IMP-6000S
Hardware User Manual

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Chapter 1 Overview

1.1. Introduction

The 6-Axis Standalone Intelligent Motion Control Platform, IMP-6000S, employs the Intelligent Motion Control (IMC) chip developed by the MSL of ITRI and is capable of evenly sending the pulse for each axis through the Pulse Generator (PGE) (Note 1) based on the Digital Differential Analyzer (DDA) principle to realize 6-axis synchronous/asynchronous motion control. During the pulse output control period, it allows the encoder to read the motor's encoding values from its input terminal so it is suitable for pulse-command servomotor or stepper motor control.

IMP-6000S can connect with an adapter (IMP-6000S-1 or IMP-6000S-2, Note 2) and an analog/digital conversion adapter (IMP-6AB, Note 3) to form a complete controller ready to connect with various machines. Featuring 6-axis servomotor open-loop or closed-loop synchronous motion control, IMP-6000S is built-in with the hardware-based PID and FF (FeedForward, Note 4) control algorithm to provide output voltage between -10V and 10V for driving velocity-command servomotors. It can be used for multi-axis high-precision servo control and provides a software-based servo control interface for solving problems associated with tracking errors and steady-state errors. Each axis has a set of input/output that includes mechanical home position, forward limit point, and backward limit point. In addition, it also provides Servo On outputs, Position Ready outputs, and Emergency Stop inputs.

IMP-6000S has a built-in microprocessor (Power PC440) with a hardware double-precision floating-point unit. By running the real-time operating system (RTOS) VxWorks, it can be used to construct an embedded motion control platform which can be operated in the standalone mode to carry out the motion control mission. In addition to standalone motion control operations, the platform is integrated with the widely used Ethernet controller to communicate with external devices. The user can use a personal computer or other user interface to send motion commands to IMP-6000S and monitor its operation through a network. For input/output expansion, the IMP-ARIO / IMP-ARIO64 (Asynchronous Remote I/O Board) can be used to provide up to 512 inputs and up to 512 outputs.

Note 1: For the PGE, please refer to Fig. 1-6 and Fig. 1-7.

Note 2: IMP-6000S-1: universal adapter, IMP-6000S-2: dedicated adapter. See Section 1.3.

Note 3: IMP-6AB: analog/digital conversion adapter (6-Axis Analog Board).

Note 4: For the PID and FF control algorithm, please refer to Fig.1-5.

1.2. IMP-6000S Hardware Specifications
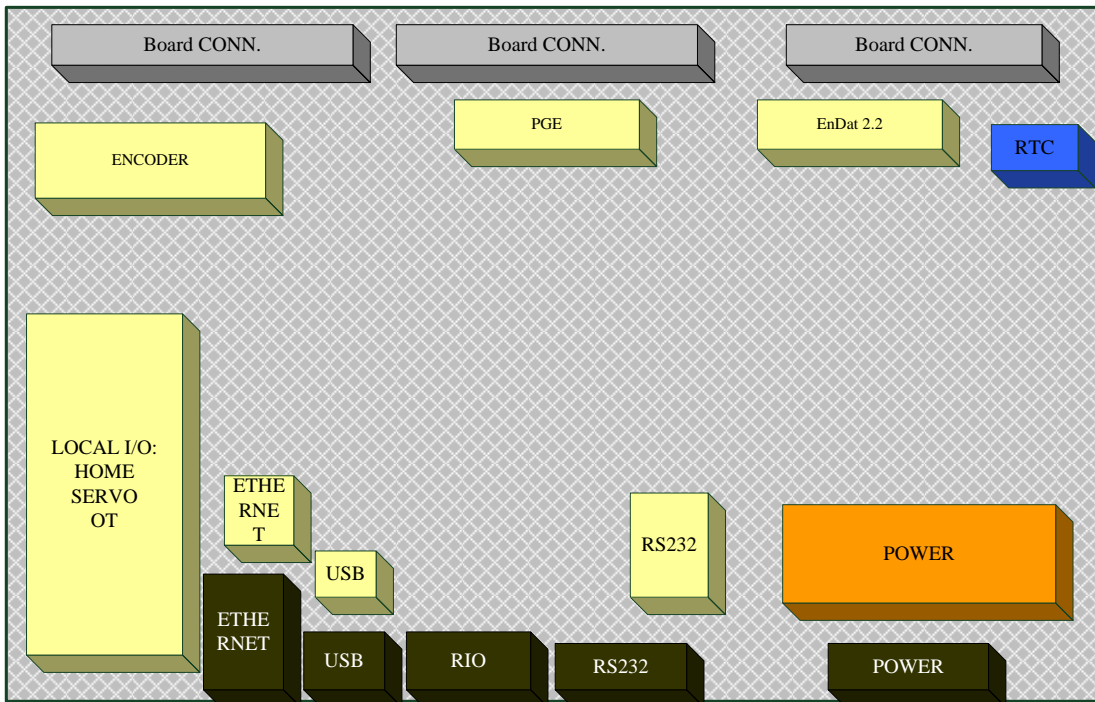
Fig. 1-1 Diagram of IMP-6000S Hardware Layout

Motion		System/Peripheral	
PGE	32-bit* 6 Channels	CPU	32-bit RISC 400MHz
Encoder Interface	32-bit * 6 Channels	Flash	32MB
EnDat 2.2 Interface	3 Channels	PROM	32MB
PCL	6 Channels (PID & FeedForward Control)	RS232	1 Set
LIO (on board)	32 terminals	USB	1 Set (USB 2.0)
RIO	Max: 512In / 512Out	DDR	128MB
Timer	32-bit	Ethernet	1 Set (10/100Mbps)
Watchdog Timer	32-bit		

Note:

        PGE: Pulse generator   RIO: Remote Input/Output

        LIO: Local Input/Output   RTC: Real-Time Clock

        PCL: Position Control Loop

1.3. Description of Operation Modes and Connection Diagram

IMP-6000S can be operated in **A⁺PC Ethernet mode** and **standalone mode**, which are described as follows:

A⁺PC Ethernet mode:

This mode allows the user to develop, compile, and execute application software using a personal computer. The computer communicates with IMP-6000S through a network when executing application software. In order to achieve multi-tasking and distributed processing, the related motion control functions are computed and processed by IMP-6000S, while the user interface and other application programs are computed and processed by the personal computer.

Standalone mode:

This mode allows the user to develop, compile, and **upload** application software using a personal computer. IMP-6000S must be supplied with power in order to execute an application program independently. Trajectory planning operations can be monitored with computers or various types of user interface. A detailed description of the operation method can be found in the "IMP Series Standalone Mode User Guide".

