GOOGOL **TECHNOLOGY**

INVERTED PENDULUM

INSTRUCTION MANUAL
Suitable for GLIP Series

Second Edition, April, 2006

Be sure to give this instruction manual to customers!

- Thank you very much for purchasing INVERTED PENDULUM (GIP Series) of Googol Tech.
- Be sure to read this manual carefully before operation.
- For any technical trouble, call us or visit http://www.googoltech.com on the World Wide Web for consultation.
- After reading this manual, keep it handy so that it can be referred to at anytime.

CONTENTS

CHAPTER 1   SAFETY PRECAUTION

1.1 Cautions on Safety

Please note the cautions. Otherwise, a misoperation will lead to an unexpected accident or damage.

The following symbolic indication of "**DANGER**" and "**CAUTION**" may lead to serious results depending on situations.

❌	**DANGER**	Incorrect operation may result in such a dangerous situation as death or serious injury.
⚠️	**CAUTION**	Incorrect operation may result in such a dangerous situation as medium or slight injury.

☞   The following symbols indicate what should not be done and what should be done by all means.

✋	**PROHIBITION**
❗	**COMPULSION**

Before removing the control board from its conductive packaging, touch your hand on a grounded metal object for discharging static electricity. Avoid touching the components on the board. A pair of static electricity-proof glove is suggested.

Otherwise, the board may be damaged.

For your first use, please discharge the pendulum arm, run the test program to confirm if the product runs correctly. Don't adjust the motor driver without permission. Otherwise, you shall bear responsibility for all the serious consequences caused.

Otherwise, you may be injured or troubles may occur.

The Sequence to turn on/off the power: first to enter DOS environment (PC), then turn on the power of the Electric Control Box; contrarily, the sequence is contrary. Check the wiring carefully, wrong or disconnected wiring for the coder may cause collision.

Otherwise, the pendulum may be damaged or you may be injured.

Don't stand in the two sides of the Linear Inverted Pendulum when it is running, but face at it. For the Circular Inverted Pendulum, don't stand in the area of its running.

Otherwise, you may be injured.

1.2 Cautions on Unpacking

- When unpacking the product, check if what you have received are as your order;
- Check if the components of the product are damaged during transportation, such as the limit switch and so on;
- Check if the components (including the connected cable) of the product are lacking;
- If any abnormality is detected, please contact our dealer or authorized agency.

CHAPTER 2   INTRODUCTION

GLIP200X is a series of three state-of-the-art linear inverted pendulum systems from Googol Technology. Each of the system consists of a cart which slides on a parallel track and is powered by a servo motor, a DSP-based control system with interface electronics, and a chain of pendulums mounted to the cart through a passive joint. GLIP2001 contains a single pendulum, GLIP2002 a double pendulums and GLIP2003 a triple pendulums.

GRIP20XX is a series of three state-of-the-art circular inverted pendulum systems. The common module of the GRIP20XX is a rotary servo system. When two single pendulums are parallel suspended from the instrumented joints，It constructs a GRIP2011 inverted pendulum. If only a single pendulum is suspended from an instrumented joint, it constructs a GRIP2001. If a double pendulum is suspended, that constructs GRIP2002. High-resolution encoder sensors mounted on the servo motor and the joint axes of the pendulum provide position information of the cart and the pendulum, respectively.

2.1 System Configuration

In general each Inverted Pendulum (IP) System of Googol Technology consists of the following components: mechanism, the sensors and actuators, the control hardware, and the control software. In a linear IP system, the mechanism is a linear servo motion cart with a chain of pendulums, and in a circular IP system, the mechanism is a rotary servo system with a chain of pendulums. The types of systems presently available are briefly described in the table below.

Inverted Pendulums		
Type	**Main Model**	**Description**
Linear IP Systems	GLIP2001	Linear single inverted pendulum
	GLIP2002	Linear double inverted pendulum
	GLIP2003	Linear triple inverted pendulum
Circular IP Systems	GRIP2001	Circular single inverted pendulum
	GRIP2002	Circular series double inverted pendulum
	GRIP2011	Circular parallel double inverted pendulum

2.2 Mechanism and Parts Identification

2.2.1 Linear Inverted Pendulum

As shown in Figure 2-1, the mechanical unit of linear inverted pendulum consists of the following parts:

Base

Cart
Sliding shaft
Timing belt
Timing wheel
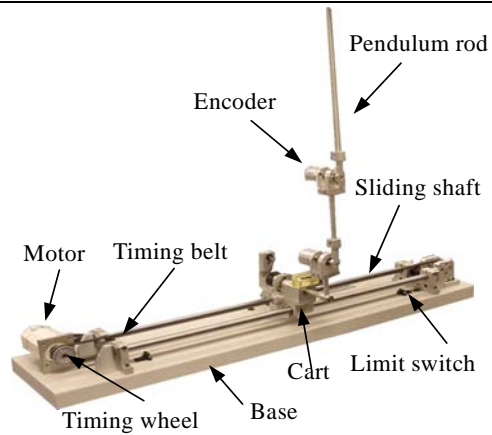Optical encoder
Limit switch
Pendulum rod
Motor.

Figure 2-1

2.2.2 Circular Inverted Pendulum

The entire view of the circular inverted pendulum is as shown in Figure 2-2. The Mechanism is designed and fabricated without mechanical limit, and a slipring is used to output the signal from angle encoders, and eliminate damage-prone wires dangling from movable pendulums.

