Warner Instruments, Inc.

SUNS*tir*-3

SUNS*tir* Dual-Function Controller with SPIN-2 Stirplate and SUN-1 Lamp

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The **SUNS*tir*-3** system is comprised of a **SPIN-2 Bilayer Stirplate**, a **SUN-1 Halogen Lamp** and a convenient **SUNS*tir* Rack Mount Controller**.

The **SPIN-2** is a unique device designed to allow the simultaneous stirring of two solutions, one on each side of a bilayer membrane. The unit incorporates two counter-rotating dipoles and the phase angle between the dipoles is digitally controlled to minimize the influence of a time-varying magnetic flux on the headstage circuitry. The quiet electronics and mechanical stability of the device allows the user to adjust its rotation speed using the external controller.

The **SUN-1** is an externally controlled, noise free halogen light source suitable for inclusion in a shielded enclosure. The magnetic base attaches securely to any steel tabletop and the lamp swivel-head allows projection of the beam in virtually any direction.

The **SUNS*tir*** is the companion controller for the **SUN-1** and **SPIN-2**. This instrument combines the separate controllers for the **SUN-1** and **SPIN-2** into a single rack mountable unit. This approach simplifies the operation of these devices and helps reduce the amount of clutter around your setup.

The result is a quiet and versatile system that can allow the illumination and stirring of your sample while recording.

Features include:

- ✓ Dedicated design for the Planar Lipid Bilayer
- ✓ External, rack mountable controller

SPIN-2

- ✓ Independent *cis*/*trans* dipoles
- ✓ Minimized magnetic flux at membrane
- ✓ Steel side panels for attachment of magnetic components
- ✓ Liquid crystal dipole position indicator
- ✓ Vibration free operation

SUN-1

- ✓ Dichroic reflector
- ✓ Noise free electronics
- ✓ DC Halogen bulb
- ✓ Adjustable spotlight intensity
- ✓ Magnetic base with gooseneck
- ✓ Swivel-head lamp

THIS EQUIPMENT IS NOT DESIGNED NOR INTENDED
FOR USE ON HUMAN SUBJECTS

NOMENCLATURE

Text conventions

To minimize the potential for confusion, we have employed several text conventions which are specified below. Since our goal is to provide clarity rather than complexity, we welcome any feedback you may wish to provide.

- Warner Instrument product numbers are presented using **bold type**.
- References to separate components controls are specified using UNDERLINED SMALL CAPS.
- References to specific controls are specified using NON-UNDERLINED SMALL CAPS.
- References to control settings are specified in *italic type*.
- Special comments and warnings are presented in highlighted text.

Any other formatting should be apparent from context.

INTRODUCTION

Lamp

Illumination of the cup/chamber is most often, and most critically, applied during membrane formation. A properly illuminated cup will reveal the aperture, greatly simplifying the task of membrane formation in the absence of a microscope.

The **SUN-1** lamp is comprised of a magnetic base with 12” gooseneck for accurate positioning of the illumination spot. A jointed swivel-head at the end of the gooseneck allows the beam to easily subtend a solid angle of 2π steradians (half of a sphere). Beam intensity is adjustable to one of eight levels via the rack-mount controller. A dichroic reflector minimizes the projected heat from the lamp and allows longer illumination times without significantly warming the object illuminated.

The lamp electronics are well isolated to prevent the introduction of external EMF into the Faraday enclosure and allows recording of data even while the lamp is on.

Stirplate

Stirring of solutions in a bilayer cup and chamber has traditionally been achieved using either a commercial stirplate or a home-made device. Unfortunately, commercial stirplates are not designed for use in a bilayer rig and home-made devices can be inadequate due to the limited engineering resources often available in a biochemistry lab. In either case, the most common design for the resulting stirplate is that of a *single rotating magnetic dipole* being presented to the bilayer chamber.

A result of this approach is that the chamber must be repositioned if the stirbar is moved from the *cis* or *trans* well to the other side. More importantly, it is virtually impossible to simultaneously stir both wells since the respective stirbars will be drawn to the common rotational axis defined by the stirplate magnet. The resulting collisions between stirbars and the bilayer cup introduces a large noise artefact into the acquired data.

