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Communication with the trigger port: A beginner's guide

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Communication with the trigger port - A beginner's guide

All of our amplifiers include a digital port or trigger port, a port that can register hardware triggers. As the amplifiers are intended to be used in different research scenarios and surroundings, the trigger port's properties also vary.

What is a digital port?

A digital port or trigger port can register transistor-transistor (TTL) triggers sent on hardware level. Such triggers can, for example, be sent from an internal parallel port (LPT) of your stimulation PC or our TriggerBox . For a schematic view of the two possible trigger pipelines, please refer to Figure 1. In Figure 1 a) a trigger pipeline based on the use of an internal LPT port is depicted; in Figure 1 b) triggers are sent to the amplifier via a USB port and the TriggerBox. A few parameters must be chosen on the sender side, including trigger duration (sampling rate-specific and amplifier-specific minimum trigger duration), and the trigger bit. Further, there are several options for how to interpret incoming signals that can be configured in the Digital Port Settings in Recorder (Amplifier -> Digital Port Settings...).

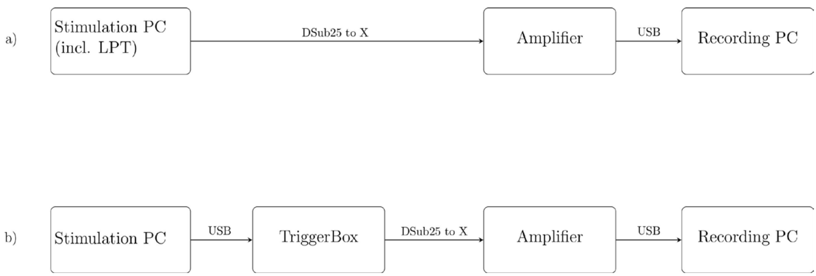


Figure 1: Schematic view of two types of potential trigger pipelines.
a) Trigger pipeline with an LPT Port. b) Trigger Pipeline with TriggerBox.

Transistor-transistor Logic (TTL) trigger levels

Among different logic level standards, our systems support the transistor-transistor logic (TTL) voltage levels. TTL trigger levels allow us to define a signal equal to either low or high. If triggers are sent for example from an LPT port, the state depends on the voltage level between ground (GND) and a corresponding pin of the port sending the signal. TTL logic levels are defined for input and output voltages as visualized in Figure 2. The range in between a logic low and high is not defined and may also be referred to as noise margin. A voltage in this range results in an uncertain, invalid state. If you are using a "plug and play" trigger source, such as our TriggerBox, there is no need to worry about these voltage levels as they comply to TTL specifications.

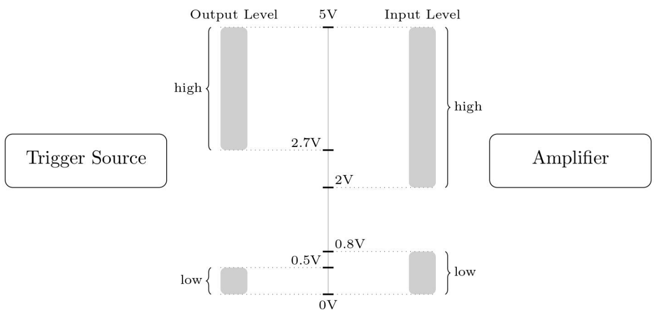


Figure 2: Input and Output voltage levels for TTL trigger at output and input level. Ranges between "high" and "low" are referred to as "noise margin" and are not defined.

High active vs low active

Trigger pulses should always have a rectangular shape. Therefore, they go from an idle state (logic 0) to an active state (logic 1) for the trigger duration, and then return to the idle state (logic 0). As shown in Figure 3, this results in two options of sending trigger pulses. Consequently, there are also two options for the interpretation of incoming signals in Recorder. When using the setting "high active" option, the amplifier interprets a voltage of 5V as logic 1. The setting "low active" results in the interpretation of a voltage of 0V as logic 1. These options can be found in the Digital Port Settings (see red box in Figure 4). Here, it is possible to choose the interpretation for all incoming triggers. Which of the two options is correct, depends on the trigger source.

Generally, a trigger marker should be generated on the rising edge of the trigger time t (see Figure 3). If the high active/low active setting is inconsistent with the trigger source, a trigger marker will instead be generated at time t+T where T is the trigger pulse duration. This causes a delay of T in the co-registration of the trigger marker with the EEG data, which might be critical for the post hoc data analysis. The difference between the two settings is also visualized in Figure 3. For more information on how to set the trigger duration T, please refer to section Trigger Duration.