Referring to Fig.1-2, in the A⁺ PC Ethernet mode and the standalone mode, IMP-6000S can work with an adapter (IMP-6000S-1 or IMP-6000S-2, Note 1) to send motion control commands (velocity/pulse commands) to the drives and motors. The adapters provide wiring terminals for local input/output to facilitate wire connection. Furthermore, IMP-6000S provides remote I/O interface for connecting with up to 32 IMP-ARIO or 16 IMP-ARIO64 and for controlling remote I/O.
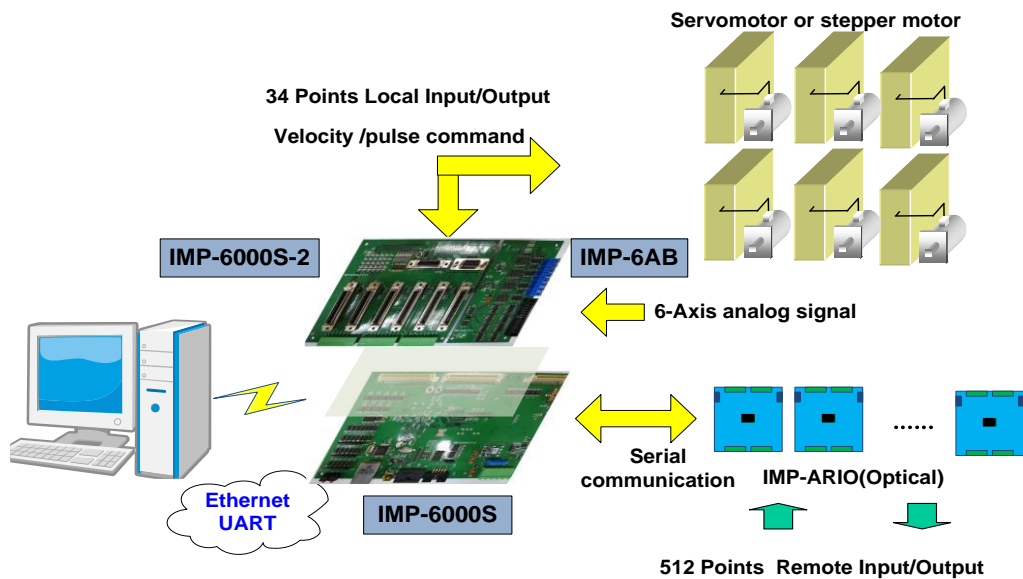
Fig. 1-2 Diagram of Peripheral Connections of IMP-6000S

Note 1: Applicable adapters:

IMP-6000S-1: Universal adapter.

IMP-6000S-2: Dedicated adapter. This adapter is workable with using specific adapter cables for drives of specific manufacturers (Panasonic MINAS A4, Mitsubishi MR-J3-A, Delta ASDA-A2-U, and Yaskawa SGDVΣ-V).

1.4. Software Support

IMP-6000S is built-in with a real-time multi-tasking operating system (VxWorks) and is complete with integration development kits, motion control command libraries, and several development tools to provide the user with a complete (from basic to advanced) system development process.

In the A+PC Ethernet mode, the user can use Visual C++ / Basic / C# to develop the application software, while in the standalone mode, the user can use WindRiver Workbench 3.2 to develop the application software.

The motion control command libraries provide the user with various IDDL and MCCL functions as described below:

■ IDDL (IMC Device Driver Library) --- IMP Series Device Driver Library

It has more than 120 functions for the users to call. For more details, please refer to the "IMP Series Device Driver Library User Manual" and "IMP Series Device Driver Library Reference Manual".

■ MCCL (Motion Control Command Library) --- IMP Series Motion Control Command Library

It provides motion control functions such as 2D and 3D point-to-point, line, curve, circle, helix, and other useful control commands, and allows the user to configure the mechanical and motion parameters. It provides approximately 250 functions in total. For more details, please refer to the "IMP Series Motion Control Command Library User Manual" and "IMP Series Motion Control Command Library Reference Manual".

1.5. Function Descriptions
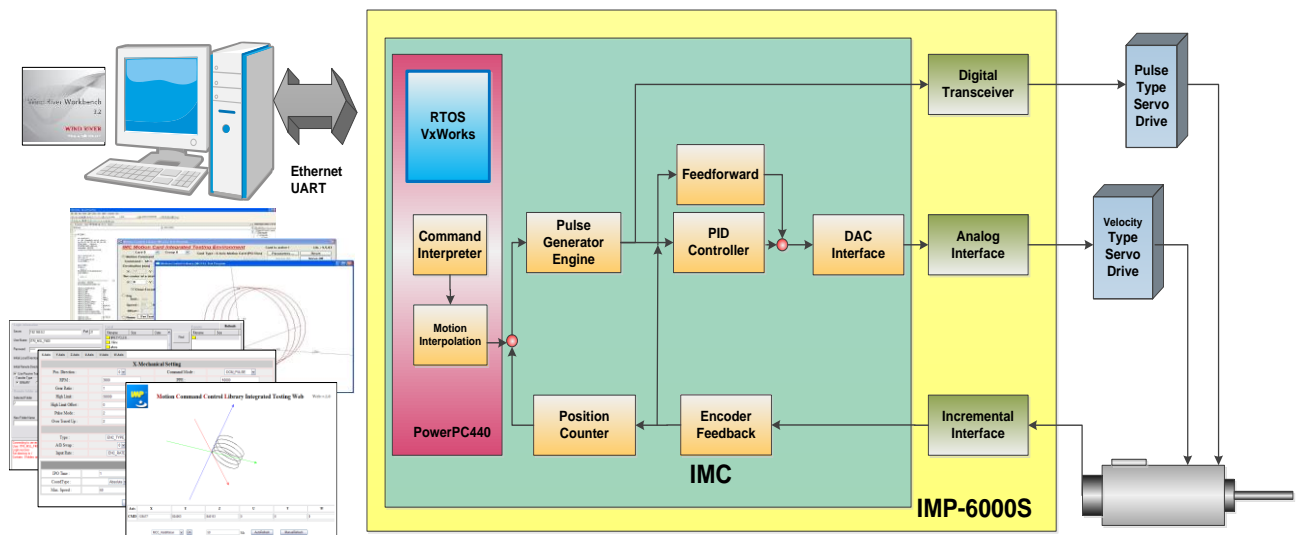
Fig. 1-3 Diagram of Functional Block Diagram of IMP-6000S

