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## STMISOLA LINEAR ISOLATED STIMULATOR

The Constant Current and Constant Voltage Isolated Linear Stimulator (STMISOLA) will connect to any analog output signal drive (±10 V input) and provides considerable flexibility in stimulation protocols:


- **Voltage and current stimulator (unipolar or bipolar)**—

  The STMISOLA connects directly to the STM100C (OUTPUT 50 Ω port) or the AMI100D/HLT100C/UIM100C (Analog Output 0 or 1 port) associated with the MP160/150 system.

  Interface STMISOLA to MP36R or MP36R Analog Out port; the DSUB9 to 3.5 mm mono jack allows the MP36R/MP36 to be used with the STMISOLA for arbitrary stimulus output. Works with Acq*Knowledge* 4.4.2 or above (MP36R) or BSL 4.1.2 or above (MP36).

  **Linear stimulator**—the STMISOLA can be used to generate stimulation signals that can have arbitrary waveshape. Typically, stimulators can only generate simple unipolar or bipolar pulses. The STMISOLA, however, can output unipolar or bipolar arbitrary waves such as pulse (single or train), square, sine, triangle, exponentially decaying, modulated envelopes, and fully user-specified types.

The STMISOLA can output either voltage or current waveforms.

- **Voltage (V) mode**—the STMISOLA multiplies the Control Input Voltage by a factor of 20, to present that amplified signal at the STMISOLA output.
  - In the case of a maximum ±10 V input control signal, the STMISOLA will output a ±200 V signal, with an output of either 100 ohms or 1 K ohms. These output impedance settings will act to limit the available output current.
- **Current (I) mode**—two settings.

The STMISOLA provides two options for output current mode.

1) High current mode (Zout switch set to 100 ohms), provides a gain factor of 10 ma/volt.
2) Low current mode (Zout switch set to 1 K ohms), provides a gain factor of 1 ma/volt. Low current mode permits much improved control for currents less than 10 ma.

The STMISOLA multiplies the Control Voltage by the factor indicated (K in ma/V) to present that associated output current at the STMISOLA output.

In the case of a maximum ±10 V Control Input Voltage, for:

- Zout = 100 ohms, K=10 ma/V: the STMISOLA will output ±100 ma
- Zout = 1000 ohms, K=1 ma/V: the STMISOLA will output ±10 ma
- In both cases, the voltage compliance is ±200 V.

There are two basic **stimulation modes** for the STMISOLA:

- Voltage
- Current

In voltage mode, the STMISOLA has two different output impedance (Zout) settings (100 ohms and 1 K ohms). Depending on the setting, the output voltage (Vout) on the electrode impedance load (Ze) will be subject to the following formula:

- Vout = [Ze/(Ze+Zout)] * Vc * 20
- Where: Vc is the input control voltage

In current mode, electrode load impedance does not impact STMISOLA gain accuracy. The STMISOLA will simply output the specified current (subject to the applied control voltage), despite the electrode load impedance, up to the point of maximum voltage compliance (+/- 200 volts).

**Isolation characteristics**—The STMISOLA isolates the Control Input Voltage from the stimulus output to 1500 VDC HiPot and approximately 1000 pF of coupling capacitance.

This *very high degree of input/output isolation* helps ensure subject safety and helps to substantially reduce, or eliminate, stimulus artifact.

Stimulus artifact results when some percentage of electrical current from the stimulation site is directed to the recording site due to electrical leakage paths intrinsic to the stimulation/recording equipment. In the case of the STMISOLA, the leakage conductance and capacitance that permit this artifact to occur are reduced to very small values.

**Power ON Safety**—when you Power ON the STMISOLA, you must also hold Reset for at least 3 seconds. This forces the unit into an "operational but no output state" and protects the subject if accidentally connected to electrodes on power up.