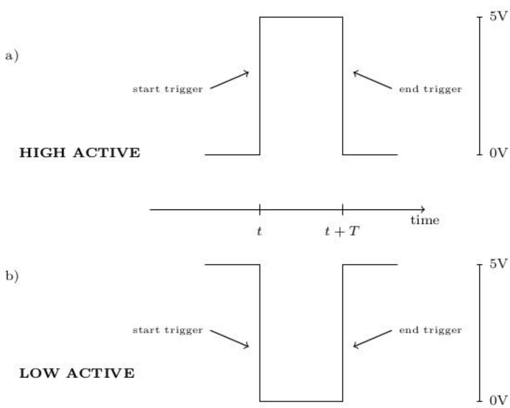


Figure 3: Difference between high active and low active setting.
a) high active trigger signal.
b) low active trigger signal.

An easy way to figure out which setting should be used, is to open up the Digital Port Settings Window in Recorder, set all bits to “idle” or “0” on the sender side, and check the “Current State” (see purple box in Figure 4): if the bits are marked in black, therefore, their current state is “low”, the setting “high active” is likely to be appropriate. If the bits are marked in red, therefore, their current state is “high”, the setting “low active” is likely to be appropriate (see yellow box in Figure 4).

Trigger duration

The trigger duration T (see Figure 3) must be set on the sender side. Setting an appropriate trigger duration is crucial for reliable registration of each trigger. If the duration is too short, a trigger might not be registered at all. The minimum trigger duration depends on two factors: 1) the amplifier; and 2) the current sampling rate. For each amplifier and sampling rate, there is a mandatory minimum duration. For lower sampling rates, longer trigger durations are needed to make sure triggers are reliably detected. Tables for all values can be found in Section Amplifier-specific settings.

Enable a trigger bit

Looking at the Digital Port Settings window, there are a few other options that may be adjusted to fit your requirements. Since most of our amplifiers offer an 8-bit trigger port (for more information on this see Table 5), it is possible to disable single trigger bits. This is done by ticking or unticking individual bits (see green box in Figure 4).

Be aware that all enabled bits together are concatenated to form a binary code. This code corresponds to a specific trigger marker that is co-registered with your EEG. Hence, if you disable one bit, the resulting binary code will change, and this will, in turn, change your trigger markers.

Trigger type

Additionally, each bit can be assigned to a specific „type“ which is the string entered in the Digital Port Settings (see blue box in Figure 4). By default, there are two trigger types in BrainVision Recorder: “Stimulus” and “Response”. Each trigger bit can be named individually according to user-specific requirements.

The type will be shown in full when evaluating data e.g. in BrainVision Analyzer 2. Please note that in BrainVision Analyzer the notation changes from “trigger” to “marker”. During a recording, an abbreviation of the type consisting of its first letter (e.g. „S“ for Stimulus) will be shown in combination with the integer n related to the trigger. If two different strings begin with the same letter (e.g. „CF1“ and „CF2“) both will show as „Cn“ in Recorder, but the marker abbreviations will be displayed in different colours. BrainVision Analyzer and the marker file (.vmrk) show the full description (in this case: „CF1n“ and „CF2n“).

If you name each bit differently, for example, bit 0, Type „A“, bit 1, Type „B“.... up to bit 7, Type „H“, you will have one possible trigger per type/bit (A1, B1, C1,..., H1).

Debouncing

Finally, it is possible to enable a “Debouncing” option and select a duration for which this setting should be enabled (see yellow box in Figure 4). This setting should only be used if you expect multiple triggers within a short period and want to reject all but the first. A pattern like this might occur when using a pushbutton actuated by a subject to generate triggers. It can be a useful tool to keep your data clean, however, you should be aware of the risk of rejecting “real” triggers unintentionally.