The main functional block diagram is shown below. IMP-6000S provides 6-axis synchronous/asynchronous open-loop control (pulse command), 6-axis synchronous/asynchronous closed-loop control (velocity command), local I/O, remote I/O, A/D converters, D/A converters, etc., which are described in the following sections.
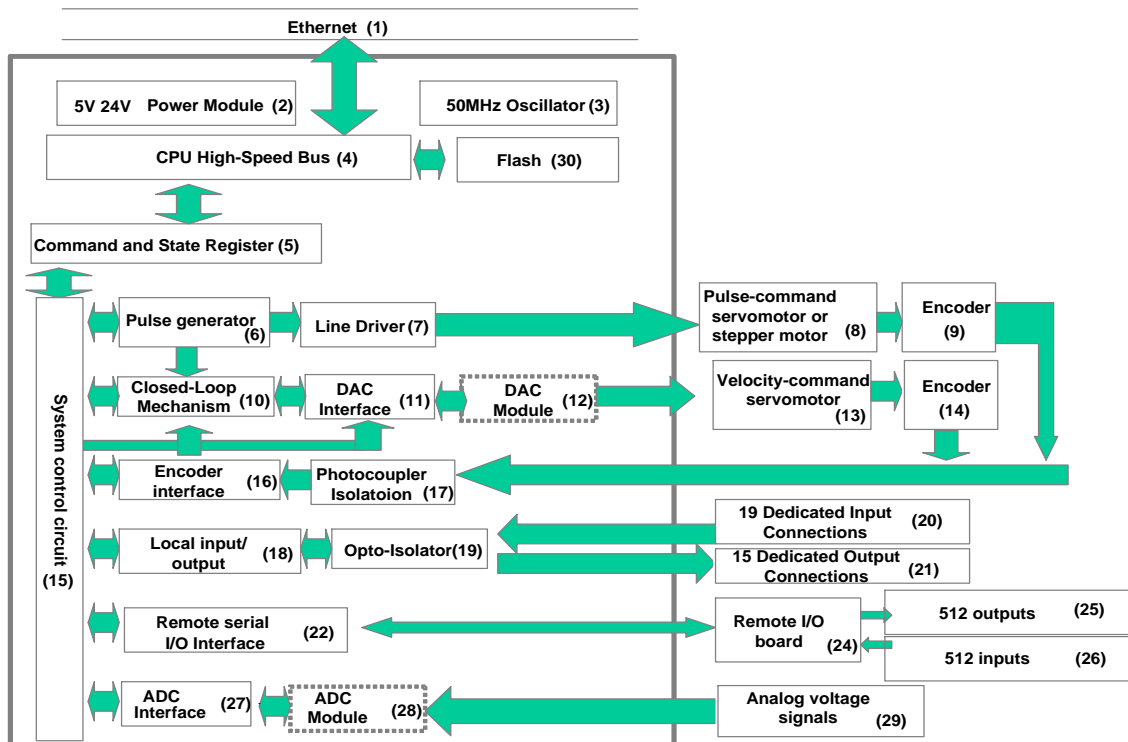
Fig.1-4 Diagram of Functional Block Diagram of IMP-6000S

Note 1: ⬚ indicates modules built on IMP-6AB.

1.5.1.   6-Axis Synchronous/Asynchronous Open-Loop Control (Pulse Command)

Referring to the system block diagram of Fig. 1-4, the *CPU High-Speed Bus (4)* delivers motion control commands to the internal *Command and State Register (5)* and *System Control Circuit (15)* in order to drive the internal *Pulse generator (6)* to evenly generate the pulses (pulse command) (three formats selectable: A/B phase, CW/CCW, and Pulse/Direction). The pulses pass through the *Line Driver (7)* (MC3487), as differential signals, to the external motor driver to drive the *Pulse-Command Servomotor/Stepper Motor (8)*. Signals from the motor's *Encoder (9)* enter the *Encoder Interface (16)* via the *Photocoupler Isolation (17)* and are stored into the *Command and State Register (5)* through the *System Control Circuit (15)*.

1.5.2.   6-Axis Synchronous/Asynchronous Closed-Loop Control (Velocity Command) (IMP-6AB is optional)

Referring to the system block diagram of Fig. 1-4, the *CPU High-Speed Bus (4)* delivers motion control commands to the internal *Command and State Register (5)* and *System Control Circuit (15)* in order to drive the internal *Pulse generator (6)* to evenly generate the pulses (pulse command), which will be sent to the *Closed-Loop Module (10)* while the feedback signals from the motor's *Encoder (14)* (differential signals) are transmitted to IMP-6000S. The signals are received and isolated by the *Photocoupler Isolation (16)* prior to entering the *Encoder Interface (15)* for signal processing (including filtering) and then fed into the *Closed-Loop Module (10)* for calculation. The *Closed-Loop Module (10)* carries out the feedback control based on the PID and FF algorithm (Note 1) according to the number of pulses from the *pulse generator (6)* and the number of pulses fed back from the encoder. The resultant signal will drive the *DAC Module (12)* (including AD1866R and TL074 amplification stage) of **IMP-6AB** through the *DAC Interface (11)* (D/A➔ digital to analog) to generate a voltage signal between -10V and +10V (velocity command). In the end, the velocity command is sent to the *Velocity-Command Servomotor (13)* (Note 2) through IMP-6AB.

Note 1: The closed-loop control of PID and FF control algorithm is described in Fig. 1-5.
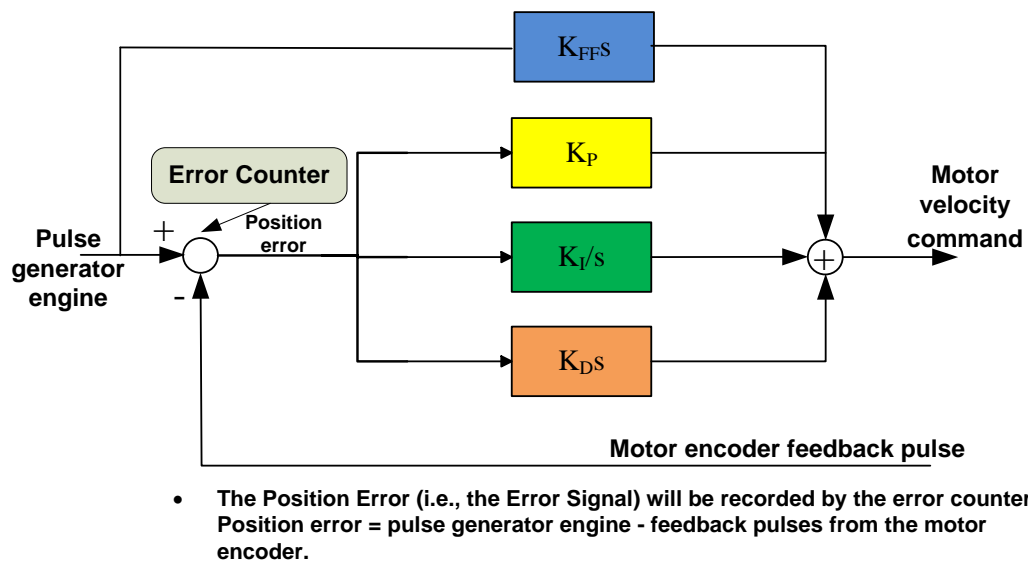
- **The Position Error (i.e., the Error Signal) will be recorded by the error counter. Position error = pulse generator engine - feedback pulses from the motor encoder.**

Fig. 1-5 Diagram of the Closed-Loop Control Algorithm

Note 2: The velocity mode of the servo motor: The motor driver uses the velocity command input format (the velocity command is expressed by a voltage signal). The typical range of the voltage input is from -10V to +10V, which two limits correspond to the maximum backward rotation speed and the maximum forward rotation speed of the motor respectively. The rotation speed is linearly correlated to the input voltage.