A second obstacle is associated with the interaction of a rotating magnetic dipole with the headstage circuitry. The time-varying magnetic flux through this closed loop generates an electromotive force resulting in the appearance of a sinusoidal current artefact in the data.

Many researchers avoid these problems by not stirring while recording, which is often undesirable. The **SPIN-2** has been specifically designed to address these difficulties and is the only apparatus commercially available to provide an integrated solution to these issues.

Several design strategies have been implemented in the **SPIN-2**. Most notable is the presence of dual rotating dipoles, one each for the *cis* and *trans* wells. This approach allows the stirbar within each well to be independently manipulated which abolishes cup/stirbar collisions. The relative separation between dipoles is adjustable allowing the apparatus to be used with bilayer cups and chambers of various sizes.

Second, the rotation (phase and speed) of the two SPINning dipoles is digitally controlled. This approach allows the **SPIN-2** to present the smallest possible magnetic flux to the bilayer membrane resulting in a reduced induction current in the headstage circuit. A liquid crystal display on the top of the stirplate allows the researcher to view the rotating dipoles in real-time.

Third, the mechanical assembly is very quiet. This feature introduces the possibility of placing the bilayer chamber directly onto the stirplate during use. Most researchers currently place their chambers on an independent support stage which de-couples the chamber from the mechanically noisy stirring mechanism. The magnetic strength of the **SPIN-2** dipoles permits the use of either strategy to minimize noise in their setup.

The apparatus is electrically isolated and well shielded, allowing the controller to remain outside of the Faraday cage during use.

Controller

The **SUNStir** controller combines the separate table top controllers for the **SUN-1** and **SPIN-2** into a single rack mountable unit. This reduces the number of power supplies necessary and reduces the clutter around the setup.

CONTROL DESCRIPTION

SUNS*tir *Dual Function Controller

The **SUNS*tir* Controller** is used to provide power to both the LAMP and STIRPLATE, to adjust the rotation speed of the STIRPLATE dipoles, and to adjust the intensity of the LAMP.

Front panel

The CONTROLLER front panel is comprised of two control sections and a master power switch..

The **SUN-1** section has an *on/off* TOGGLE SWITCH, a *power on* LED, and an INTENSITY CONTROL. LAMP INTENSITY is adjusted via a continuously variable knob. *Low* and *high* intensity positions are indicated. A GREEN LED indicates LAMP power *on* status.

The **SPIN-2** section has an *on/off* TOGGLE SWITCH, a *power on/rotation speed* LED, and a SPEED ADJUSTMENT control. SPEED ADJUSTMENT is via a continuously variable knob used to set the rotation speed of the dipoles in the STIRPLATE. *Slow* and *fast* speed positions are indicated. A GREEN LED indicates STIRPLATE power *on* status as well as the relative rotational speed of the dipoles. The faster the rotational speed, the more rapidly the LED *blinks*.

The **MASTER** *on/off* switch provides power control for all attached units. A GREEN LED indicates power *on* status.

Rear panel

Several attachment points are located on the rear of the **SUNS*tir* Controller**. These include a 6-pin DIN connector for connecting the **SPIN-2**, a 5-pin DIN connector for connecting the **SUN-1**, circuit and chassis grounds, a fuse, and a power input jack.

As a safety measure, the DIN connectors for the LAMP and STIRPLATE are respectively keyed and will not accept the other device.

The *green* and *black* banana jacks provide for attachment to the instrument CHASSIS and CIRCUIT grounds, respectively. Both ground jacks accept standard banana plugs. Ideally, the circuit and chassis grounds should be interconnected and are factory shipped with a bridging bar. However, the bridging bar can be removed to isolate the two grounds if necessary.

IMPORTANT: Make a connection from the *green* banana jack on the controller to the common ground of your setup. If this connection is not made the LAMP and STIRPLATE will radiate EMF into your Faraday cage.

SPIN-2 Bilayer Stirplate

Front panel

The **SPIN-2** stirplate has a single control, located on the front panel, used to adjust the relative separation between the rotating dipoles. Minimum separation is 0.4 in.

Top panel

The top panel has a liquid crystal window to reveal the position and rotation of the dipoles. Two steel strips are located on either side of the liquid window (under the overlay) for attachment of magnetic supports.