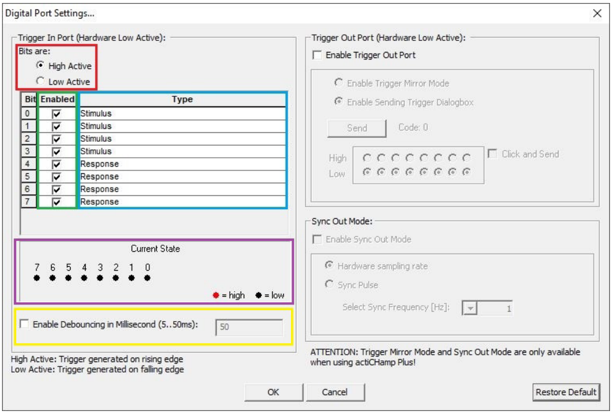


Figure 4: Example of Digital Port Settings in Recorder for actiCHamp family showing high/low active setting (red), options to enable single bits (green), trigger types (blue), the current state of single bits (purple), and the debouncing option (yellow).

Marker file

The marker file lists all trigger markers co-registered with the EEG data. Each trigger marker entry is accompanied by a number of descriptive parameters:

1. marker number (within recording)
2. type (see Section Trigger Type)
3. description (abbreviation of trigger type and number)
4. channel number (0 = marker is related to all channels)
5. size in data points (how many data points did the trigger duration span)

Depending on the Recorder license you are using the extension for this file may be: .vmrk, .bmrk, .amrk, .lmrk.

Examples

In Figure 5, Figure 6 and Figure 7 you can see two examples for what markers could be generated, using the same input signal but different configurations in the Digital Port Settings.

In Figure 5, the trigger type (see also section Trigger Type) is identical for all bits. Consequently, the incoming signals are interpreted as one 8-bit number and markers “S1” to “S255” are possible. In this example, we can therefore, sum all bits together and get:

$$1*2^0 + 0*2^1 + 1*2^2 + 0*2^3 + 1*2^4 + 1*2^5 + 1*2^6 + 0*2^7$$
$$= 1 + 0 + 4 + 0 + 16 + 32 + 64 = 117$$

The resulting marker is “S117”.

The marker file entry could look as follows:
Mk13=Stimulus,S 117,8599,1,0

Stimulus	Stimulus	Stimulus	Stimulus	Stimulus	Stimulus	Stimulus	Stimulus
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	1	1	0	1	0	1
$0 \cdot 2^7$	$1 \cdot 2^6$	$1 \cdot 2^5$	$1 \cdot 2^4$	$0 \cdot 2^3$	$1 \cdot 2^2$	$0 \cdot 2^1$	$1 \cdot 2^0$

Figure 5: Example of how to calculate the trigger value of a specific trigger. Results in the bottom row must be summed, therefore, the resulting trigger is 1 + 4 + 16 + 32 + 64 = 117 -> S117.

In Figure 6, the type for bits 0 to 3 is “Stimulus”, whereas the type for bits 4 to 7 is “Response”. In this case, incoming signals are interpreted as two 4-bit numbers and markers “S1” to “S15” as well as “R1” to “R15” are possible. In this example, we can, therefore, sum respective bits together and get:

Type “Stimulation”

$$1*2^0 + 0*2^1 + 1*2^2 + 0*2^3$$
$$= 1 + 0 + 4 + 0 = 5$$

Type “Response”

$$1*2^0 + 1*2^1 + 1*2^2 + 0*2^3$$
$$= 1 + 2 + 4 + 0 = 7$$

The resulting markers are “S5” and “R7”.

The marker file entry could look as follows:
Mk20=Stimulus,S 5, 13559,1,0
Mk21=Response,R 7, 13559,1,0

Response	Response	Response	Response	Stimulus	Stimulus	Stimulus	Stimulus
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	1	1	0	1	0	1
$0 \cdot 2^3$	$1 \cdot 2^2$	$1 \cdot 2^1$	$1 \cdot 2^0$	$0 \cdot 2^3$	$1 \cdot 2^2$	$0 \cdot 2^1$	$1 \cdot 2^0$

Figure 6: Example of how to calculate the trigger value of a specific trigger. Results in the bottom row for Bit 0 to Bit 3 and Bit 4 to Bit 7 must be summed, therefore the resulting triggers are 1 + 4 = 5 -> S5 and 1 + 2 + 4 = 7 -> R7.

In Figure 7, the type for bits 0 to 3 is “Stimulus”, whereas the type for bits 4 to 7 is “Response”. Further Bits 1 and 4 are disabled. In this case, incoming signals are interpreted as two 3-bit numbers and markers “S1” to “S7” as well as “R1” to “R7” are possible. The disabled bits are disregarded, and the remaining enabled bits of the same type are concatenated. In this example, we can, therefore, sum respective bits together and interpret them as two 3-bit numbers:

Type “Stimulation”

$$1*2^0 + 1*2^1 + 0*2^2$$
$$= 1 + 2 + 0 = 3$$

Type “Response”

$$1*2^0 + 1*2^1 + 0*2^2 + 0*2^3$$
$$= 1 + 2 + 0 = 3$$

The resulting markers are “S3” and “R3”.

