STANFORD UNIVERSITY
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GRAVITY PROBE B, RELATIVITY GYROSCOPE EXPERIMENT
STANFORD, CALIFORNIA 94305-4085

LEVITATION OF GYROSCOPES IN PROBE C

GP-B SCIENCE MISSION PROCEDURE

P0481 Rev B

24 July, 2001

PREPARED	_____	_____
	R. Brumley, Gyroscope RE	Date
APPROVED	_____	_____
	D. Hipkins, LT Test RE	Date
APPROVED	_____	_____
	B. Clarke, RT Test RE	Date
APPROVED	_____	_____
	D. Ross, Quality Assurance	Date
APPROVED	_____	_____
	B. Muhlfelder, Hardware Test Leader	Date

REVISION HISTORY

Rev	Date	Comments
-	06/04/99	
A	11/16/00	Change procedure to incorporate minor redlines from the previous run. Main structure of the procedure has not been changed. Include guidelines for handling the contingency where a gyroscope delevitates during the completion of this procedure.
B	07/24/01	Update Section 3.7 to include guidelines for the contingency where a gyroscope charges during the completion of this procedure.

1. SCOPE

This procedure is to be used every time a gyroscope is levitated in Probe C. The first time a gyroscope is levitated in the probe with a certain suspension system, there are certain steps which must be taken to ensure that the DDC is calibrated correctly, mechanical vibration is acceptable, etc. These sections are so noted in the procedure. Also, delevitation may happen long after the initial levitation. Finally, the suspension cables need to be connected and disconnected. Therefore this procedure has five major parts: (1) Initial Connection, (2) Levitation, (3) Initial Suspension Checkout, (4) Delevitation, and (5) Disconnection of Suspension System. Which portion of the procedure is to be done must be specified in the parent procedure that calls this document. All sections were included in this single document so that the operator could gain a coherent understanding of the entire suspension process. Note that it is possible that only one section of operations may be performed at a given time. Therefore each operation section begins with an instruction to review the beginning non-operations part of the procedure. This is to ensure that the person performing the procedure is conscious of all hardware safety concerns, quality assurance requirements, etc.

The following table indicates which section covers the various operations related to DDC operation. This table is included for informational purposes only.

Name	**Section #**
Initial DDC Connection	6
Initial Levitation and Calibration	7
Levitation (after Initial)	8
Delevitation	9
DDC Disconnection	10

2. REFERENCES

2.1 Plans and Procedures

P0059	Probe C Contamination and Control Plan
PO147	GPB Contamination and Control Plan
P0057	Stanford Magnetic Control Plan

3. GENERAL REQUIREMENTS

3.1. Environmental Requirements

3.1.1 Cleanliness

This procedure may take place in the Class 1000 cleanroom in the HEPL building. Minimum protective garments for personnel working in the clean rooms shall be the standard Tyvek clean room apparel. Note that all electrical connectors should be kept clean and free from any contamination that might interfere with the electrical contact.

3.1.2 Particulate Contamination

All parts and tools shall be cleaned at least to the cleanliness levels of the rooms where they are used for assembly or testing. All connectors which mate to flight parts must be inspected for particulate contamination that could potentially damage the flight part or interfere with a proper mating of the two connectors.

3.1.3 Magnetic Contamination

All parts and tools shall be cleaned using methods consistent with achieving Mil Spec Level 100 cleanliness. In addition, all parts shall be maintained at level 100 cleanliness per GP-B Magnetic Control Plan, Science Mission (P0057). Take all necessary precautions to keep tools and handling equipment free of particulate contamination.

3.2 Integration and Test Personnel

3.2.1 Test Director

The test director for this procedure is Robert Brumley, or his appointed replacement.

3.2.2 Personnel

The following personnel are qualified to perform this procedure:

- David Hipkins
- Bruce Clarke
- Chris Gray
- Ken Bower
- Robert Brumley
- Dr. William Bencze
- Dr. Sasha Buchman

See section 3.4 for details as to when Quality Assurance personnel are required to be notified and/or witness this procedure.

3.3 Safety

3.3.1 General

All participating personnel shall ensure they are aware of the specific and hardware safety concerns indicated in the safety requirements, cautions, and warnings in the procedure.

3.3.3 Hardware Safety

The high voltage switch on the DDC should never be thrown from off to on when the DDC is connected to the probe to avoid possible damage to the SQUIDs.