1.5.3. Overview of IMP-6000S's Motion Control Core Mechanism

(I) Open-loop and closed-loop control mechanism

1. IMP-6000S has six motion control core mechanisms, where each can be configured as one of the following two output control modes:

----Closed-loop control (velocity command).

---Open-loop control (pulse command).

M sets of closed-loop control and N sets of open-loop control are available for configuration by the user, where the criterion M+N $\leqq$ 6 must be satisfied.

2. The hardware resources corresponding to each control core on IMP-6000S are as follows:

----1 set of closed-loop control core [closed-loop control core = ***Pulse generator (6)*** + ***Closed-Loop Module (10)***].

----1 set of open-loop control core [open-loop control core = ***Pulse generator (6)*** + ***Line Driver (7)***].

----1 set of DAC = ***DAC Interface (11)*** + ***DAC Module (12)***.

----1 set of encoder interface = ***Encoder Interface (16)*** + ***Photocoupler Isolation***

(17).

3. When a certain control core is configured for open-loop control (pulse command), IMP-6000S will use the ***Pulse generator (6)*** of the control core and a set of ***Line Driver (7)***. In this case, the associated DAC and encoder interface of the control core are left unused and available for other uses. On the contrary, if it is configured for closed-loop control (velocity command), IMP-6000S will use the ***Pulse generator (6)***, the ***Closed-Loop Module (10)***, a set of DAC output, and a set of encoder interface of the control core. In this case, the associated ***Line Driver (7)*** of the control core is not activated.

4. Example

If the user configures IMP-6000S with 4 sets of closed-loop control and 2 sets of open-loop control, the hardware resource allocations of IMP-6000S are as follows:

➔4 sets of closed-loop control: It requires 4 control cores, 4 DACs, and 4 encoder interfaces.

2 sets of open-loop control: It requires 2 control cores and 2 ***Line Drivers (7)***.

As a result,

6 control cores----all in use.

6 ***Line Drivers (7)***----2 line drivers are in use, and the remaining 4 line drivers cannot be used (because of the 4 sets of closed-loop control).

8 DACs----4 DACs are occupied, and the remaining 4 DACs are available for other uses.

6 encoder interfaces----4 encoder interfaces are in use, and the remaining 2 encoder interfaces are available for other uses.

(II) For the principle of the pulse generator, please refer to Fig. 1-6 and Fig. 1-7.

Function:

After the user sets a pulse position command (i.e., the required number of encoder counts for the rotation of the motor) and specifies the time required to execute the command (i.e., Interpolation Time, IPO Time), the pulse generator performs related calculations and sends out the required number of counts, in the form of pulses, evenly over the IPO Time.

Description 1:

Referring to the figure below, if the position command is for forward rotation through 1000 encoder counts (with the motor starting position being the 0th count) and the IPO Time is 1ms, the pulse generator will send out 1000 pulses evenly over 1 ms in order for the motor to rotate evenly (i.e., at a constant speed) through 1000

counts.＞

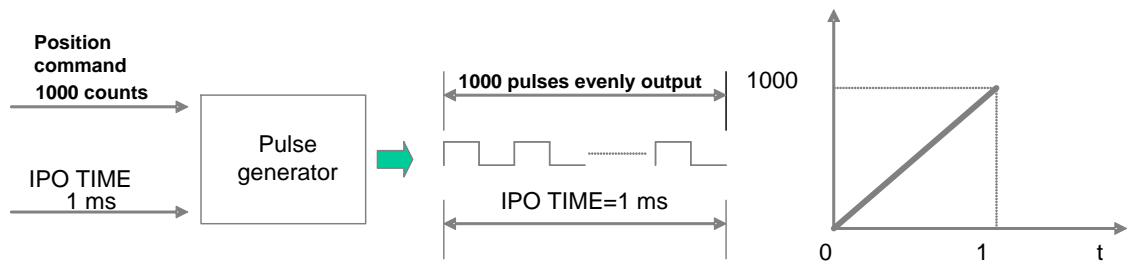**The number of counts through which the motor rotates**

Fig.1-6 Diagram of Pulse generator

Description 2:

In the following figure, the horizontal axis indicates the time, in which $\triangle t$ represents the IPO Time. The vertical axis indicates the number of counts through which the motor rotates.

Zone Ⅰ: The motor rotates forward from the 0th count to the 1000th count at a constant speed of 1000 counts/$\triangle t$.

Zone Ⅱ: The motor stops at the 1000th count.

Zone Ⅲ: The motor rotates forward from the 1000th count to the 1500th count at a constant speed of 500 counts/$\triangle t$.

Zone Ⅳ: The motor remains still at the 1500th count.

Zone Ⅴ: The motor rotates backward from the 1500th count to the 0th count at a constant speed of 1500 counts/$\triangle t$.

The more counts per $\triangle t$, the faster the motor rotates and the farther it travels. For the same number of counts, the smaller the $\triangle t$, the faster the motor rotates.
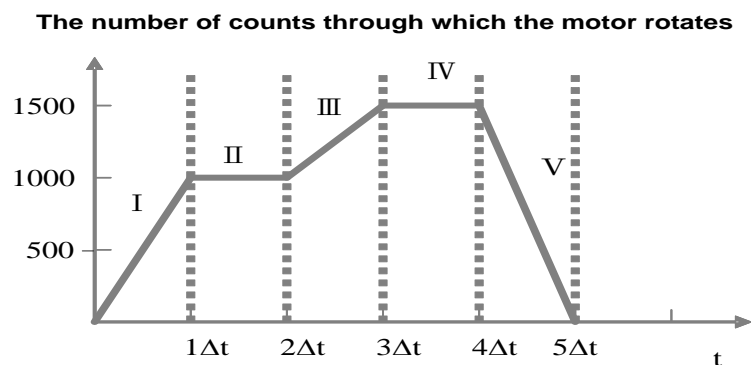

