W. W. Hansen Experimental Physics Laboratory

STANFORD UNIVERSITY
STANFORD, CALIFORNIA 94305 - 4085

Gravity Probe B Relativity Mission

70KHZ DIGITAL D.C. SUSPENSION SYSTEM CHECKOUT AND RELEASE PROCEDURE

GP-B P0381 Rev. A

13 September 2000

Prepared by: David Hipkins **Date**
Engineer

Approved by: Rob Brumley **Date**
Manager, Gyroscopes

Approved by: D. Ross **Date**
GP-B Quality Assurance

Approved by: William Bencze **Date**
Manager, Science Mission Electronics

P0381 - DOCUMENT REVISION HISTORY

Date	Rev. #	Description of Change	Entered by:
8 Jan 98	–	Initial release	W. Bencze
8 Sept 00	A	Added matlab calibration routine in section F. to improve sensor bias and gain adjustments. Also included a sign off page to document the date of completion.	D. Hipkins

P0381 - TABLE OF CONTENTS

70KHZ DIGITAL D.C. SUSPENSION SYSTEM CHECKOUT AND RELEASE PROCEDURES

I. SCOPE:

This procedure is used to perform the final calibration and performance checks on a Digital D.C. (DDC) suspension system prior to delivery for use as GSE equipment in GP-B science mission gyroscope commissioning.

II. APPLICABLE DOCUMENTS:

1.	S0298	DDC Suspension System Software, Configuration, and Tuning Standards
2.	(n/a)	DDC tuning and performance report, attached to DDC system in question.

III. CLEANLINESS PRECAUTIONS:

As GSE equipment, no special cleanliness precautions are required for this equipment. It should be housed indoors in a clean (generic laboratory), dry environment.

IV. ESD PRECAUTIONS:

The DDC operator during the execution of this checkout procedure shall be connected to the DDC suspension system rack via a ESD wrist strap and connecting cable.

V. REQUIRED TEST EQUIPMENT:

As GSE equipment to flight hardware, the DDC system must be checked out with calibrated test equipment. The list of the types of equipment required for this checkout is as follows:

1. Digital voltmeter, ≥ ±1000 VDC range, ≤ 0.1 V resolution.
2. Handheld capacitance meter. ≤ 0.1 pF resolution.

Item	Description (Manufacturer and model number)	S/N	Cal Expires

Other required test equipment and hardware:

1. Calibrated, adjustable gyroscope dummy load.

Measurements of dummy load capacitances are attached in Appendix A.

2. Calibrated suspension cable set, 300pF nominal capacitance.

Measurements of cable capacitances are attached in Appendix B

3. Portable gyroscope cart (RT-5 through RT-8) with gyroscope installed.

Cart used: RT - ______

Gyroscope installed: ___________

VI. PRE-TEST CONDITIONS:

The DDC suspension system in question has already been tuned and calibrated to the standard set of DDC suspension system specifications and has been shown to be functional in the DDC laboratory.

VII. PROCEDURE:

A. Verification of proper DDC software set:

1. The gyroscope commissioning process shall use the version-controlled DDC software version 1.07 for all commissioning work. Verify that the following files are loaded on the DDC computer:

Location	Name	Timestamp	Pass/fail
c:\ddc_exe	ddc.exe	9/24/97 4:17 PM	
c:\ddc_exe	ddc.cfg	<varies>	
c:\ddc_exe	config.ddc	<varies>	
c:\ddc_exe	c30v107.out	9/24/97 4:19 PM	
c:\ddc_exe	c30_file.ddc	<varies>	
c:\ddc_exe\include	ddc_map.h	9/9/97 1:51 PM	

2. Verify that at least 100 Mbytes of free hard disk space is available on the computer.
3. Archive if necessary and then erase the old suspension system data files in the `c:\ddc_exe\data` directory.