SUN-1 Lamp

There are no user controls on the lamp body, however, the lamp stem is comprised of a flexible gooseneck and a jointed swivel-head at the lamp end of the gooseneck allows the beam to easily subtend a solid angle of 2π steradians (half of a sphere).

SETUP

*SUNS*tir *controller*

1. Mount the **SUNS*tir*** CONTROLLER into your rack or place in a convenient location near your setup.
2. Complete the ground circuit by connecting the CONTROLLER GROUND (the *green* banana jack on the rear panel) to your amplifier or cage ground (otherwise known as the *setup common ground*).
3. Verify that the MASTER POWER is *off*. Verify that the individual ON/OFF TOGGLES are also *off*.
4. Attach the power cord into rear of the instrument and plug into a convenient outlet

SPIN-2 setup

1. NOTE: Remove the **5 red shipping screws** from the bottom of the STIRPLATE prior to use.
2. Place the STIRPLATE within your Faraday cage and route the attached connector cable to the CONTROLLER. The cable carries its own internal shielding and so no additional steps need be taken to shield the unit.
3. Connect the STIRPLATE to the CONTROLLER by attaching the 6-pin DIN connector at the rear of the CONTROLLER.
4. The **SPIN-2** is now ready to use.

SUN-1 setup

1. The LAMP is shipped with separate magnetic base. Attach the magnetic base to the bottom of the LAMP assembly using the four supplied screws.
2. Make sure the power switch on the base of the LAMP is in the *on* position (on some models).
3. Place the LAMP into position in the cage and run the lamp cable to the CONTROLLER. The cable carries its own internal shielding and so no additional steps need be taken to shield the unit.

5. Connect the LAMP to the CONTROLLER by attaching the 5-pin DIN connector at the rear of the CONTROLLER.
6. The **SUN-1** is now ready to use.

OPERATION

SUN-1

Operation of the **SUN-1** is straightforward. The external controller both turns the unit on and adjusts the intensity. Positioning of the illumination spot is achieved by adjustment of the gooseneck and swivel head.

For optimal operation, aim the illumination spot inside the cup. This strategy will backlight the aperture allowing it to be easily resolved as a small black dot against the bright background.

NOTE: The lamp houses a dichroic reflector which dissipates 60% of the heat generated by the bulb. As a result, the sample is exposed to less radiant heat at the expense of a warmer lamp head. Use care when making adjustments to the lamp head as it may be warm to the touch.

SPIN-2

The **SPIN-2** stirplate contains two rotating dipoles. One dipole is positionally fixed relative to the stirplate case while the other is adjustable using the POSITION ADJUST control. We will refer to the fixed dipole as the front dipole and the adjustable dipole as the rear dipole. The general setup procedure is to first orient one well in the bilayer chamber to the front dipole and then to 'dial in' the rear dipole to the other well.

In general, a mechanical noise artefact is usually generated by collisions between a rotating stirbar and the cup. Since the **SPIN-2** is designed to independently control two stirbars (one in each well), it is critical that all stirbars are optimally centered within their respective wells.

1. Begin by assembling your cup and chamber. Apply lipids, add solutions and agar bridges.
2. Place a single stirbar into the chamber's front well and place the chamber on top of the stirplate.
3. Turn the stirplate *on* and position the chamber so that the stirbar rotates quietly within the well and on top of the front dipole. (Move the rear dipole away from the front dipole if needed.)
4. Now, without moving the chamber, place a second stirbar into the rear well and begin moving the rear dipole into position.
5. Continue to adjust the position of the rear dipole until the rear stirbar rotates quietly on top of the rear dipole.

   NOTES: You may also need to adjust the side-to-side position of the rear well to find the optimal well/dipole position. Do this by rotating the chamber about an axis defined by the front dipole/front well pair. Take care to not disturb the position of this pair !
6. Once the magnets within both wells have been positioned, turn the stirplate off, insert your electrodes and continue with membrane formation.

NOTE: In the event that the chamber is moved during membrane formation, simply reposition the chamber over the dipoles without re-adjusting the position of the dipoles. In addition, we have included a small rubber mat which can be used to further secure the position of the chamber on top of the stirplate. Place the mat under the chamber before centering the first stirbar.

7. Check for mechanical artefacts by turning *on* the **SPIN-2** once a stable membrane is formed. Make final positional adjustments as necessary.

