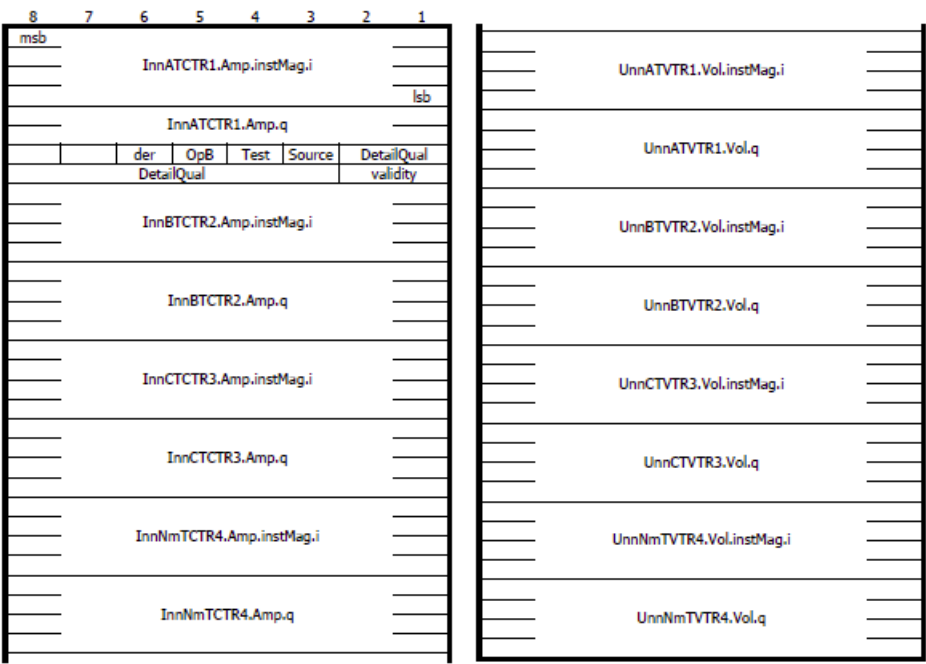


As defined by the IEC 61850-9-2LE guide, every ASDU field must contain the following fields:

- svID - Sampled Values Identifier, a user-defined unique string identifier used for subscription.
- smpCnt - index of the Sampled Values message
- confRev - configuration revision
- smpSynch - defines the synchronization mechanism of the clock used for sending the SV messages. The value can be:
 - 0 - None
 - 1 - Local
 - 2 - Remote
- Sequence of Data - sequence of measured voltage and current values as shown on Sequence of Data encoding [Figure 5](#).

The guide also defines the scaling factors for current and voltage measurements. Current measurements should be scaled with the factor of 1000 and the voltage with the factor of 100 and written in integer format.

Figure 5. Sequence of Data encoding



Sampled Values protocol in Typhoon HIL toolchain

As mentioned, SV protocol is implemented using IEC 61850-9-2LE. It is supported by the following Typhoon HIL devices: HIL402, HIL404, HIL602+, HIL604, and HIL606.

The whole SV protocol is defined by using following components from Schematic library: [SV Setup](#), [SV Publisher](#) and [SV Subscriber](#).

SV Setup

The SV Setup component window is shown in [Table 2](#).

The SV Setup component is used to define SV parameters. If SV protocol is used in the model, there must be exactly one SV Setup component for each HIL device that uses SV protocol.

The component is shown in [Table 2](#).

Table 2. SV Setup component


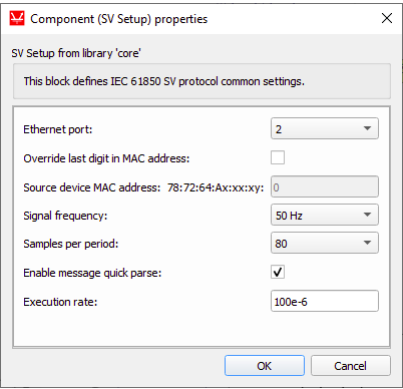
Component	Component dialog window	Component properties
 SV Setup		<ul style="list-style-type: none">• Ethernet port• Override last digit in MAC address• Source device MAC address• Signal frequency• Samples per period• Enable message quick parse• Execution rate