The software configuration is a specified in this section:

Pass:____________ Fail:____________

B. Record DDC system configuration:

1. Record in the table below the gain and bias settings for the high voltage amplifiers, found in the "Config|HV amp and bridge gains" dialog box:

Channel	**Gain**	**Bias**
X1		V
X2		V
Y1		V
Y2		V
Z1		V
Z2		V

2. Record in the table below the gain and bias settings* for the position bridge, found in the "Config|HV amp and bridge gains" dialog box:

Channel	**Gain**	**Bias**
X		V
Y		V
Z		V

*These settings are not necessarily going to reflect the optimal values upon completion of P0381. For the final settings go to section F.

C. High Voltage Amplifier Bias Calibration Verification:

1. Verify that the DDC suspension system software is running in "idle" mode; the system status line on the DDC suspension program main panel should read "Gyro down; system idle"
2. Ensure the high voltage power supply is switched off and that the low voltage power is switched on.
3. Connect the six suspension cables to the rear of the high voltage amplifier boxes.
4. Select Config|HV Amp calibration menu item.
5. Check the "Enable HV amp calibration voltages" box and set the voltage to 0.0 volts. Close the dialog box.
6. Turn on the power to the high voltage amplifier.
7. Using a digital volt meter with a BNC adapter, measure the MHV center pin (+) to shield (-) voltage at the end of each of the six suspension cables. Record the results in the following table.

Channel	Measured voltage	Acceptance range	Pass/Fail
X1 (red)	V	-1.0 to +1.0 V	
X2 (purple)	V	-1.0 to +1.0 V	
Y1 (brown)	V	-1.0 to +1.0 V	
Y2 (orange)	V	-1.0 to +1.0 V	
Z1 (white)	V	-1.0 to +1.0 V	
Z2 (yellow)	V	-1.0 to +1.0 V	

Status of the complete set of HV bias tests:

Pass:____________ Fail:____________

D. High Voltage Amplifier Gain Calibration Verification:

1. Verify that the DDC suspension system software is running in "idle" mode; the system status line on the DDC suspension program main panel should read "Gyro down; system idle"
2. Ensure the high voltage power supply is switched off and that the low voltage power is switched on.
3. Connect the six suspension cables to the rear of the high voltage amplifier boxes.
4. Select Config|HV Amp calibration menu item.
5. Check the "Enable HV amp calibration voltages" box and set the voltage to 500 volts. Close the dialog box.
6. Turn on the power to the high voltage amplifier.
7. Using a digital volt meter with a BNC adapter, measure the MHV center pin (+) to shield (-) voltage at the end of each of the six suspension cables. **Note: use extreme care during the measurement process; high voltage is present at the ends of the cables.** Record the results in the following table:

Channel	Measured voltage	Acceptance range	Pass/Fail
X1 (red)	V	+495.0 to +505.0 V	
X2 (purple)	V	+495.0 to +505.0 V	
Y1 (brown)	V	+495.0 to +505.0 V	
Y2 (orange)	V	+495.0 to +505.0 V	
Z1 (white)	V	+495.0 to +505.0 V	
Z2 (yellow)	V	+495.0 to +505.0 V	

Status of the complete set of HV gain tests:

Pass:____________ Fail:____________

E. Bridge bias calibration verification:

1. Verify that the DDC suspension system software is running in "idle" mode; the system status line on the DDC suspension program main panel should read "Gyro down; system idle"
2. Ensure the high voltage power supply is switched off and that the low voltage power is switched on.
3. Connect the six calibrated suspension cables to the rear of the high voltage amplifier boxes. The calibration table for these cables is given in Appendix B.
4. Connect the six suspension lines to the calibrated dummy load. Ensure that the six delta capacitance switches are in the 0 pF position. The calibration table for this dummy load is given in Appendix A.
5. Measure the output voltage for each bridge axis at the BNC on the front panel of each of the three bridge boxes and record it in the column marked "1" in the table below.
6. Record the indicated position for each axis for as given on the main DDC suspension system program status window in the column marked "2" in the table below.