Fig.1-7 Diagram of Pulse generator

(III) There are three formats of the pulse commands sent from the pulse generator: Pulse/Direction, CW/CCW, and A/B phase, as shown in Fig. 1-8 below. Format selection should be based the motor's acceptable format.
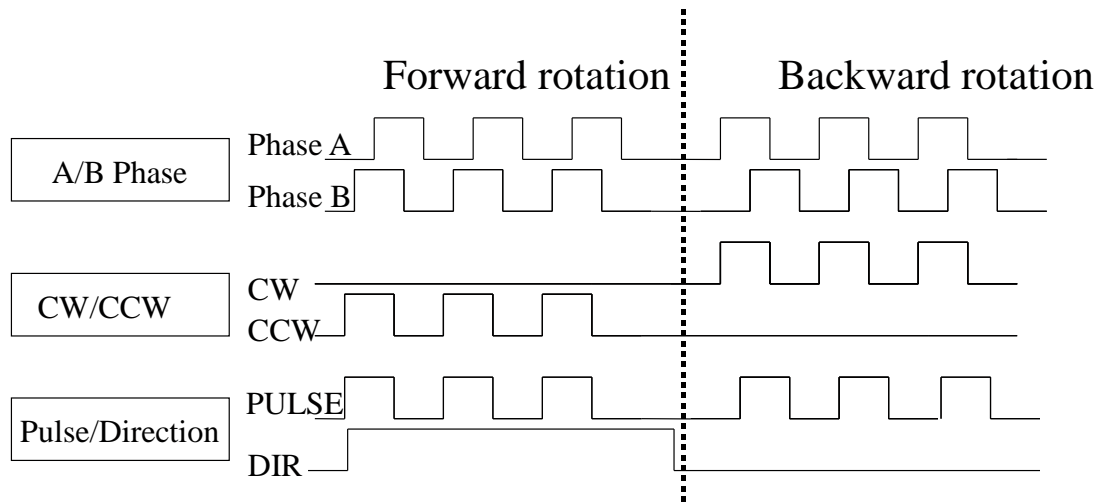
Fig.1-8 Diagram of Pulse Commands

(IV) The differential transmission is described in Fig. 1-9 as below.
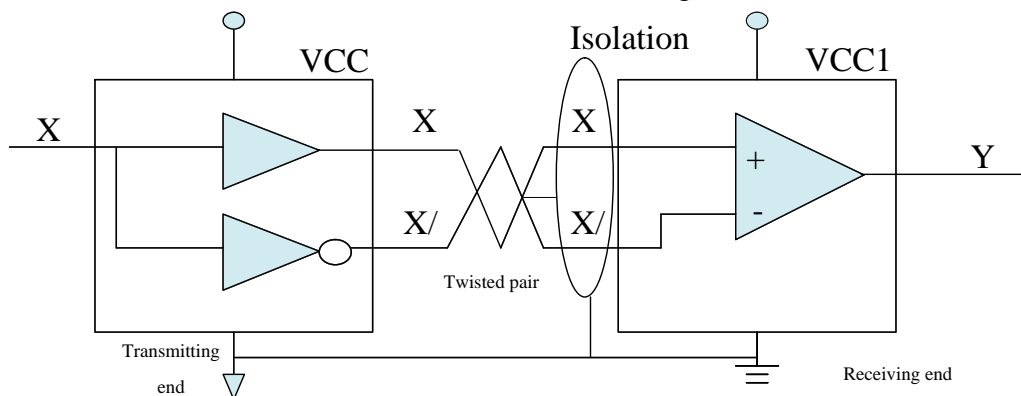
Transmitting end	Signals in the transmission cable		Receiving end
X	X	X/	Y
0	0	1	0
1	1	0	1

※ The transmitting end converts signal X into X and X/ and outputs the latter two.
※ The receiving end compares the inputted X and X/ and converts them into Y.
※ The truth table is shown on the left.
※ Common-mode noise can be effectively eliminated through differential transmission.
※ The reference ground of the transmitting end must be connected with that of the receiving end so that the transmitting end and the receiving end will not be damaged by leak current resulting from a difference in ground potential.
※ Twisted-pair transmission plus an isolating net is advised.

Fig. 1-9 Diagram of Differential Transmission

(V) The differential signals sent out from IMP-6000S are in the pulse formats shown in Fig. 1-10.

Fig.1-10 Diagram of Differential Pulses

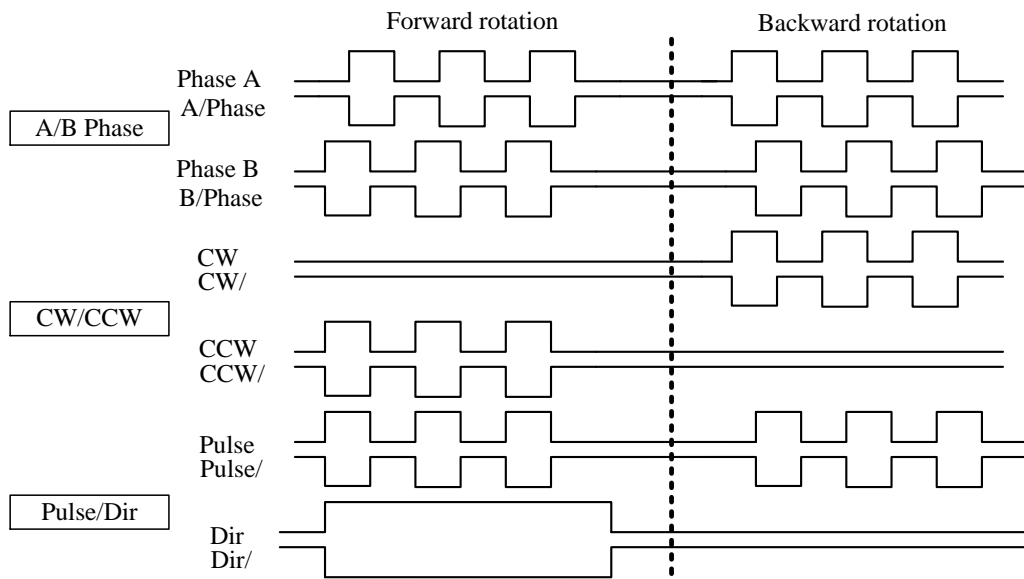(VI) The encoder interface can impart a selected format, i.e., A/B phase, CW/CCW, or Pulse/Direction, to the index signal input. When the A/B phase format is selected, it allows the encoder input signal to be multiplied by 0 (input disabled), 1, 2, or 4.