The marker file entry could look as follows:
Mk2=Stimulus,S 3, 4630,1,0
Mk3=Response,R 3, 4630,1,0

Response	Response	Response	Response	Stimulus	Stimulus	Stimulus	Stimulus
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	1	1	1	0	1	0	1
$0 \cdot 2^3$	$1 \cdot 2^1$	$1 \cdot 2^0$		$0 \cdot 2^2$	$1 \cdot 2^1$		$1 \cdot 2^0$

Figure 7: Example of how to calculate the trigger value of a specific trigger. Bits 1 and 4 are disabled, therefore, the remaining trigger bits must be added differently compared to the previous example. The resulting triggers are 1 + 2 = 3 -> S3 and 1 + 2 = 3 -> R3.

Amplifier-specific information

There are some properties, that are not present in every amplifier. For example, our amplifiers may have a varying number of trigger bits or additional capacities. Amplifier-specific settings and options are described in the sections below.

actiCHamp family

The following section describes trigger options for our actiCHamp and actiCHamp Plus amplifiers. Some functions are specific to each, and some identical.

Both amplifiers have an 8-bit trigger in port and an 8-bit trigger out port. You can connect to either of the ports using a DSub9 cable.

To be detected by the amplifier, trigger pulses must have a minimum duration proportional to the sampling rate, as mentioned in the section Trigger Duration. Appropriate trigger durations are listed in Table 1. The pin assignments for the Trigger In and Trigger Out ports are shown in Table 2 and Table 3.

Sampling Rate [Hz]	Minimum trigger duration [ms]
100	20
200	10
250	8
500	4
1000	2
2500	0.8
5000	0.4
10000	0.2
25000	0.08
50000	0.04
100000	0.02

Table 1: Recommended minimum trigger durations for actiCHamp and actiCHamp Plus.

Table 2: Trigger In pin assignment on amplifiers of actiCHamp family.

Pin number on DSub9 connector (female)	Function
1	Bit 0
2	Bit 1
3	Bit 2
4	Bit 3
5	Bit 4
6	Bit 5
7	Bit 6
8	Bit 7
9	GND

Table 3: Trigger Out pin assignment on amplifiers of actiCHamp family.

Pin number on DSub9 connector (male)	Function
1	Bit 0
2	Bit 1
3	Bit 2
4	Bit 3
5	Bit 4
6	Bit 5
7	Bit 6
8	Bit 7
9	GND

actiCHamp

actiCHamp has an eight-bit trigger in port. The trigger out port can be used only while the Digital Port Settings window is open (see Figure 8). It can be used to send single triggers.

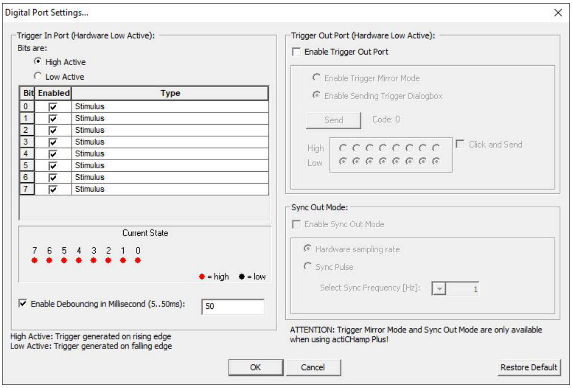


Figure 8: actiCHamp and actiCHamp Plus Digital Port Settings.

actiCHamp Plus

Additional to the functions provided by actiCHamp, actiCHamp Plus can mirror the triggers received at the Trigger In port to its Trigger Out port. The "Trigger Out" port will mirror all trigger bits, regardless of the settings for "Trigger In". Additionally, a "Sync Out" synchronization trigger can be sent corresponding to either the hardware sampling rate or a frequency selectable from the drop-down menu in the Digital Port Settings. This synchronization trigger is accessible via a 3.5mm phone jack connector. A more detailed description of this feature can be found in the actiCHamp (Plus) operating instructions.