3.4 Quality Assurances

- ***Stanford QA must be notified at least one hour before beginning this procedure.***
- ***ONR QA must be notified at least one hour before beginning this procedure.***
- ***Russ Leese (or his designate) must be present to monitor the completion of this procedure.***

This procedure shall be conducted on a formal basis to its latest approved and released version. The QA Program Engineer shall be notified of the start of this procedure. A Quality Assurance representative designated by B. Taller shall review any discrepancy noted during assembly or test. Redlines shall be approved by the QA representative. The QA representative will nominally be Russ Leese. Upon completion of this procedure, the QA Program Engineer, D. Ross or Russ Leese, will certify her or his concurrence that the effort was performed and accomplished in accordance with the prescribed instructions by signing and dating his approval line at the end of the procedure.

3.5 Red-line Authority

Authority to red-line (make minor changes during execution) this procedure is given to the qualified personnel listed in section 3.2.2. All redlines must be approved by the QA representative. In addition, approval by the Technical Manager shall by required if, in the judgement of the test director or QA Representative, experiment functionality may be affected. For procedures in the cleanroom, "redlines" shall be accomplished using red bold italics and "signatures" in black bold italics.

3.6 Electrical Connections

The DDC must always be connected or disconnected from the probe with the high voltage switch on. It is never permissible to throw the high voltage switch while the DDC is connected to Probe C.

When mating to any flight connector, the following items are required:

- An grounded ESD strap must be worn by any person handling a connector on Probe C.
- Inspect both connectors being mated to ensure that there are no particles that might interfere with the mate.
- Each mate and demate of flight connectors must be logged in that connector's mate/demate log sheet. Note that these log sheets have already been started for all suspension lines.

3.7 Gyroscope Testing in 1 g

Testing gyroscopes in a one-g environment requires very large voltages (on the order of 1000 V to achieve levitation, and approximately 620 V to maintain levitation in the center of the housing). These high voltages introduce the potential for additional complications when conducting a ground-based gyroscope test which are not issues for on-orbit gyroscope operation. Specifically, there is the potential for charging and gyroscope delevitation. These contingencies are discussed in more detail below.

Note that suspension voltages are much lower on orbit, so that the concerns about gyro delevitation and charging due to high voltage on the electrodes are not a concern.

3.7.1 Gyroscope Charging

Gyroscope charging on the ground is dominated by field emission due to the high one-g voltages. Gyroscope charging may be indicated when there is a mismatch in the control efforts such that the X and Y axes move in one direction (e.g. get larger), and the Z axis moves in the other (e.g. gets smaller). This is because the lifting electrode on the Z axis has a different sign than on the X and Y axes.

As noted above, the mechanism for gyroscope charging which exists in one g does not exist on orbit, and therefore gyroscope charge is not cause for concern in evaluating on-orbit gyroscope performance. However, gyroscope charge above a certain level (approximately 20 V) will start to reduce the stability of the gyroscope suspension. In the event that the gyroscope begins to charge at any time during the test then, at the discretion of the suspension system operator, the gyroscope may be delevitated. An attempt at re-levitation may only be started with the concurrence of QA and the Gyroscope RE. Gyroscope charging alone is not sufficient reason for the gyroscope to fail the performance checkout. However, in the event that significant gyroscope charging is observed, a report shall be generated to record the details of the gyroscope

performance. As always, a Discrepancy Report may be opened if, at the discretion of Quality Assurance, it is warranted given the specifics of the situation.

3.7.2 Gyroscope Delevitation

If a gyroscope delevitates during the completion of this procedure, all work shall cease and the configuration shall not be broken. Work may only continue under the guidance of the MRB. A Discrepancy Report shall be immediately opened recording the details of what happened. The immediate concern of the investigation should be to determine whether the GSE was at fault in the delevitation, and it should usually be re-tested on non-flight gyroscopes prior to attempting levitation on a flight gyroscope. The exceptions to this are cases where it is abundantly clear that the delevitation was due to gyroscope charging.

The delevitation of a gyroscope does not necessarily mean that the gyroscope fails the room temperature test. The voltages necessary for ground levitation cause an extreme over-test, and it is expected that arcs due to field emission may occur from time to time. However, if a gyroscope does delevitate it will be necessary to conduct a certain amount of penalty testing. The exact nature of this penalty testing will depend on the details of the gyroscope delevitation, and therefore can not be indicated here (it will be under the control of the MRB). However, the following shall be used as a guideline for a standard set of penalty testing:

- Relevitation according to P0481
- Exploration of the housing according to P0178 (exact ranges may vary according the judgement of the MRB).
- New spindown test of the gyroscope according to P0178 (exact positions used and time spans used are at the discretion of the MRB).