1.5.4. Local Digital Input/Output

Referring to the system block diagram of Fig. 1-4, when receiving the user's input/output command, IMP-6000S carries out data reading or writing operation at the *Local I/O (18)*. The output signals pass through the *Photocoupler Isolation (19)* and are amplified in driving capability before they are connected to an external device. The input signals also pass through the *Photocoupler Isolation (19)* and then are transmitted to the *Local I/O (18)*.

1.5.5. Remote Digital Input/Output (IMP-ARIO / IMP-ARIO 64(Optical) is optional)

Referring to the system block diagram of Fig. 1-4, IMP-6000S is connected with the remote I/O board (IMP-ARIO / IMP-ARIO64 (Optical)) developed by MSL of ITRI. By using optical fiber transmission and the asynchronous master/slave serial communication method together with a plurality of *Remote I/O Control Boards (24)* series-connected to the *Remote Serial I/O Interface (22)*, the system can be expanded to accommodate up to *512 outputs (25)* and *512 inputs (26)*.

1.5.6. 8-Channel Analog-to-Digital Converter (IMP-6AB is optional)

Referring to the system block diagram of Fig. 1-4, 8 channels of *analog voltage signals (29)* (ranging from -5V to 5V or from 0 to 10V) can be connected to the *ADC module (28)* of IMP-6AB, in order for IMP-6000S to read the voltage values (in 14-bit resolution) through the *ADC Interface (27)*.

1.5.7. 8-Channel Digital-to-Analog Converter (IMP-6AB is optional)

Referring to the system block diagram of Fig. 1-4, the command received by the *System Control Circuit (15)* is converted into an analog voltage command by the *DAC Interface (11)* and by the *DAC Module (12)* of IMP-6AB and then output via the adapter (IMP-6000S-1 or IMP-6000S-2). IMP-6000S provides 8 channels of analog voltage output, the output voltage ranging from -10V to +10V. Each of these 8 channels of analog voltage output can work with an encoder feedback and a pulse output control in order to perform hardware closed-loop control. When a DAC channel is not used for hardware closed-loop control, it can be used separately.

To use the hardware closed-loop control mode, please refer to Section 1.5.2 6-Axis Synchronous/Asynchronous Closed-Loop Control. In the hardware closed-loop control mode, due to the load circuits of the motor drive, the 0V output from the DAC may have a small voltage offset from the 0V recognized

by the drive. Such a small voltage offset may cause a slow drift to the motor, which is normal. Once the closed-loop function is enabled, the closed-loop mechanism will automatically correct the drift, and the motor will stop drifting and enter a controlled state. The magnitude of the offset can be read from the internal error counter of IMP-6000S. If the offset is too large, the user can adjust the driver's 0V offset or the variable resistor on IMP-6AB.

Chapter 2 Specifications

2.1. System Specifications

Item	Specification
Dimensions	190mm * 115 mm
Power Requirement	5V(3A) / 24V(500mA)
Frequency	System Clock Frequency 100 MHz, External Clock 50MHz
Central Processing Unit (CPU)	400MHz 32-bit 7-stage pipeline RISC 32KB D Cache / 32KB I Cache
Hardware Double-Precision Floating-Point Unit (FPU)	100MHz 5-stage pipeline double-precision FPU with 2.0 MFLOPS/MHz
DDR Controller	DDR333 128MB
Ethernet Controller	10/100Mbps
Asynchronous Transmission Interface (UART)	115200bps
Pulse generator	6 32-bit 10MHz with DDA capability
Encoder Counter	6 32-bit 16M Counts/s Differential Input + Digital Filtering
PID+FF Position Closed-Loop Control	6-Ch 4*8-bit (PID & FF Gain) Parameter Register

Analog Output	8 Ch 16-bit 800k/s -10V~10V
Analog Input	8 Ch 14-bit 28.8ksps Bipolar mode: -5V~5V Unipolar mode: 0~10V
USB	
Local Digital I/O (On Board)	6 OT+, 6 OT-, 6 HOME, 6 SERVO, 6 SRDY,1 PRDY, 1 ESTOP (32 I/O in total)
Remote I/O Control (RIO)	Asynchronous Master/Slave Serial Transmission Protocol, 16 Input Points + 16 Output Points. Maximum up to 512 inputs + 512 outputs

2.2. Motion Control Specifications

IMP-6000S has 6 motion control core mechanisms, each of which can be configured for closed-loop control (velocity command) or open-loop control (pulse command). As a result, up to M sets of closed-loop control and N sets of open-loop control can be used, in which $M+N \leqq 6$.

In IMP-6000S, there are many interrupt sources that generate interrupt signals (to be described later). Each interrupt source corresponds to a latch value. When an interrupt occurs, the latch value is set to 1, and an interrupt signal is sent to the CPU. Once the CPU receives the interrupt signal and reads the latch value, the value is cleared and reset to 0. Each interrupt source can be enabled/disabled by software (default: Disable).
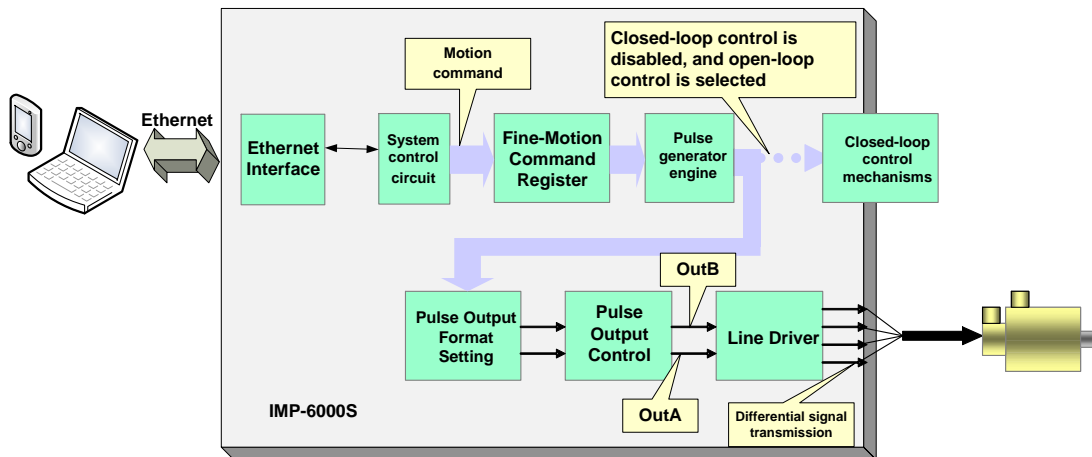
2.2.1 Open-Loop Control (Pulse Command)

Fig.2-1 Diagram of Open-Loop Control

(一) Fine-Motion Command Register (FMC FIFO): It can store 64 fine-motion commands. The pulse generator will read commands and send out pulses evenly for each axis after every IPO time.