Table 3. SV Setup component properties description

Property name	Description
Ethernet port	Choose which Ethernet port will be used for SV protocol.
Override last digit in MAC address	Manually specify the last digit of MAC address
Source device MAC address	Modify the MAC address of the device. The MAC address of the HIL device is set to 78:72:64:Ax:xx:xy, where 78:72:64:A refers to Typhoon HIL products, x:xx:x is derived by the device's serial number, and y is defined by the selected port value. If <i>Override HIL device ID</i> is selected, you can manually specify the last digit.
Signal frequency	Signal frequency of 16.7, 25, 50 and 60 Hz can be selected for each HIL device
Samples per period	80 and 256 samples per period resolution is defined

Property name	Description
Enable message quick parse	This option is used for SV Subscriber components. When the message is first received, the message will be parsed and checked for validity. During parsing, the position of the <i>Sequence of Data</i> field will be saved and used later for faster parsing of the message. If this option is not selected, the message will be parsed every time it is received. It is highly recommended to enable this option if the SV message structure does not change during simulation.
Execution rate	Signal processing execution rate. Execution rate must match with the other components used in the model.

SV Publisher

The SV Publisher component is used for specifying parameters for one ASDU field inside the APDU (Figure 4). With each SV Publisher component, you can specify if the component creates a new SV message or if it will add an ASDU in an existing SV message. If the component creates a new SV message, you can specify the destination address, user priority, VLAN ID, and APP ID values.

Table 4. SV Publisher component

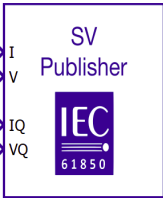
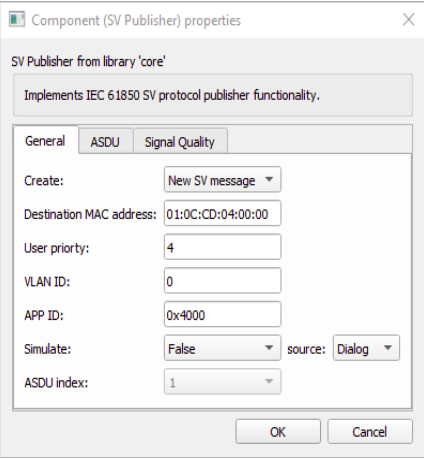
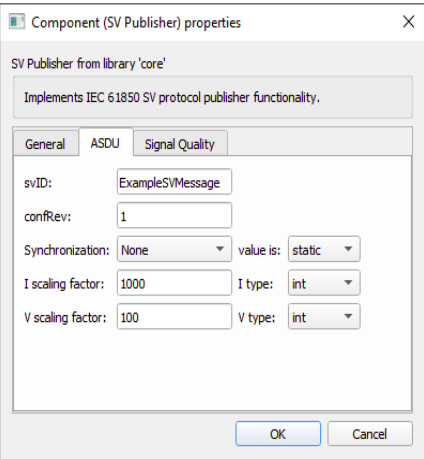
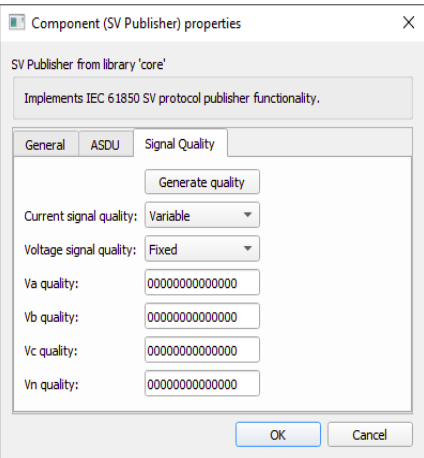
Component	Component dialog window	Component properties
<div><p>SV Publisher</p></div>	<div></div> <div></div> <div></div>	<ul style="list-style-type: none">General:<ul style="list-style-type: none">CreateDestination MAC addressUser priorityVLAN IDAPP IDSimulatesourceASDU indexASDU:<ul style="list-style-type: none">svIDconfRevSynchronizationvalue isI scaling factorI typeV scaling factorV typeSignal Quality<ul style="list-style-type: none">Generate qualityCurrent signal qualityVoltage signal qualityVa qualityVb qualityVc qualityVn quality