Finally, note that gyroscope delevitation during the performance of P0481 (Gyroscope Levitation) is not necessarily a discrepancy. This is the procedure where the gyroscope undergoes initial levitation and the suspension system is tuned to the gyroscope. If, while the parameters are still be adjusted, the gyroscope delevitates then it is likely the cause was improper suspension parameters. The operator is allowed to attempt relevitation with different parameters in order to achieve a stable levitation. Formally, this point is reached at the time the levitation section of P0481 is signed off. However, based on the specifics of the situation, QA still has the option for opening a Discrepancy Report if they feel it is justified.

4. REQUIRED EQUIPMENT

4.1 Flight Hardware

Probe C without sunshade. Vacuum can is on, and vacuum system is pumping on the probe.

4.2 Ground Support Equipment

The following equipment is necessary to perform these tests:

Item	Quantity
DDC Digital Suspension System Rev B or Rev C	1-4*
230 pF MHV-MHV Suspension Cables	14
MHV to Reynolds Interface Units	14
386i Workstations with FFT Program	2
Oscilloscope (no calibration required)	1

* One DDC is required for each gyroscope that must be levitated concurrently.

4.3 Tools and Miscellaneous

Fluke meters, capacitance meters

OPERATIONS

5.0 DDC Prelevitation Qualification

5.1 Gyro-Cart Checkout

Any DDC used to levitate gyroscopes in Probe C must have been used to levitate a gyroscope in a gyro cart for at least 6 hours prior to being connected to Probe C. This checkout is intended to be rough and qualitative, but *must have been concluded with an 'Operator Shut Down (OSD)' within 120 hours of the initial levitation attempt of the SM gyroscopes*. It is preferable that this checkout be done in the same room as Probe C, so that no significant moving of the DDC needs to be done between this checkout and levitation of the SM gyroscopes.

Levitation of a gyroscope on Probe C concluding with an OSD within the past 120 hours may also be used to satisfy this requirement.

Confirm Requirements of Sect. 5.1 have been met: _____ (please 4)

Notes:

_____

_____

6.0 Initial DDC Connection

Note: Please review sections 1-5 before completing this section. They contain information and warnings vital to the successful completion of this procedure.

Note: Do NOT complete this section if the DDC is already connected to the probe.

6.1 Initial Setup

Start Date: _____

Start Time: _____

Item	Data

Gyroscope Position	
DDC Serial Number	
DDC Code Revision	
Vertical Probe Axis	
DDC Control Gain	
DDC Sensor Bias [X Y Z]	
DDC Sensor Gain [X Y Z]	
Sample Rate (3501 Hz)	
Electrode Configuration (e.g. PPM)	

6.1.1 Make sure the probe pressure is less than 5×10^{-5} torr and that the pumping system has been pumping on the probe for at least 12 hours. Record the pressure below:

Vacuum Can Pressure (torr): _____

6.1.2 Make sure that the DDC has at least 300 Megabytes of free disk space. If necessary, backup old files and delete. _____

6.1.3 If necessary, connect all Reynolds to MHV adapter boxes to Probe C connections for gyroscope of interest. Record the mate in connector log. _____

6.1.4 Make sure DDC DSP is reset, position values are being updated in the software, and that the DDC is ***NOT*** in high voltage calibration mode. _____

6.1.5 Make sure the DDC cables are ***NOT*** connected to the probe. Turn on DDC High Voltage Switch _____

6.1.6 Connect DDC Cables to MHV connections on connector adapter box. Consult Table A as a reference for which DDC cables should be connected to each connector on Probe C. _____

6.1.7 Record Indicated Rotor Position (μin) _____

X Position:

Y Position:

Z Position:

6.1.8 Swap DDC cables on each axis at the back of the DDC.

X1 → X2 Y1 → Y2 Z1 → Z2
X2 → X1 Y2 → Y1 Z2 → Z1

6.1.9 Record Indicated Rotor Position (μin)

X Position:

Y Position:

Z Position:

6.1.10 Calculated Desired Rotor Position R_D according to these rules:

- The absolute value of R_D is the average of the absolute values of the numbers recorded in 6.1.7 and 6.1.9
- The sign of R_D is the sign of the positions in 6.1.7