## Operating Details

**→ Review Important Notes and Safety Notes before operating the STMISOLA**

### Important Notes

A) **The Current Feedback Monitor Cable (CBLCFMA) is recommended** for use with any voltage stimulator; to isolate CBLCFMA output, use INISOA and AMI100D/HLT100C. Always make sure to place the electrodes on the participant at least 10 minutes before starting any electrical stimulation. Use a CBLCFMA to monitor and record the actual current delivered to the participant at ALL times. A large enough change in current delivered to the participant will alter the subjective perception of the stimulation. Thus, an unpleasant shock may become painful if more current starts being delivered or become ineffectual if less current is being delivered than during threshold identification. Changes in the levels of delivered current are due to changes in impedance. Changes in impedance could be due to a number of factors: gel saturating the skin over time; gel drying up – over longer period of times; hydration level of participant; sweating; decoupling of electrodes and skin due to motion artifacts; etc.

B) In Current (I) Mode stimulation, if the output has a load (typically high impedance) that induces railing for the specific output current, the STMISOLA will immediately go into “Protect” mode. In the case of an unloaded output, this state will happen as soon as the STMISOLA is placed into Current (I) Mode stimulation. This happens because an “unloaded” STMISOLA output simply means that an arbitrarily high resistance load is attached to the STMISOLA. To correctly operate in Current (I) Mode stimulation, the proper load must be placed between stimulation electrodes and then “Reset” pushbutton must be pressed to 3 seconds to activate the unit.

C) In either stimulation mode (V or I), the output level (OL) will directly be a function of the applied Control Input Voltage (CIV). The conversion ratios are as follows:

| | |
|---|---|
| Voltage (V) Mode: | CIV (volts)*20 (volts/volts) = OL (volts) |
| Current (I) Modes: | Zout = 100 ohms: CIV (volts)*10 (ma/volts) = OL (ma) |
| | Zout = 1 K ohms: CIV (volts)*1 (ma/volts) = OL (ma) |

D) When an output waveform is present, the output waveform indicator—**red** LED just above BNC output connector —will glow. Waveform output level indication can be observed as an increasing intensity of this red LED. This output waveform indicator is designed to provide a visual indication of output, even if the wave duration is extremely short, so it may be possible that this indicator shows a waveform output for some brief period of time after the output wave has already passed.

### Safety Notes

1. Never place the stimulation electrodes so that it’s possible for stimulation current to pass through the subject’s heart. This can happen if electrodes are placed so that the leads “straddle” to the left and right sides of the subject’s body. Place the stimulation electrodes close together on the SAME (left or right) side of the subject’s body appendage. Only place stimulation electrodes so they are on the appendage of interest. For example, for left leg stimulation, only place stimulation electrodes on the left leg and on NO other location on the body.

2. Do not power ON or OFF the STMISOLA unit while electrodes attached to the subject. Always be sure to place the STMISOLA in VOLTAGE mode, with zero volts applied to input, before attaching/removing electrodes to/from the subject. Zero volts is automatically applied to the STMISOLA input if the STMISOLA input cable is unplugged from any signal source.
3. For MRI Applications, when possibly considering the use of the STMISOLA for associated electrical stimulation of human subjects, please refer to BIOPAC Application Note 257 for context, warnings and details.
4. It is ideal to use the STM100C for stimulation control, because it permits manual control of the stimulation level. To use the STM100C:
   - Plug the Control Input Voltage line for the STMISOLA into the 50 ohm output of the STM100C.
   - Before stimulation begins, turn the Output Level Control knob to 0%.
   - Initiate stimulation in the Acq*Knowledge* software (see Application Note AH162).
   - After stimulation is initiated, slowly turn the STM100C Output Level Control to the desired level.
   - When the stimulation session is ended, turn the STM100C Output Level Control back to 0%.
5. **Do not remove electrodes** while in current (I) mode; it's possible for subjects to receive a shock if they remove electrodes while the STMISOLA is in current (I) mode because the STMISOLA responds to the impedance increase and causes the current source to swing to a positive or negative rail.

**STMISOLA: Additional Notes Regarding Use of Current Mode Output**

Current Mode stimulus output can appear to demonstrate non-intuitive behavior. This behavior is very different than Voltage Mode stimulus output.