BrainAmp family

The BrainAmp family supports 16 trigger bits received via the USB 2 Adapter. The connector for the BrainAmp trigger port is a DSub26. The setting for "High Active" or "Low Active" can be changed for two groups of trigger bits: Bits 0-7 and Bits 8-15. Further, the function "Both Active" allows the user to detect rising and falling edges of a trigger pulse rather than either rising or falling edges. Finally, the DC correction feature can be actuated by an arbitrary bit, by setting the Trigger Type to "DC correction" (see also here). A screenshot of the Digital Port Settings that are available for amplifiers of the BrainAmp family is available on the right. Recommended minimum trigger lengths are listed in Table 4.

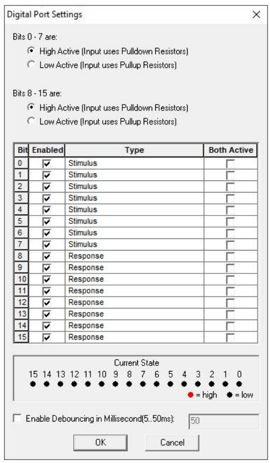


Table 4: Recommended minimum trigger durations for amplifiers of the BrainAmp family

Sampling Rate [Hz]	**Minimum trigger duration [ms]**
100	10
200	5
250	4
500	2
1000	1
2500	0.4
5000	0.2

Table 5: Pin assignment for trigger port on amplifiers of the BrainAmp family.
NC = not connected.

Pin number on DSub26 connector (female)	**Function**
1	GND
2	Bit 1
3	Bit 3
4	Bit 5
5	Bit 7
6	Bit 9
7	Bit 11
8	Bit 13
9	Bit 15
10	NC
11	NC
12	VCC (3.3V)
13	NC
14	0
15	2
16	4
17	6
18	8
19	10
20	12
21	14
22	GND
23	Block +
24	Block -
25	5 kHz out
26	NC

LiveAmp

Depending on its configuration, your LiveAmp amplifier will have a different number of trigger bits available. If you are using a LiveAmp 8, 16, or 32 without the Sensor and Trigger Extension you have a one-bit Trigger In port available. The connector is a 2.5 mm phone jack. Accordingly, LiveAmp 64 (two LiveAmp 32 amplifiers and a LiveAmp 64 adapter), has two trigger bits available, consisting of two 2.5 mm phone jack connectors. Without the Sensor and Trigger Extension, no Trigger Out ports are available. Minimum trigger lengths for specific sampling rates are displayed in Table 6.

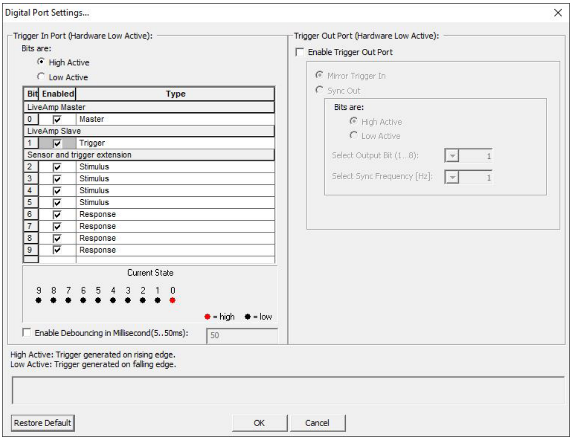


Figure 9: Digital Port Settings for LiveAmp 64 with Sensor and Trigger Extension.

Sampling Rate [Hz]	Minimum trigger duration [ms]
250	8
500	4
1000	2

Table 6: Recommended minimum trigger durations for LiveAmp.

LiveAmp and Sensor and Trigger Extension

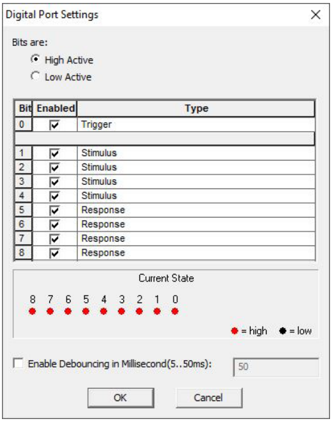
With the Sensor and Trigger Extension LiveAmp's trigger ports can be extended by an eight-bit Trigger In and an eight-bit Trigger Out port. Each of these ports is accessed with a DSub9 connector. As an alternative to the "Mirror Trigger In" option, the Trigger Out Port is capable of sending "Sync Out" triggers (more information about this feature can be found in the LiveAmp operating instructions).