Theoretical considerations

Sources

In a bilayer stirplate there are three possible sources of noise: electrical, mechanical and magnetic. Electric sources include the motor used to drive the rotation of the dipoles and the power/control wires entering the Faraday cage. Mechanical sources include the mechanism providing the rotation to the dipoles and collisions between the stirbars and the chamber. The interaction of the rotating magnetic field with the headstage electrodes represents the primary magnetic noise source in a stirplate.

Electrical noise

Electric noise sources are well controlled in the **SPIN-2**. The stirplate enclosure, as well as the associated connecting cable, are internally shielded which effectively makes the inside of the stirplate topologically outside the Faraday cage. In addition, the drive motors are of the dual bearing, DC type which provides for very quiet operation. This approach allows the **SPIN-2** to be adjusted using an external controller with no electrical impact on the Faraday cage contents.

Mechanical noise

Mechanical artefacts are usually a stirplate bane and can be difficult to control. The fundamental issue is that the bilayer membrane represents an exquisitely sensitive transducer for mechanical movements and any vibrations presented to the chamber are received and amplified by the system. Relevant sources include those from the chamber holder, from within the chamber itself, and from the surrounding air.

<u>Chamber holder</u>

Vibrations associated with the chamber holder include the opening and closing of Faraday cage doors, and the motion of the stirrer and other items placed on the isolation table. Peristaltic pumps placed on the table within the cage are notorious noise sources, as are many fluid control systems placed in direct contact with the bilayer chamber. These problems are often addressed by placing the chamber on an isolated, stand-alone platform or stage which effectively separates the chamber from the offending noise source.

The mechanical components within the **SPIN-2** have been precision engineered using high mass materials and the device operates smoothly as a result. Furthermore, the top of the stirplate is somewhat isolated from its base and so can function as a stage.

NOTE: The magnetic dipoles within the **SPIN-2** are sufficiently strong so that the stirplate can be placed under a secondary stage if further isolation is desired.

Chamber

Vibrations within the chamber are usually a result of collisions between a stirbar and the chamber wall. These large amplitude artefacts are reasonably expected whenever a misalignment between the rotational axes of a stirbar and the stirplate exists. This misalignment can be easily corrected by repositioning the chamber so that the axes are in alignment. However, this approach is effective whenever only one side of the membrane is being stirred and can become intractable if stirring on both sides of the membrane are attempted.

The **SPIN-2** addresses this difficulty by providing two rotating dipoles, one for each side of the bilayer membrane. This approach allows each stirbar to remain centered within its respective well without influencing the motion of the other. Careful positioning of the dipoles beneath the cup and chamber can eliminate noise artefacts due to stirbar collisions.

NOTE: Stirbar collisions are not an intrinsic property of the stirplate but are rather associated with the geometry of the cup/chamber. However, it is imperative that both dipoles be well centered for stirbar collisions to be eliminated.

Another source of chamber noise is associated with the movement of fluid during solution exchange and will not be considered here.

Surrounding air

Acoustic coupling from the surrounding environment can product a large, transient artefact into your data. Some researchers can find themselves turning the radio down or asking a coworker to not speak loudly next to the setup during a recording.

Acoustic noise can also come from a noisy device with the Faraday cage. Most notable are stirrers and pumps. While acoustic coupling from a radio is often transient, noise from a pump or stirrer can be continuous. However, this effect is usually of a much smaller amplitude when compared to the mechanical artefact these devices can produce.

Magnetic noise

Magnetic noise is not usually considered to be a problem since most researchers avoid stirring while recording. Nevertheless, magnetic effects remain the only artefact which cannot be eliminated by the careful design of a stirplate.

In general, a time varying field produced by a rotating magnetic dipole induces a small, but detectable, sinusoidal current in any current loops present. In the case of a bilayer setup, this loop would be the headstage electrodes.

NOTE: The resulting sinusoid can be differentiated from a 'ground leak' by the observation that its amplitude and period vary with the speed of the stirplate.