R_D (X):

R_D (Y):

R_D (Z):

6.1.11 Adjust the sensor bias until the indicated rotor position is equal to the positions indicated above (6.1.8). New Sensor Gain:

Sensor Bias (X):

Sensor Bias (Y):

Sensor Bias (Z):

6.1.12 Return the DDC Cables to their original positions

6.1.13 Record the new indicated position:

X Position (μin):

Y Position (μin):

Z Position (μin):

6.1.14 The above positions should match (to within a minus sign) R_D to better than 20 μin. If not, record the event in a D-Log (no DR is necessary) and repeat 6.1.5 – 6.1.11. If swapping cables does not provide consistent results (e.g. if cables are swapped several times without changing any settings yet significantly different positions are indicated) then it is likely there is a problem in the hardware. At this point notify the ITD and hardware manager. Disconnect the DDC per section 10 and begin troubleshooting the DDC. _____

6.1.15 Verify that the gyro ground plane is grounded. _____

6.1.16 Connect the oscilloscope to the 3 outputs of the oscillator on the DDC. Verify that the waveforms are of roughly equal magnitude and sinusoidal in shape. There should be no apparent clipping or obvious distortion of the signal. _____

Completion Date: _____

Completion Time: _____

7.0 Initial DDC Levitation and Calibration

Note: Please review sections 1-4 before completing this section. They contain information and warnings vital to the successful completion of this procedure. Also, Section 6 MUST be completed before proceeding with this section.

7.1 Operations

Start Date: _____

Start Time: _____

7.1.1 It is now OK to start attempting a gyroscope levitation. This is something of an art and must be done by an experienced operator. The personnel listed in Section 3.2.2 have received the proper training to _____

perform this operation. Start with the lift timeout at 5 ms then gradually increase until levitated. Adjustment of other DDC parameters may also be necessary. Record the process in the lines below. _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

7.1.2 Once the gyroscope is levitated, record the initial control effort from the screen (g's): _____

CE(X): _____ CE(Y): _____ CE(Z): _____ Net: _____

7.1.3 Record the following DDC Parameters:

Sensor Gain [X Y Z]:

Sensor Bias [X Y Z]:

Control Gain:

Lift Timeout: Gyro Gap:

Shutdown Radius: _____

Electrode Configuration (PPM, MMP, etc):

_____

7.1.4 Look at the lift snapshot, which is automatically saved by the DDC. Record the magnitude of any oscillation which is present:

Oscillation (μin peak to 0): _____

_____

7.1.5 If the oscillation is greater than 20 microinches, then, at the test director's discretion, it is appropriate to take steps to try and reduce the magnitude of the oscillation, including rotor delevitation and relevitation if necessary. Record the event in the D-Log (a DR is not necessary). Document carefully the steps taken to reduce the vibration and all levitations and delevitations, and attach to this procedure.
Notes:

_____

7.1.6 Before proceeding, wait at least 10 minutes. If there is any evidence of charging or some other abnormality, record in a D-Log or DR, as determined by the Test Director and the QA representative. _____

7.2 Calibration of DDC

7.2.1 Take a DDC Snapshot

Filename: _____

7.2.2 Record the following by taking the mean of Vx1 through Vz2 (individually) and ux through uz (individually) in the snapshot taken above: _____

	X	**Y**	**Z**
V1:	_____	_____	_____
V2:	_____	_____	_____
CE:	_____	_____	_____

Net CE: _____

7.2.3 Use the Matlab m-file gyropos.m to determine the position of the rotor (in μin) and record below: _____

	X	**Y**	**Z**
Pos:	_____	_____	_____

7.2.4 Now adjust the sensor bias and sensor gain until the calculated position is within 20 microinches of the commanded position the following positions:

[X Y Z] = [0 0 0] microinches

[X Y Z] = [+200 +200 +200] microinches
[X Y Z] = [–200 –200 –200] microinches

Record the operations and DDC snapshots necessary to achieve this in the table on the following page: _____

Item (e.g. CE, Pos, etc.)	X	Y	Z	Comment (e.g. DDC Snapshot)

7.2.5 Record the final sensor gains and biases below: _____

	X	Y	Z
Bias:	_____	_____	_____
Gain:	_____	_____	_____

7.2.6 Make sure the rotor is commanded to the center position, and take a final snapshot.

Filename: _____ _____

7.2.7 Record the following data by taking the mean of Vx1-Vz2 and ux – uz as recorded in the above shapshot. The DDC position is now calibrated. _____

	X	Y	Z
V1:	_____	_____	_____
V2:	_____	_____	_____
CE:	_____	_____	_____
Net CE:	_____		

Completion Date: _____

Completion Time: _____

7.3 Completion of Section

Record Completion of this section in traveler, as appropriate.