The STMISOLA is a voltage-controlled stimulation system. In the case of Current Mode output, options exist to map the stimulus output current to the input control voltage. These two options are:

**Option 1**

+10 V input control voltage maps to +100 ma stimulus output current

-10 V input control voltage maps to -100 ma stimulus output current

**Option 2**

+10 V input control voltage maps to +10 ma stimulus output current

-10 V input control voltage maps to -10 ma stimulus output current

For both Option 1 or 2, the behavior is essentially the same, even though the stimulus output current range is different. When the input control voltage is close to 0 V, the stimulus output current is also proportionally close to 0 ma.

**IMPORTANT NOTE:**

When attempting to set the input control voltage to zero volts, the resulting voltage will most certainly never be exactly zero volts. Instead of zero, the input voltage will simply be close to zero, perhaps on the order of +0.001 V or -0.00001 V.

So, if the input control voltage is non-zero, the current output will also be non-zero!

**Example A:**

A non-zero input control voltage of 0.001 V will result in a non-zero stimulus output current of 0.001ma, assuming STMISOLA is set to Option 2. If the STMISOLA stimulus output is connected to an infinite (or very large) impedance, the STMISOLA will attempt to drive 0.001 ma through this very large impedance. Assuming the large impedance is 200 Mohm, then:

0.001 ma x 200,000,000 ohms = 200 V (estimate)

Accordingly, in practical operation, if the STMISOLA is used in current mode and is attached to electrodes that are making intermittent contact to the tissue of the subject, intermittent shocks may be felt by subject, even if 0 V is applied to the input control voltage. This is because the STMISOLA will drive directly to the compliance voltage limit and start to behave as a voltage stimulator.

Intermittent contact with electrodes will result in intermittent +/- 200 V shocks being applied to the subject. These possible transient shocks may be felt, but only when skin electrodes dislodge and reconnect to the subject's tissue.

This possible +/- 200 V stimulus will be present on STMISOLA output leads at the point when the electrodes reconnect with the tissue, assuming the electrodes had dislodged previously. At the point of reconnect, the voltage level falls back below the compliance threshold and the errant stimulus goes away, but this process takes a few microseconds. If transient connects and reconnects happen over a period of time, many bursts of voltage will impact the electrode sites.

This potential safety issue can be mitigated through a couple of methods:

1. Employ a bipolar voltage clamp across the stimulus output current leads.
2. Employ an added parallel resistance across the stimulus output current leads.

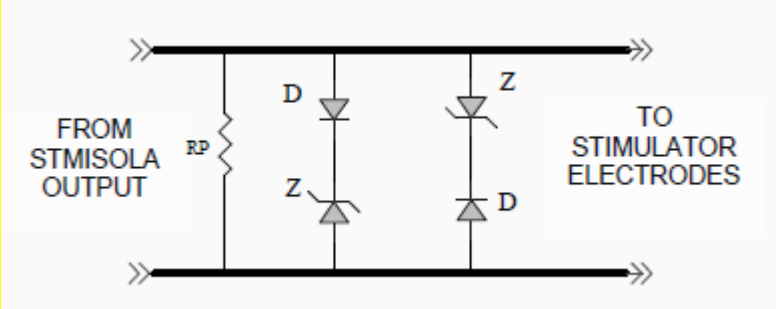
In method 1, the bipolar voltage clamp simply limits the compliance voltage to a deemed safe level.

Two, oppositely directed, diode and Zener diode series circuits are used to define the voltage clamp maximum value, assuming the stimulus electrodes may become dislodged.

In method 2, the maximum load impedance will be dictated by the chosen added parallel resistance.

Also, these two methods can be used together, for additional safety consideration.

**Components and Connections:**




**Choose:**

Rp: Resistor; should have value much larger than resistance through intended load (e.g., subject).

Z: Zener diode; breakdown voltage should be equal to desired voltage limit.

D = Switching signal diode (suggest 1N4148 TYP)

**Example B:**

Using the Example A, also assume that a parallel resistance of 1 Mohm is employed across the stimulus output current leads. Accordingly, the reference equation becomes:

0.001 ma x 1,000,000 ohms = 1 V (estimate)

In this case, the maximum stimulus voltage received by the subject, in the event of sporadic electrode contact, would be on the order of 1 V, instead of 200 V. Alternatively, if the parallel loading represented by the additional 1 Mohm resistance is not desired, a voltage clamp could be used to limit the maximum output voltage level in the event of sporadic electrode contact.