While magnetic artefacts cannot be eliminated, their effects can be reduced by (1) decreasing the strength of the magnetic field, (2) slowing the rate of change of the magnetic flux (SPIN rate), or (3) by altering the geometry of the wire loop within the magnetic field. The **SPIN-2** uses highly focused magnets to reduce the strength of the magnetic field in the vicinity of the electrodes and the variable speed control allows the user slow the rate of change of the magnetic flux.

Noise abatement

The above discussion regarding various noise sources should make it apparent that a critical understanding of the principals involved can contribute immensely to the successful use of a stirplate while recording.

Since the **SPIN-2** has been designed specifically for this purpose, care has been taken to abolish or minimize noise contributions from within the stirplate itself. As a result most noise artefacts a user will experience will be from either stirbar/chamber collisions or from magnetic effects. Here we discuss strategies useful in minimizing or abolishing these effects.

Collisions

Collisions between the stirbar and chamber will most likely be the largest amplitude noise artefact. Fortunately, this is also the easiest artefact to address. Take a moment to review the setup procedure described on page 8. The strategy described there is to first center the stirbar in the front chamber over the front dipole, then to adjust the position of the rear dipole and chamber so that the rear stirbar becomes well centered over the rear dipole.

We recognize that this procedure may seem cumbersome at first, but the approach allows tremendous flexibility in using the stirplate with cups and chambers of many sizes and geometries. Note that once the dipole separation has been set for a particular chamber, only small subsequent adjustments should be necessary to align the stirbars between uses.

Magnetic induction

Magnetic-induction effects are more difficult to control. As stated earlier, this effect stems from the raw physics and simple geometry of the setup and cannot be engineered away. However, steps can be taken to reduce the amplitude of the artefact.

The dipoles within the stirplate are digitally controlled to minimize the amplitude of the magnetic field present within the bilayer membrane. Moreover, the resulting magnetic field vector also resides entirely within the plane of the membrane. While this design reduces the amplitude of the induced current, further reduction can be achieved by (1) reducing the rotation speed of the stirplate, and (2) increasing the separation between the cup/chamber and the stirplate.

NOTE: We recommend that you adjust the speed of rotation before beginning the more complicated effort of relocating the chamber relative to the stirplate. However, if chamber relocation is necessary, then we suggest the use of a small stage under which the stirplate is placed.

Conclusions

We hope this discussion has given you a deeper understanding regarding several issues associated with the process of stirring while recording. We also hope that this discussion has provided you with the tools necessary to address these extra-stirplate issues.

APPENDIX

*SUNS*tir *Specifications*

Power	115/230V, 50/60 Hz
Fuse	0.5/0.25A, slow-blow

SPIN-2 Specifications

Controls	
Controller:	Power on/off switch, Speed rotary control, Power on LED; flashes once per complete rotation
Stirplate:	Position adjust (rotary)
Display	Magnetic field display; passive LCD
Speed range	300 to 600 RPM
Rotor	
Synchronization:	Counter-rotating
Position adjustment range: (center-to-center)	0.4 to 2.5 inches
Dimensions	5.5 x 8.0 x 2.3 in (W x D x H)
Weight	3.0 lb.

SUN-1 Specifications

Controls	Power on/off switch, Power on LED, Eight position intensity
Lamp	High impact polyamide housing; swivel head; spot reflector; clear lens, Halogen bulb, dichroic reflector; 12W-12V
Gooseneck	1.4 cm dia. x 30.5 cm length; with PVC sleeve

Warranty and service

We recommend that all questions regarding service be referred to our Technical Support Department.

Normal business hours are 8:30 AM to 5:00 PM (EST), Monday through Friday.

Our offices are located at 1125 Dixwell Avenue, Hamden, CT 06514.

We can be reached by phone at (800) 599-4203 or (203) 776-0664. Our fax number is (203) 776-1278.

We can be reached by e-mail at support@warneronline.com or through the web at http://www.warneronline.com.

Warranty

The **SUNS*tir*-3** (**SUN-1, SPIN-2** and **SUNS*tir***) is covered by our Warranty to be free from defects in materials and workmanship for a period of one year from the date of shipment. If a failure occurs within this period, we will either repair or replace the faulty component(s). This warranty does not cover failure or damage caused by physical abuse or electrical stress (inputs exceeding specified limits).

In the event that repairs are necessary, shipping charges to the factory are the customer's responsibility. Return charges will be paid by Warner Instruments, Inc.