- Structure: 64 commands of 32-bit FIFO (First In First Out) stock
- Command Format: directional (1 bit), number of pulses (31 bits)
- Through the MCCL function, whether the FIFO is full or empty, the number of remaining unexecuted commands in the FIFO, and the command being executed. For more details, please refer to "IMP Series Motion Control Command Library Reference Manual".
- The minimum number of remaining unexecuted commands can be set. When the number of remaining unexecuted commands in the FIFO is equal to the minimum number of remaining unexecuted commands, an interrupt to the system will be activated.

(二) Pulse generator:

- The pulse generator can be enabled/disabled for each axis through software (default: Disable).
- Within each IPO Time, the maximum outputs are $0\sim2^{31}$ pulses.
- It can be configured to generate an interrupt to the system after each IPO Time expires. In this case, IMP-6000S will generate an interrupt after executing each fine-motion command.
- IPO Time: There are two configuration methods:
  1. Use the IDDL (IMP Series Device Driver Library, Note 1) to set the PGE Clock Divider and the PGE Clock Number to achieve this goal.

$$IPO\,Time = \frac{1}{SystemClock} \times (ClockDivider + 1) \times (ClockNumber + 1)$$

2. Use the MCCL (IMP Series Motion Control Command Library, Note 2) to directly configure the IPO Time.

Note 1: For more details, please refer to "IMP Series Device Driver Library Reference Manual".

Note 2: For more details, please refer to"IMP Series Motion Control Command Library Reference Manual".

(三) Pulse Output Formats (refer to Fig. 1-8 and Fig. 1-10)
- Pulse/Directional (Default)
- CW/CCW
- A/B phase
- None: Pulse signal output is disabled.

(四) Pulse Output Control (refer to Fig. 2-1, in which the output pulses are indicated by OutA and OutB):
- OutA & OutB can be individually set as inverted output (Default: No inverting).
- OutA & OutB can be swapped (Default: No swapping).

(五) Line Driver
- 5V differential output.

2.2.2 Closed-Loop Control (Velocity Command) (**IMP-6AB is optional**)

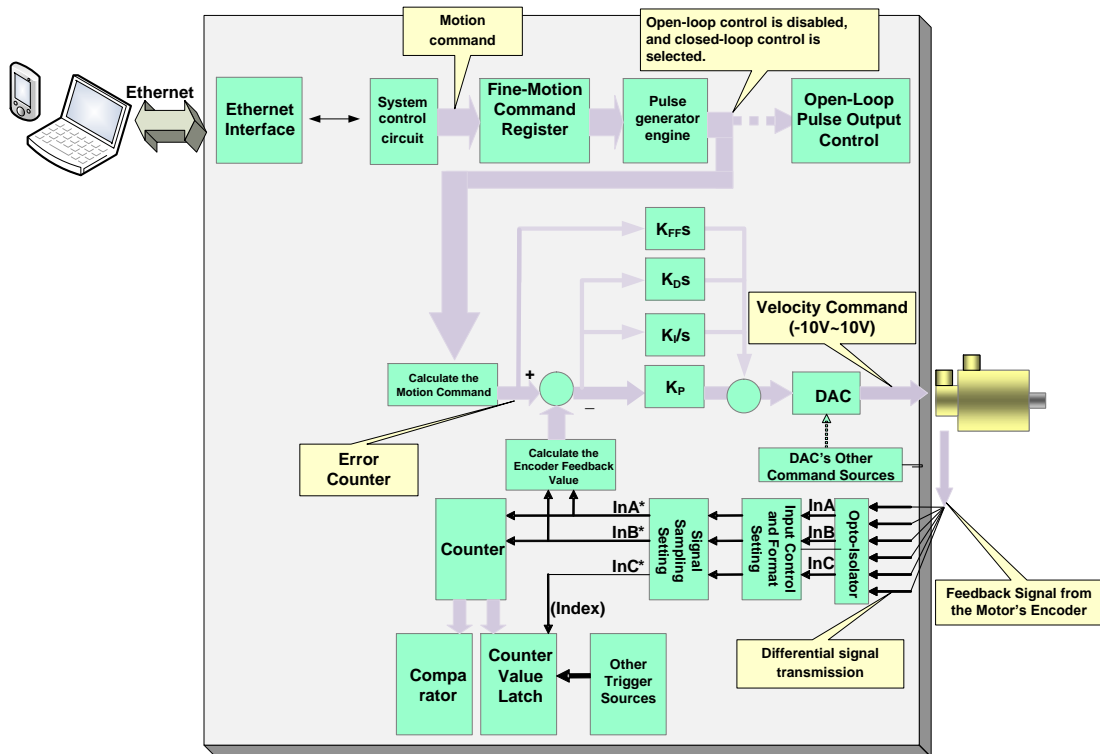**Fig.2-2 Diagram of Closed-Loop Control**

(1) Fine-Motion Command Register (Refer to Section 2.2.1 for more details)

(2) Pulse generator (Refer to Section 2.2.1 for more details)

(3) Control Method: PID+FF

- Error Counter: 16-bit. Error counter can be configured to generate interruption when the error counter overflows.
- K_P, K_I, K_D, and K_{FF} Control Method: The MCCL function can be used to set the proportional (K_P), integration (K_I), differential (K_D), and feedforward (K_{FF}) gain parameters in the closed loop. The range of settings is 0 ~ 127. The gain parameters can be adjusted as follows: After the driver is configured as voltage mode, use the Integrated Test Environment (ITE) provided by the installation CD-ROM to adjust the gain according to the tracking error (the tracking error is the difference between the desired position command and the actual position).

(4) Velocity Command Range: ±10V output from the DAC.

2.3. Encoder Input Specifications

(1) Number of Channels: 6

(2) Encoder Input Isolation
- Isolation Method: Photocoupler
- Input Frequency: Maximum 16M counts/s

(3) Input Control for Input Signals InA, InB, and InC:
- These three signals can be individually inverted (Default: no inverting).
- Signals InA and InB can be swapped (Default: no swapping).

(4) InA and InB Input Format Setting
- A/B phase, CW/CCW, or Pulse/Direction Format.
- Multiplier can be set as ×0, ×1, ×2, or ×4 (Default: ×4).
- None: The Encoder's signal input is disabled.

(5) Input Signal Sampling and Digital Filter Function
- Format: An input signal must be identical in three consecutive sampling times to be considered as a normal signal (InA, InB, InC).
- Sampling Rate: 100MHz

(6) Counter
- Length: 32-bit
- Can be enabled/disabled (Note: For closed-loop control, it must be set to Enable).
- It can be configured through software at boot-up (Default: 0).
- For counting encoder values.