Table 5. SV Publisher component properties description

Property name	Description
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Property name	Description
Create	Choose if the SV Publisher component creates a new SV message with <i>New SV message</i> or if it adds an ASDU to an existing SV message with <i>Sequence ASDU</i> .
Destination MAC address	Specify the destination MAC address
User priority	Specify the user priority of the SV message
VLAN ID	Specify the VLAN identifier of the SV message
APP ID	Specify the APP identifier of the SV message
Simulate	Define if the Simulate bit in the Reserved 1 field will be True or False as defined in Figure 3 .
source	The Simulate value can be defined either through the Dialog window, a signal from the model, or through the SCADA window. If the <i>Dialog</i> option is selected, the Simulate value is fixed and defined through the <i>Simulate</i> property value. If the <i>Model</i> value is selected, an additional terminal will be created on the component that allows you to connect any signal from the model and dynamically change the Simulate value. The <i>SCADA</i> option allows you to define the Simulate value through the SV Publisher.Simulate widget in the SCADA window.
ASDU index	Specifies the index of the ASDU index inside the APDU field of SV message. If the <i>New SV message</i> option is selected, ASDU index is fixed to 1. If the <i>Sequence ASDU</i> option is selected, an index from 2 - 8 can be specified.
svID	Specify the unique SV identifier for ASDU
confRev	Specify the configuration revision number for ASDU
Synchronization	<p>The synchronization value informs the receiver whether the Current/Voltage sampling time is synchronized with the global clock value.</p> <p>Typically, SV senders are synchronized to a global (master) clock in order to relay the exact time the Current/Voltage values are sampled. In this way the receiver knows if the values are old or up to date, so they can decide whether to accept, discard, or modify the values.</p> <p>If the SV sender is synchronized to a master clock (usually using GPS or PTP protocol), the value should be specified as <i>remote</i>.</p> <p>It the SV sender does not have a connection to a master clock, but still has a way to synchronize, the value is specified as <i>local</i>.</p> <p>If the SV sender does not have any means of clock synchronization, the value is specified as <i>none</i>.</p>

Property name	Description
value is	Defines if the Synchronization value is fixed and defined using the <i>Synchronization</i> property or if it is dynamically assigned during the simulation. The dynamic value corresponds to the status of the PTP slave running alongside the SV protocol. If the PTP Slave is synchronized to the PTP Master clock, the Synchronization value will be either <i>local</i> or <i>remote</i> depending on the time traceability of the PTP Masters clock. If the PTP Slave is not synchronized, the value will be <i>none</i> .
I scaling factor	Specify the scaling factor for input current signals. Default scaling for currents is 1000.
I type	Defines the current type that is written in the SV message. For example, if the input current is 1 A and <i>int</i> type is selected, the value 0x0000 0001 will be written in the message. If the <i>real</i> type is selected, the value 0x03f8 0000 will be written.
V scaling factor	Specifies the scaling factor for input voltage signals. Default scaling for voltages is 100.
V type	Defines the voltage type that is written in the SV message. For example, if the input voltage is 1 V and <i>int</i> type is selected, the value 0x0000 0001 will be written in the message. If the <i>real</i> type is selected, the value 0x03f8 0000 will be written.
Generate quality (button)	Opens a new dialog where you can graphically define the signal quality values. Useful if the signal quality is set to <i>Fixed</i> .
Current signal quality	Choose if the signal quality is specified by signal from the model or is fixed and user defined. If the <i>Variable</i> option is chosen, a port <i>IQ</i> will appear on the component to connect the signal.
Ix quality	If the <i>Fixed</i> option is selected for <i>Current signal quality</i> , the user can manually define signal quality for each current in binary form.
Voltage signal quality	Same as <i>Current signal quality</i>
Vx quality	Same as <i>Ix quality</i>

An example using SV Publisher components is illustrated in [Figure 6](#). Only one SV Publisher component exists in the model with the parameters defined as shown on the right of the figure. The component creates a new SV message with one ASDU entry where the values are not scaled and are written in *real* format. The signal quality is fixed and predefined.

All input signals to the SV Publisher component must be vectors of length 4. The vector should be encoded as [Ia, Ib, Ic, In], [IQa, IQb, IQc, IQn], [Va, Vb, Vc, Vn], and [VQa, VQb, VQc, VQn]

[Figure 7](#) illustrates the message captured with the network sniffing tool.