Table 7: Trigger In pin assignment on the Sensor and Trigger Extension for LiveAmp. Note that the physical port for Bit 0 is located on the LiveAmp amplifier.

Pin number on DSub9 connector (female)	Function
1	Bit 1
2	Bit 2
3	Bit 3
4	Bit 4
5	Bit 5
6	Bit 6
7	Bit 7
8	Bit 8
9	GND

Table 8: Trigger Out pin assignment on the Sensor and Trigger Extension for LiveAmp.

Pin number on DSub9 connector (male)	Function
1	Bit 0
2	Bit 1
3	Bit 2
4	Bit 3
5	Bit 4
6	Bit 5
7	Bit 6
8	Bit 7
9	GND



V-Amp

Nine trigger bits are available in the V-Amp. The first bit is numbered 0 and is located on the Trigger 2 port (3.5 mm jack) of the amplifier. All the remaining bits are located on the Trigger 1 port with a DSub9 connector. Trigger pulses must have a minimum duration, proportional to the sampling rate. Appropriate trigger durations for V-Amp are listed in Table 9. A screenshot of the Digital Port Settings for V-Amp can be seen in the screenshot on the left.

Table 9: Recommended minimum trigger durations for V-Amp.

Sampling rate [Hz]	Minimum trigger duration [ms]
100	25
250	10
500	5
1000	2.5
2000	2.5
5000	0.5
10000	0.5
20000	0.5

Table 10: Trigger In pin assignment on V-Amp. Note that the physical port for Bit 0 is located on the 3.5mm phone jack connector.

Pin number on DSub9 connector (female)	Function
1	Bit 1
2	Bit 2
3	Bit 3
4	Bit 4
5	Bit 5
6	Bit 6
7	Bit 7
8	Bit 8
9	GND

TriggerBox

The Brain Products TriggerBox helps to handle and merge triggers arriving from different sources. It can also be used to convert markers from serial USB to TTL triggers. The pin out of two Trigger In ports (PC 0-7 and In 8-15), and the Trigger Out port (Out Amp) are depicted in Table 11, Table 12, and Table 13.

For more specific information on this product please refer to the operating instructions.

Table 11: Pin out of PC 0-7 connector on TriggerBox

Pin number on DSub25 connector	Function
1	NC
2	Bit 0
3	Bit 1
4	Bit 2
5	Bit 3
6	Bit 4
7	Bit 5
8	Bit 6
9	Bit 7
10	NC
11	NC
12	NC
13	NC
14	NC
15	NC
16	NC
17	NC
18	NC
19	NC
20	NC
21	NC
22	NC
23	NC
24	NC
25	GND

Table 12: Pin out of In 8-15 connector on TriggerBox.

Pin number on DSub9 connector	Function
1	Bit 8
2	Bit 9
3	Bit 10
4	Bit 11
5	Bit 12
6	Bit 13
7	Bit 14
8	Bit 15
9	GND

Table 13: Pin out of Out (Amp) connector on TriggerBox.

Pin number on DSub25 connector	Function
1	NC
2	Bit 0
3	Bit 1
4	Bit 2
5	Bit 3
6	Bit 4
7	Bit 5
8	Bit 6
9	Bit 7
10	Bit 7
11	Bit 7
12	Bit 7
13	Bit 7
14	Bit 7
15	Bit 7
16	Bit 7
17	Bit 7
18	NC
19	NC
20	NC
21	NC
22	NC
23	NC
24	+ 5V
25	GND

Summary

There are many aspects to pay attention to when setting up triggers. This applies to both hardware and software. A summary of trigger specifications for different amplifiers can be found in. If you have additional questions about triggers in your experiment, please contact the Brain Products Technical Support Team at techsup@brainproducts.com.

Table 14: Trigger Specifications for different amplifiers.

	actiCHamp	actiCHamp Plus	BrainAmp	LiveAmp 8/16/32 (+ STE)	LiveAmp 64 (+ STE)	V-Amp
Trigger bits (in)	8	8	16	1 (+ 8)	2 (+ 8)	1 + 8
Connector	DSub9	DSub9	DSub26	2.5 mm phone jack (+ DSub9)	2x 2.5 mm phone jack (+ DSub9)	3.5 mm phone jack + DSub9
Trigger bits (out)	8 (only in Digital Port Settings)	8	0	0 + 8	0 + 8	0
Connector	DSub9	DSub9	-	- (DSub9)	- (DSub9)	-

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