The movable pendulums are driven by an AC servo motor through gear transmission.

2.3 Electric Control box

The control box of linear IP houses a power supply, a servo amplifier, circuit protection electronics and terminal interconnections.

The power switch of the control box is found on the front side panel as shown in Figure 2-3. Pull the level upward to turn on the machine.

All electric components of circular IP are housed into the base of pendulum, so there is not independent control box.

Figure 2-2

Figure 2-3

2.4 Control Platform

The Control Hardware consists of a PC for program development and user interface, a DSP-based motion control card (GT-400-SV-PCI) with advanced data I/O and storage capability, and several connection cables, connecting the PC to the **control box** and the **control box** to the pendulum base.

The Control Software comes in with one of two options. The first option is a DOS based version in which all control algorithms are programmed in C. Sample programs and source codes for

input/output are provided for educational purpose. The second option is a MATLAB based that runs under Windows 98/2000 environment. Simulink is used as an interactive tool for modeling, simulating, and analyzing pendulum systems. It enables you to build graphical block diagrams, evaluate system performance, and refine your designs.

CHAPTER 3   INSTALLATION

3.1 Mechanical Assembly

Carefully unpack the machine, and remove all packaging and securing material.

To linear inverted pendulum systems, place the Mechanical Unit on a level surface of the table so that the pendulum can freely swing up and down, and allow sufficient room for the controller box, PC and keyboard. Ensure that the pendulum is clear of any obstructions when executing a complete revolution, and is not able to make contact with any observers.

To circular inverted pendulum, place the mechanical Unit on a level surface of the floor, and allow the pendulum can freely rotate and swing up and down. Ensure that the pendulum is clear of any obstructions when executing a complete revolution, and is not able to make contact with any observers.

3.1.1 Tools

During installing the mechanical body of the IP system, five types of hexagon spanners will be used, **1.5mm, 2mm, 2.5mm, 3mm, and 4mm**. A set of the hexagon spanners will be shipped together with the product in the package.

3.1.2 IP System Mechanical Body Assembly

1) Requirement for the venue of IP installation

The pendulum should be able to be extended fully, and it should be close and parallel to the edge of the table or stand.   Make sure that when the pendulum rotates 360 degrees, the pendulum and the angle encoder will not touch the edge of the table, the wall, the safety fence, the experimental platform or the electric box. Please refer to below figures:
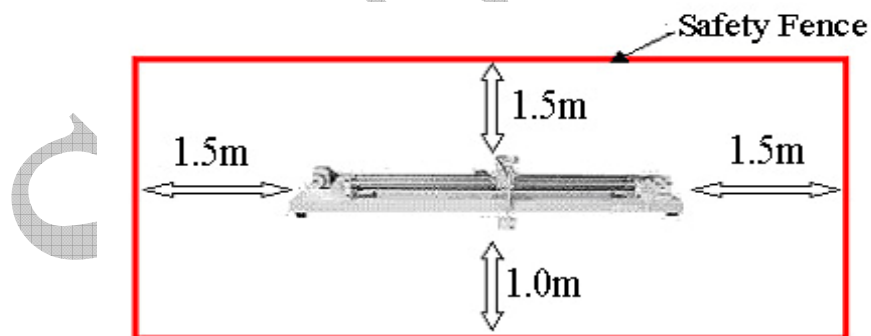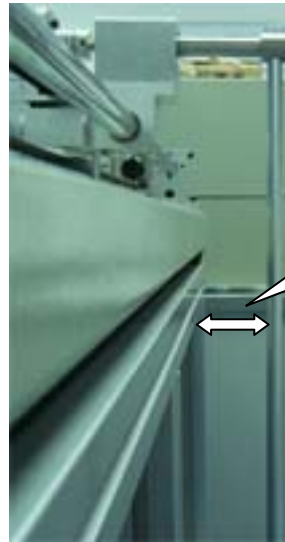
FIGURE 3-1 THE AREA OF SAFETY FENCE

Leave sufficient space between the pendulum rod and the edge of the table

FIGURE 3-2 SPACE OF THE PENDULUM MOVING FREELY

2) After placing the main body, open the package of the pendulum and check whether there is any damage on it. If there is, please contact Googol Technology immediately.

⚠ CAUTION

- **Don't drag or scissor the signal cable of the encoders when unpacking. Otherwise, it will result in system signal error, or even equipment damage.**

- **Please handle with care when operating the pendulum rod, avoid excessive shock and impact. Otherwise, the precision equipment might be damaged.**

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3) Pendulum Rod Assembly:

➤ **1-stage IP Assembly**

Assembly procedures:

Step 1: Take off the screw on the end of the pendulum. As shown in Figure 3-3.

M4 Screw

FIGURE 3-3 TAKE OFF THE SCREW

Step 2: Loosen the screw on one end of the encoder axis on the cart by the inner hexagon spanner,

as in Figure 3-4.

FIGURE 3-4 THE SCREW ON ONE END OF ENCODER AXIS ON THE CART

Step 3: Insert the end of the pendulum with a screw thread and a flat face into the hole of the encoder axis on the cart. The flat face on the pendulum should face the lateral screw, fasten the screw and then fix the pendulum using the screw taken down in Step 1 through the other end of the hole, which the pendulum is inserted in. As shown in the following figure.

FIGURE 3-5 END OF THE PENDULUM

FIGURE 3-6 FIX THE PENDULUM OF 1-STAGE IP