Figure 6. SV Publisher component example

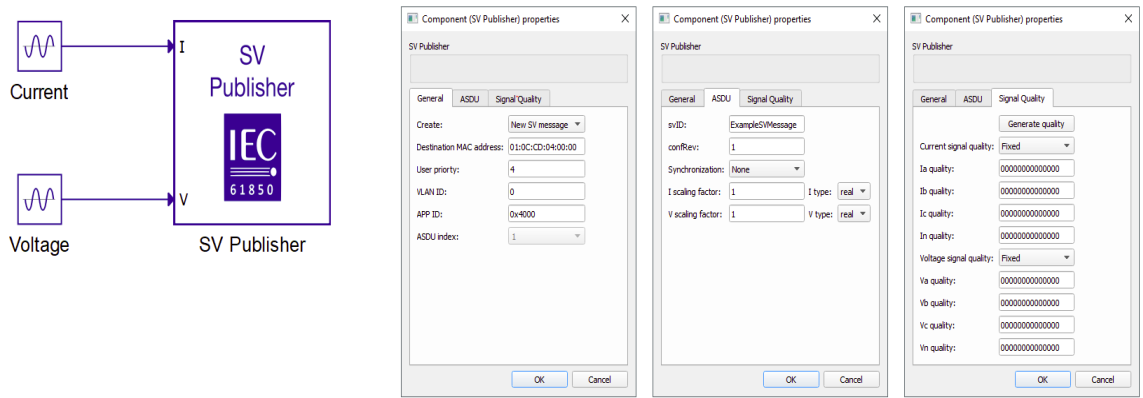


Figure 7. SV message capture

```
> Frame 3354: 128 bytes on wire (1024 bits), 128 bytes captured (1024 bits) on interface 0
▼ Ethernet II, Src: Dell_7d:02:10 (34:e6:d7:7d:02:10), Dst: Iec-Tc57_04:00:00 (01:0c:cd:04:00:00)
  > Destination: Iec-Tc57_04:00:00 (01:0c:cd:04:00:00)
  > Source: Dell_7d:02:10 (34:e6:d7:7d:02:10)
  Type: IEC 61850/SV (Sampled Value Transmission (0x88ba))
▼ IEC61850 Sampled Values
  APPID: 0x4000
  Length: 110
  Reserved 1: 0x0000 (0)
  Reserved 2: 0x0000 (0)
  ▼ savPdu
    noASDU: 1
    ▼ seqASDU: 1 item
      ▼ ASDU
        svID: ExampleSVMessage
        smpCnt: 3304
        confRef: 1
        smpSynch: none (0)
        seqData: 3f6af1f800000000bf6af1f800000000bf6af1f800000000...
```

To add an extra ASDU in the existing SV message, just add another SV Publisher component and choose the *Create: Sequence ASDU* option. This is illustrated in [Figure 8](#). The *SV Publisher* component is the same as in the example above and creates a new SV message. The *SV Publisher1* component is defined to add an ASDU to the message with APP ID 0x4000 as shown on the right of the figure.

A capture of the newly created message is illustrated in [Figure 9](#).

Figure 8. SV Publisher component example (adding ASDU)