The STMISOLA has the capability of acting as a nearly ideal current stimulator, with very high performance. Adding a parallel resistance or a voltage clamp reduces performance from ideal, but enhances safety. Please contact BIOPAC Systems, Inc. at www.biopac.com for more information.

## Operating Procedure

**→ Review Important Notes and Safety Notes before operating the STMISOLA**

The included 3.5 mm mono splitter (3.5 mm male mono phone plug to two 3.5 mm female mono sockets) and one CBL100 (3.5 mm mono male to 3.5 mm mono male cable) permit the analog drive signal to be directed to two locations. The drive signal – usually from DA0 or DA1 – is typically directed to the splitter cable. One socket output of the splitter cable is directed to the STMISOLA input.

The other socket output of the splitter cable is looped back to drive an available MP input, via CBL100, through the UIM100C or AMI100D/HLT100C (CBL122 adapter required for AMI100D/HLT100C). In this manner, during acquisition, the stimulus level and timing will be indicated on the recording.

1. Plug AC300 into back of STMISOLA unit.
2. Connect Control Input (3.5 mm male phono plug) to output: AMI100D/HLT100C/UIM100C (Analog Out 0 or 1) or STM100C (50 ohms) or MP36 Analog Out (via OUT5 adapter) or external signal generator.
3. **Before powering ON the STMISOLA** (turning from OFF to ON), make sure that stimulation electrodes are not attached to the subject.
4. Power ON STMISOLA.
   - Note that "Protect" red LED on front panel is ON, when STMISOLA is powered ON.
5. Set "Output Mode" switch to **V** for Voltage stimulation.
6. Press "Reset" pushbutton switch for 3 seconds to enable STMISOLA.
7. Make sure that STMISOLA input voltage is Zero volts.
8. Connect electrodes to subject and then to STMISOLA output.
9. Place STMISOLA in Current (I) mode, if desired.
   - Note that if output is unloaded and if STMISOLA is in Current (I) Mode, then the "Protect" light will stay ON, thus activating shutdown protection (see Important Note A).
10. Send Control Voltage (STMISOLA input) to affect desired wave output (see Acq*Knowledge* Software Guide or BIOPAC Application Notes AH162 and AS200).
11. When stimulation session is ended, place STMISOLA in Voltage (V) Mode and make sure that STMISOLA unit input control voltage is Zero volts.
12. **Before powering OFF the STMISOLA** (turning from ON to OFF), remove stimulation leads and/or electrodes from subject.

    **WARNING:** Do not remove electrodes while in current (I) mode; it's possible for subjects to receive a shock if they remove electrodes while the STMISOLA is in current (I) mode because the STMISOLA responds to the impedance increase and causes the current source to swing to a positive or negative rail.
13. Power OFF STMISOLA after making sure that stimulation electrodes are not attached to the subject.

## STMISOLA Specifications

The STMISOLA is a linear, isolated, constant voltage or constant current stimulator. The STMISOLA has one output voltage mode and two output current modes. The output voltage mode multiplies the input control voltage (±10 V) by a factor of 20 to the output. When operating in output current mode, there are two options: Low current mode (Zout=1 K ohm) and High current mode (Zout = 100 ohms). In Low current mode there is a 1:1 relationship between the input control voltage (in volts) and output current (in ma). In High current mode there is a 1:10 relationship between the input control voltage (in volts) and output current (in ma). The Zout selector switch determines the output impedance of the STMISOLA is voltage mode (100 ohms or 1 K ohms). The Zout selector switch determines the output current range (±100 ma for Zout = 100 ohms) or (±10 ma for Zout = 1 K ohms). The Zout switch has different operation, depending on output mode of STMISOLA. In Voltage output mode, the Zout setting simply specifies the output impedance of the STMISOLA. In Current output mode, the Zout setting determines the gain factor (K) which sets the desired current range, either +/- 100 ma or +/-10 ma.

The STMISOLA is also well-suited for transcranial direct current stimulation (tDCS). tDCS is a form of neuro-stimulation which employs the use of low level (typically under 10 ma) constant, unipolar, direct current.