Record any abnormalities or deviations from this procedure in the D-Log. If the QA representative decides it is appropriate, then open a Discrepancy Report to document the event.

This test has been completed according to the procedure contained herein. All redlines used have been integrated into this document (sign):

Test Director: (print)	(sign)
QA Representative: (print)	(sign)

8. Levitation of Gyroscope (after first levitation)

Note: This section is intended to be used when the DDC has already been used to levitate the gyroscope in question so that the correct levitation parameters are known. If there has been any servicing of the DDC since the last levitation, then sections 6 and 7 should be completed.

Note: Please review sections 1-4 before completing this section. They contain information and warnings vital to the successful completion of this procedure.

8.1 Operations

Start Date: _____

Start Time: _____

8.1.1 Make sure the probe pressure is less than 5×10^{-5} torr. Record pressure below:

Pressure (torr): _____ _____

8.1.2 If necessary, connect all Reynolds to MHV adapter boxes to Probe C connections for gyroscope of interest. Record the mate in connector log. _____

8.1.3 *If the DDC cables are already connected to the probe,* check to see if the High voltage switch is on. ***DO NOT TURN HIGH VOLTAGE SWITCH ON YET.***

If the high voltage switch is already on, proceed to step 8.1.5.

If the high voltage switch is not on, disconnect all suspension cables from the probe at the MHV connector, turn on the high voltage switch, then reconnect the cables to the probe. Note the mate and demate in the appropriate log. _____

8.1.4 *If the DDC cables are not connected to the probe*, turn on the high voltage, then connect the cables. Note that the appropriate connections are detailed in Table A. _____

8.1.5 Using the same parameters used during the previous levitation, levitate the rotor by pressing the lift button in the DDC software. _____

8.1.6 Write down the control efforts indicated in the DDC software window. _____

X-axis CE (g's): _____

Y-axis CE (g's): _____

Z-axis CE (g's): _____

Net CE (g's): _____

8.1.7 If, in the judgement of the DDC operator, the control efforts show indication of charge > 50V, delevitate the rotor, abort the procedure, and record the incident in a Discrepancy Report.

8.1.8 Take a DDC snapshot.

Filename: _____ _____

8.1.9 Wait at least 10 minutes. If there is, in the judgement of the DDC operator, no indication of significant charging after this time, it is OK to proceed to the next operation. _____

Completion Date: _____

Completion Time: _____

8.2 Completion of Section

Record Completion of this section in traveler, as appropriate.

Record any abnormalities or deviations from this procedure in the D-Log. If the QA representative decides it is appropriate, then open a Discrepancy Report to document the event.

This test has been completed according to the procedure contained herein. All redlines used have been integrated into this document (sign):

Test Director: (print)	(sign)
QA Representative: (print)	(sign)

9. Gyroscope Delevitation

Note: Normally Section 9.1 should be completed to delevitate the rotor. However, on occasion the DDC computer may stop responding in some way (which is usually due to a bug in the Windows 95 operating system, not a bug in the DDC software itself). If this happens, the DSP is still running so the gyroscope will not crash. The delevitation procedure, however, is somewhat different. Therefore, if the DDC computer has stopped responding in some way, complete Section 9.2 instead of Section 9.1.

Note: Please review sections 1-4 before completing this section. They contain information and warning vital to the successful completion of this procedure.

9.1 Normal Delevitation

Start Date: _____

Start Time: _____

9.1.1 Delevitation of the rotor is not permitted at spin speeds greater than 0.3 Hz. If necessary, spin down the rotor to <0.3 Hz using the appropriate signed procedure.

Record Final Spin Speed: _____

9.1.2 Take a DDC snapshot.

Filename: _____

9.1.3 If the rotor is not in the center of the housing, command it to the center and take another DDC snapshot.

Filename (if taken): _____

9.1.4 Delevitate the rotor by pressing the delevitate button in the DDC software window. When it asks if you really want to delevitate the rotor, press "Yes". _____

9.1.5 Note that it is not permitted to turn the high voltage switch on while the cables are connected to the probe. To avoid the possibility of someone turning on the high voltage with the cables connected to the probe, the user is discouraged from turning *off* the high voltage while the DDC is _____

connected to the probe unless there is a very strong reason for doing so.