Bridge channel	1. Measured output voltage	2. Indicated position on DDC main window	Acceptance range	Pass/fail
X channel	V	µin	−10 to +10 µin	
Y channel	V	µin	−10 to +10 µin	
Z channel	V	µin	−10 to +10 µin	

Status of the bridge bias tests:

Pass:____________ Fail:____________

F. Bridge gain calibration verification:

1. Verify that the DDC suspension system software is running in “idle” mode; the system status line on the DDC suspension program main panel should read “Gyro down; system idle”
2. Ensure the high voltage power supply is switched off and that the low voltage power is switched on.
3. Connect the six calibrated suspension cables to the rear of the high voltage amplifier boxes. The calibration table for these cables is given in Appendix B.
4. Connect the six suspension lines to the calibrated dummy load. Ensure that the six delta capacitance switches are in the 0 pF position. The calibration table for this dummy load is given in Appendix A.
5. Switch the X1 (red), Y1 (brown), and Z1 (white) delta capacitance switches to the 15 pF position.
6. Measure the output voltage for each bridge axis at the BNC on the front panel of each of the three bridge boxes and record it in the column marked “1” in the table below.
7. Record the indicated position for each axis for as given on the main DDC suspension system program status window in the column marked “2” in the table below.

Bridge channel	1. Measured bridge output voltage	2. Indicated position on DDC main window	Acceptance range	Pass/fail
X channel	V	μin	+125 to +135 μin	
Y channel	V	μin	+125 to +135 μin	
Z channel	V	μin	+125 to +135 μin	

Status of the bridge bias tests:

Pass:____________ Fail:____________

G. System operation verification:

This verification process should be performed by a qualified DDC suspension system operator. A list of qualified operators is attached in Appendix C.

1. Verify that the DDC suspension system software is running in "idle" mode; the system status line on the DDC suspension program main panel should read "Gyro down; system idle"
2. Ensure that *both* the high-voltage and low-voltage power supplies are switched on.
3. Connect the suspension system to the gyro cart using the calibrated cables.
4. Suspend the gyroscope; treat the gyroscope as an unknown and suspend the gyroscope using incrementally more aggressive lift timeout and loop gains until the gyroscope suspends.
5. Adjust the loop gain for stable suspension and then the gap parameter until the indicated net suspension force is 1.0g ±0.05g.
6. Calibrate the sensor bias with the rotor centered and sensor gain at +/- 200 microinches using the Matlab m-file, gyropos2. This can be an iterative process. If so, record only the last iteration.

Commanded Rotor Position [XYZ]	Actual Rotor X Position	Actual Rotor Y Position	Actual Rotor Z Position
[0 0 0]			
[-200 –200 –200]			
[200 200 200]			

Channel	Sensor Gain	Sensor Bias
X		V
Y		V
Z		V

Final calibrated results

7. Record the indicated DDC configuration parameters in the following table:

Parameter:	**Value:**
Amp polarity configuration (MMP, etc)	
Time to lift:	msec
Loop gain at lift:	
Indicated gyro gap:	µin
Nominal operating loop gain:	
Net suspension force, all axes	g
Suspension force, X axis	g
Suspension force, Y axis	g
Suspension force, Z axis	g

Status of the suspension system operation verification test:

Pass:_____________ Fail:_____________

H. System performance verification:

This verification process should be performed by a qualified DDC suspension system operator. A list of qualified operators is attached in Appendix C.

1. Verify that the DDC suspension system software is running in "idle" mode; the system status line on the DDC suspension program main panel should read "Gyro down; system idle"
2. Ensure that *both* the high-voltage and low-voltage power supplies are switched on.
3. Connect the suspension system to the gyro cart using the calibrated cables.
4. Suspend the gyroscope using the nominal DDC parameters found in section VII-G
5. Ensure the gyroscope position command is 0 µin on all axes.
6. Incrementally lower the gain in 0.005 step increments until the gyro suspension system automatically shuts down. Record the gain at shutdown in column 1 below.
7. Suspend the gyroscope using the nominal DDC parameters found in the previous section.
8. Incrementally increase the gain in 0.02 step increments until the gyro suspension system automatically shuts down. Record the gain at shutdown in column 2 below.
9. Compute the resulting gain margin and enter the value in column 3. The gain margin is found via the formula:

$$GM = 20\log_{10}\left(\frac{\text{High gain}}{\text{Low gain}}\right)$$

10. Repeat steps 4 through 9 at the other two non-zero gyroscope positions as indicated in the table below.

Rotor position (all axes)	1. Low gain shutdown	2. High gain shutdown	3. Resulting gain margin	Acceptance range	Pass/fail
0 µin			dB	≥ 12 dB	
+300 µin*			dB	≥ 9 dB	
-300 µin*			dB	≥ 9 dB	

* Make sure to change the safety radius to allow for this off-center position.