The STMISOLA will support arbitrarily long, constant, non-varying, direct output currents, so long as the associated voltage compliance is 100 VDC or less. The tDCS level is adjusted by holding a stable voltage to the control voltage input of the STMISOLA. This control voltage can be set in Acq*Knowledge*, to be output to STMISOLA via analog output, or can be provided by any 3rd party power supply or signal generator.

**Control Voltage Input:** ±10 V maximum input

**Control Voltage Impedance:** 1 Mohm

**Control Voltage Input Interface:** Male 3.5 mm mono phone plug

**Isolation:** Control Voltage Ground to Isolated Output Ground: 1000 pF at 1500 VDC HiPot

Isolated Output Ground to Mains Ground: 2000 pF at 1500 VDC HiPot

**OUTPUT:**

**Stimulation Voltage (V) Mode: ±200 V with:**

Zout = 100 ohms: ±100 ma compliance; Output Impedance = 100 ohms

Zout = 1 Kohm: ±10 ma compliance; Output Impedance = 1000 ohms

**Current (I) Mode: ±200 V compliance; Output Impedance - 1 Gohm**

Zout = 100 ohms: ±100 ma

Zout = 1 K ohm: ±10 ma

**Input to Output Ratio:**

**Voltage (V) Mode:**

±10 V DC input creates output of ±200 VDC (1:20 ratio - V/V) for Zout either 100 ohms or 1 K ohms

**Current (I) Mode:**

±10 V DC input creates output of:

Zout = 100 ohms ±100 mA (1:10 ratio - V/ma)

Zout = 1 K ohms ±10 mA (1:1 ratio - V/ma)

**Rise Time Measurement Setup:**

**Load:** 1 K ohm

**Input Control Signal:** 0-1 Volt (1 µsec rise time or less)

**Current Monitor:** CBLCFMA Current Monitor (in series with stimulus output current)

**Rise Times** (10%-90% stimulus output current amplitude levels indicate rise time)

1) Voltage mode (Zout = 100 ohms or 1 K ohms): 10 µsec nominal

2) Current mode (Zout = 100 ohms – 15 µsec nominal, Zout = 1 K ohms – 10 µsec nominal

**Max output pulse width**: Less than 100 VDC (voltage output or compliance level) – arbitrarily long

More than 100 VDC (voltage output or compliance level) – 100 ms typical

**Max sine frequency:** 30 kHz (-3 dB)

**Input Control Voltage:** ±10 V max

**Physical Interface:** 3.5 mm male mono phone plug

**Compatibility MP:** UIM100C (Analog Out 0 or 1), AMI100D or HLT100C (Analog Out 0 or 1 via CBL122 cable adapter), STM100C (50 ohm output), Generic signal generator w/ ±10 V output range

**Voltage or Current output noise (rms):** nominally +/-0.02% of Full Scale Range (FSR)

**Accuracy:** Voltage or Current output (Zout is 100 ohms or 1 K ohms): ± 1%

**Linearity:** ± 0.1%

**Output Pulse Duration:** Output or current compliance voltage (Vout < 100 V) - fully arbitrary, no limit to wave (pulse) duration, subject to user-supplied control voltage signal drive

**Output or current compliance voltage (Vout > 100 V)** : 100 msec typical and limiting to 20 ms at 100 ma current output

**Current Limiting:** ±350 ma (short circuit)

**Voltage Limiting:** ±210 V (nominal)

**Reset Push Button:** Required with each power ON – push in for 3 seconds to Reset

**Manual Test Voltage Output Pulse:** 100 V for 2 msec

**Current Output Pulse:**

Zout = 100 ohms: 50 ma for 2 msec

Zout = 1 K ohms: 5 ma for 2 msec

**Full Scale Range:**

**Voltage mode:** ±200 V (Zout = 100 ohms or 1 K ohms)

**Current mode:**

±100 ma (Zout = 100 ohms)

±10 ma (Zout – 1 K ohms)

**Output Indicator:** ON for P-P amplitudes > 1% FSR

**Fuse:** 2 amp fast blow

**Power Adapter:** 12 VDC at 1 amp (AC300A)