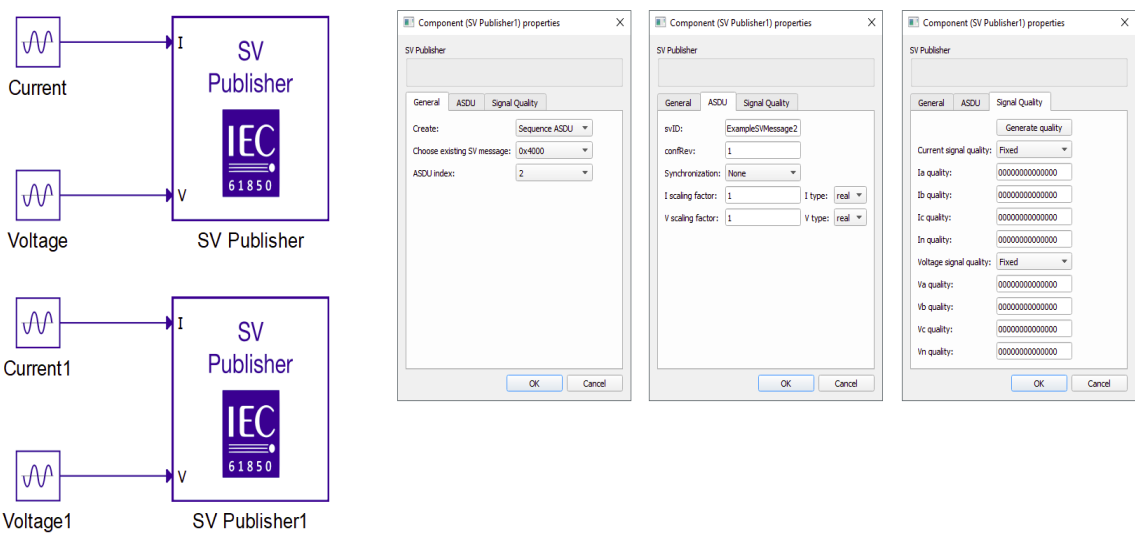


Figure 9. SV message capture (added ASDU)

```
> Frame 4005: 230 bytes on wire (1840 bits), 230 bytes captured (1840 bits) on interface 0
▼ Ethernet II, Src: Dell_7d:02:10 (34:e6:d7:7d:02:10), Dst: Iec-Tc57_04:00:00 (01:0c:cd:04:00:00)
  > Destination: Iec-Tc57_04:00:00 (01:0c:cd:04:00:00)
  > Source: Dell_7d:02:10 (34:e6:d7:7d:02:10)
  Type: IEC 61850/SV (Sampled Value Transmission (0x88ba))
▼ IEC61850 Sampled Values
  APPID: 0x4000
  Length: 212
  Reserved 1: 0x0000 (0)
  Reserved 2: 0x0000 (0)
  ▼ savPdu
    noASDU: 2
    ▼ seqASDU: 2 items
      ▼ ASDU
        svID: ExampleSVMessage
        smpCnt: 3840
        confRef: 1
        smpSynch: none (0)
        seqData: 3dc0bbdc00000000bdc0bbdc00000000bdc0bbdc00000000...
      ▼ ASDU
        svID: ExampleSVMessage2
        smpCnt: 3840
        confRef: 1
        smpSynch: none (0)
        seqData: 3dc0bbdc00000000bdc0bbdc00000000bdc0bbdc00000000...
```

PTP synchronization

The PTP synchronization mechanism ensures that all devices on the network have the same time reference. This time reference is dictated by the Master device on the network, usually called the Grandmaster clock.

Time synchronization of the SV Publishers ensure that they all start counting samples from the same moment in time. In other words, the SV Publishers reset their sample count (*smpCnt*) value to 0 each time the seconds value is changed (i.e. seconds rollover). This way, a SV Receiver that receives two SV data streams can easily compare the current/voltage values and detect phase shifts.

The PTP Slave runs automatically alongside the SV application and enables the synchronization of SV Publishers to the PTP Master clock.

PTP synchronization is available through the same Ethernet port used for the SV protocol.

IRIG-B synchronization

The use of this synchronization method is limited to devices with an IRIG-B port. The list of compatible devices can be found in the [General Specifications](#).

Each time the IRIG-B signal is received it resets the sample count (smpCnt) value and updates the internal clock of the HIL device which allows for accurate timestamps in SV Publisher messages.

If both PTP and IRIG-B synchronization methods are active, PTP will have higher priority.

More information about the IRIG-B signal can be found in the [Time synchronization](#) page.

SV Subscriber

The SV Subscriber component is used for subscribing to a certain ASDU field from a certain SV message on the network. To subscribe to an SV message, the APP ID and SV ID must be specified for message filtering. The APP ID value is used to filter the SV message from the network, and the SV ID is used to extract the corresponding ASDU from the message.

All output terminals of SV Subscriber component are vectors of length 4. The vectors are encoded as [Ia, Ib, Ic, In], [IQa, IQb, IQc, IQn], [Va, Vb, Vc, Vn], and [VQa, VQb, VQc, VQn].

Table 6. SV Subscriber component


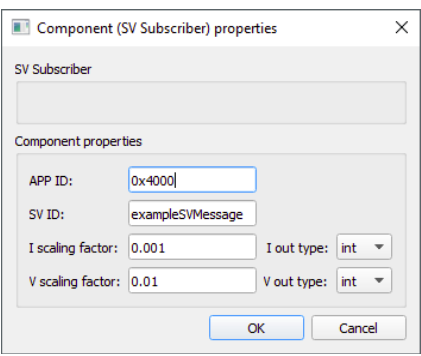
Component	Component dialog window	Component properties
 SV Subscriber		<ul style="list-style-type: none">• APP ID• SV ID• I scaling factor• I out type• V scaling factor• V out type

Table 7. SV Subscriber component properties description

Property name	Description
APP ID	APP ID value for message filtering
SV ID	SV ID for ASDU filtering
I scaling factor	Scaling factor to be applied to current values
I out type	Define the current value type which is written in the SV message
V scaling factor	Scaling factor to be applied to voltage values
V out type	Define the voltage value type which is written in the SV message

Virtual HIL support

[Virtual HIL](#) currently does not support this protocol. When using a Virtual HIL environment (e.g. when running the model on a local computer), inputs to this component will be discarded and outputs from this component will be zeroed.