If the high voltage is turned off, then label a piece of paper "DO NOT TURN HIGH VOLTAGE ON UNLESS DISCONNECTED FROM THE PROBE" and tape it over the high voltage switch. _____

Completion Date: _____

Completion Time: _____

9.2 Delevitation when DDC Computer has Stopped Responding

For use only if the DDC computer has stopped responding in some way. If Section 9.1 has already been completed, skip this section and go to 9.3.

Start Date: _____

Start Time: _____

9.2.1 If the DDC computer has stopped responding, the DSP should still be running, so the gyroscope will still be levitated. Therefore this is not an emergency. Note the fact that the DDC software has stopped responding in the D-Log, however (a DR is not necessary). _____

9.2.2 Delevitation of the rotor is not permitted at > 0.3 Hz spin speed without the authorization of the Hardware Manager. If necessary, spin down the rotor to < 0.3 Hz using the appropriate signed procedure. _____

9.2.3 Turn off the high voltage switch. The rotor is now down. _____

9.2.4 Disconnect the DDC cables from the probe. This is done to help ensure that the high voltage switch will not be turned back on the cables attached to the probe. _____

Completion Date: _____

Completion Time: _____

9.3 Completion of Section

Record Completion of this section in traveler, as appropriate.

Record any abnormalities or deviations from this procedure in the D-Log. If the QA representative decides it is appropriate, then open a Discrepancy Report to document the event.

This test has been completed according to the procedure contained herein. All redlines used have been integrated into this document (sign):

Test Director: (print)	(sign)
QA Representative: (print)	(sign)

10. Disconnect DDC

Note: Please review sections 1-4 before completing this section. They contain information and warning vital to the successful completion of this procedure.

10.1 Operations

Start Date: _____

Start Time: _____

10.1.1 The rotor should already be delevitated. If necessary, complete Section 9 before proceeding to delevitate. _____

10.1.2 Disconnect all DDC cables at the MHV connection closest to the Probe. _____

10.1.3 If necessary, disconnect the MHV to Reynolds adapters from the Probe. Note the demate in its log sheet. _____

10.1.4 Archive all files used in the previous levitation attempts. If the DDC disk space is <300 MB, delete the old files. _____

Completion Date: _____

Completion Time: _____

10.2 Completion of Section

Record Completion of this section in traveler, as appropriate.

Record any abnormalities or deviations from this procedure in the D-Log. If the QA representative decides it is appropriate, then open a Discrepancy Report to document the event.

This test has been completed according to the procedure contained herein. All redlines used have been integrated into this document (sign):

Test Director: (print)	(sign)
QA Representative: (print)	(sign)

TABLE A: DDC CONNECTIONS IN PROBE C

Gyroscope #1 Connections

Gyroscope Electrode	Probe C Connection	DDC Axis	Color	Notes
R1	C11	X1	Red	
S1	C12	X2	Purple	
R2	C13	Y1	Brown	
S2	C15	Y2	Orange	
R3	C16	Z1	White	
S3	C17	Z2	Yellow	
GP	CG18	N/A	N/A	

Gyroscope #2 Connections

Gyroscope Electrode	Probe C Connection	DDC Axis	Color	Notes
R1	C21	X1	Red	
S1	C22	X2	Purple	
R2	C23	Y1	Brown	
S2	C24	Y2	Orange	
R3	C25	Z1	White	
S3	C27	Z2	Yellow	
GP	CG28	N/A	N/A	

Gyroscope #3 Connections

Gyroscope Electrode	Probe C Connection	DDC Axis	Color	Notes
R1	C32	X1	Red	
S1	C33	X2	Purple	
R2	C34	Y1	Brown	
S2	C35	Y2	Orange	
R3	C31	Z1	White	
S3	C37	Z2	Yellow	
GP	CG38	N/A	N/A	

Gyroscope #4 Connections

Gyroscope Electrode	Probe C Connection	DDC Axis	Color	Notes
R1	C43	X1	Red	
S1	C47	X2	Purple	
R2	C41	Y1	Brown	
S2	C42	Y2	Orange	
R3	C44	Z1	White	
S3	C45	Z2	Yellow	
GP	CG48	N/A	N/A	