Status of the suspension system performance verification test:

Pass:____________ Fail:____________

I. System robustness verification:

<u>This verification process should be performed by a qualified DDC suspension system operator. A list of qualified operators is attached in Appendix C.</u>

1. Verify that the DDC suspension system software is running in "idle" mode; the system status line on the DDC suspension program main panel should read "Gyro down; system idle"
2. Ensure that *both* the high-voltage and low-voltage power supplies are switched on.
3. Connect the suspension system to the gyro cart using the calibrated cables.
4. Suspend the gyroscope using the nominal DDC parameters found in section VII-G.
5. Set the gyroscope position command to -300 µin on all axes.
6. Allow the system to run unattended and undisturbed for more than 24 hours in a quiet laboratory environment. Enter the start and stop times in the table below:

Start	Time:	Date:
End	Time:	Date:

7. <u>Pass criteria</u>: The system keeps the gyroscope levitated continuously during this greater-than 24 hour period; no shutdowns.
8. In the result of a failure of this test, attach a printout of the shutdown trace to this procedure. Also attach a computer disk with both the shutdown trace (filename is in the <month><day><hour><min>.dn format) and the associated long-term voltage data file trace (filename is in the ch<day><hour><min>.dat format) to this procedure.

   Record the names of the files below, or check "N/A" if not applicable:

File type:	**Filename:**	**N/A**
Shutdown trace file		
Long-term voltage data file:		

Status of the suspension system robustness verification test:

Pass:____________ Fail:____________

J. ***Procedure completed on: ________________________***

Engineer(s) who helped in the commissioning of the unit:

____________________________________	______________________________
Name of engineer	(Section(s) of the procedure
____________________________________	______________________________
Name of engineer	(Section(s) of the procedure
____________________________________	______________________________
Name of engineer	(Section(s) of the procedure

Notes:

VIII. APPENDIX A - DUMMY LOAD CAPACITANCE CALIBRATION

The capacitance values of the gyroscope dummy load used in this checkout procedure are as indicated below and have been measured with a calibrated capacitance meter.

Meas. date	Manufacturer/model	S/N	Cal Expires

Dummy load capacitance values:

Channel	Nominal capacitance	Cap with 15 pf delta-C switch thrown.
X1 (red)	pF	pF
X2 (purple)	pF	pF
Y1 (brown)	pF	pF
Y2 (orange)	pF	pF
Z1 (white)	pF	pF
Z2 (yellow)	pF	pF

This dummy load is stored in HEPL Rm. 125, the DDC development laboratory, and is marked "Calibrated DDC Dummy Load."

IX. APPENDIX B - SUSPENSION CABLES CAPACITANCE CALIBRATION

The capacitance values of the suspension cables used in this checkout procedure are as indicated below and have been measured with a calibrated capacitance meter. The nominal cable capacitance is 300 pF.

Meas. date	Manufacturer/model	S/N	Cal Expires

Cable capacitance values:

Channel	Nominal capacitance
X1 (red)	pF
X2 (purple)	pF
Y1 (brown)	pF
Y2 (orange)	pF
Z1 (white)	pF
Z2 (yellow)	pF

These cables are stored in HEPL Rm. 125, the DDC development laboratory, and are marked "Calibrated 300 pF DDC Suspension Cables."

X. APPENDIX C - QUALIFIED DDC SUSPENSION SYSTEM OPERATORS

The following is a list of qualified DDC suspension system operators. Qualification is achieved through a personal training session with a currently qualified operator followed by a significant amount of field experience on gyroscope carts and in other venues not associated with gyroscope commissioning.

1. William Bencze.
2. David Hipkins
3. Robert Brumley.
4. Yoshimi Ohshima.
5. Chris Gray.
6. Bruce Clarke.