(7) Counter Latch
- It allows the user to set the index or other trigger signal sources to latch the counter for value reading. And the trigger mode can be set as single trigger or multiple triggers.
- It can be set to Enable/Disable (Default: Disable) (Please refer to "IMP Series Device Driver Library User Manual").

(8) Index
- The current state (high/low) of the encoder index signal can be read.
- The encoder's input index can be set to generate an interrupt to the system.

(9) Comparator
- The comparator sets the Comparator Flag to 1 when the counter value is equal to the predefined value in the comparator. It can also be configured to generate an interrupt to the system.

2.4. Digital-to-Analog Converter (IMP-6AB is optional)

(1) Number of Channels: 8
- Each DAC channel corresponds to the closed-loop control of one axis. To perform closed-loop control (velocity command) on a certain axis, the command source of the DAC must be directed, by software, to the closed-loop mechanism of that axis. When the closed-loop mechanism of an axis is not in use, the corresponding DAC channel is available for other uses.
- The DAC can be set to Start or Stop (Default: Stop). When the DAC stops, the DAC output value remains the value of the previous command.

(2) Resolution: 16 bits

(3) Output Voltage of IMP-6000S at boot-up: 0V (If it is not 0V, adjust it to 0V by adjusting the variable resistor. Refer to "IMP-6000S-1/2 IMP-6AB Hardware User Manual").

(4) DAC Output Interface Specifications
- Load: must be over $2K\Omega$
- Output Voltage: $\pm10V$

(5) The three sources of DAC conversion values are listed below:
  1. PCL (closed-loop control) mode: It is used for closed-loop control (velocity command).
  2. Direct write buffer mode : In this mode, a conversion value can be directly sent to the DAC in order for the DAC to output a voltage directly.
  3. Trigger buffer mode : Preset a conversion value in the trigger buffer. When a preset trigger signal is triggered, the preset conversion value in the trigger buffer is sent to the DAC and converted into an output voltage. There are 6 trigger signal sources. For more details, please refer to the "IMP Series Motion Control Command Library".

2.5. Local Digital Input/Output

(1) 25 dedicated inputs

- Local input can be operated independently by the CPU and is not related to other functions.
- Operating Voltage: DC 24V±10%
- When the input is 18V~30V (voltage difference between input and COM), the internal reading is 0.
- When the input is 0V~1V (voltage difference between input and COM), the internal reading is 1.
- Isolation: photocoupler
- Classification

    1. Forward limit inputs: 6 inputs in total, which are OT0+, OT1+, OT2+, OT3+, OT4+, and OT5+.
    2. Backward limit inputs: 6 inputs in total, which are OT0-, OT1-, OT2-, OT3-, OT4-, and OT5-.
    3. Home inputs: 6 inputs, which are HOM0, HOM1, HOM2, HOM3, HOM4, and HOM5.
    4. Server Ready inputs: 6 inputs, which are SRDY0, SRDY1, SRDY2, SRDY3, SRDY4, and SRDY5.
    5. Emergency Stop input: 1 input, which is ESTOP. When an emergency stop occurs (i.e., the Emergency Stop input value is 1), the hardware will disable pulse output and set the DAC output value to 0V. The built-in latch of IMP-6000S can latch the emergency stop state.

Note 1: To terminate the emergency stop state: Please clear the state for the emergency stop (i.e., the user can use the MCCL function to read the emergency stop state, and the reading should be 0), and then reset IMP-6000S with software to terminate the emergency stop state.

Note 2: The ESTOP jumper is provided on IMP-6000S's adapter. For more details, please refer to "IMP-6000S-1/2 IMP-6AB Hardware User Manual".

(2) 7 dedicated outputs

- Operating Voltage: DC 24V±10%.
- Driving Method: open collector output

    The open collector is in the ON state when the internal output value

of IMP-6000S is 0, and in the OFF state when the internal output value is 1.

- Maximum current-carrying capacity at each point: 60mA (Do not connect a 24V power without load.)
- Isolation: photocoupler.
- Classification
    1. Servo On/Off: 6 inputs, which are SVON0, SVON1, SVON2, SVON3, SVON4, and SVON5.
    2. PRDY: Position Ready, indicating that IMP-6000S is in standby state.

(3)   1 internal safety control output:

After the system is booted and before execution of the initialization software is completed, there might be a short period of instability. To ensure that during this period the motors will not move unexpectedly, IMP-6000S is designed with a built-in dedicated safety control output that shuts down pulse output and voltage output at boot-up. After the initialization process has been completed, the MCCL will automatically enable this safety control output. When IDDL is used alone, this safety control output can be enabled or disabled by the user, as explained in more detail in the "IMP Series Device Driver Library Reference Manual".

Note 1: Before enabling the safety control output, please make sure that the system is not in the emergency stop state; otherwise, the output will be enabled in vain . Please refer to the description for the emergency stop in the previous section.

Note 2: When the safety control output is disabled, no matter how other portions of IMP-6000S are set, both pulse output and voltage output are disabled.

2.6. Remote Digital Input/Output (IMP-ARIO / IMP-ARIO 64 (Optical) is optional)

(1)   IMP-6000S has an optical fiber transmission connector for connecting in series with asynchronous remote serial I/O boards (IMP-ARIO / IMP-ARIO64 (Optical)).Each asynchronous remote serial I/O board has 16 inputs and 16 outputs. IMP-6000S can be expanded with up to 32 such boards so that a total of 512 inputs and 512 outputs can be supported.

(2)   For details of use, please refer to "IMP-ARIO / IMP-ARIO64 Hardware User Manual".

2.7.   Analog-to-Digital Converter (IMP-6AB is optional)

(1)   Number of Channels: 8

(2)   Voltage Input Range:

Bipolar mode: -5V~5V

Unipolar mode: 0V~10V

(3) Resolution: 14 bits

(4) Conversion Mode: polling

Of the 8 ADC channels, some can be configured for conversion while the others are disabled. Conversion will be carried out sequentially in the enabled channels.

(5)   Comparator and Comparator Interrupt

- MASK function:

The comparator first masks the last 1, 2, or 3 bits of the voltage reading from the ADC to form the masked value, and then compares this with the comparison value in the comparator. The comparison result is made known to the CPU through an interrupt.

- Any of the following three comparison methods can be selected to trigger an interrupt:

1. When the masked value changes from less than the comparison value to greater than or equal to the comparison value.

2. When the masked value changes from greater than or equal to the comparison value to less than the comparison value.

3. Both of the above two conditions can trigger an interrupt.

- The comparison value is defined first. After the comparison, if one of the above three conditions is satisfied, an interrupt signal to the system will be generated. Each comparator can be set to generate an interrupt signal (there are 8 interrupt signal sources).

2.8. Timer and Watchdog Timer

(1)   Timer

- It can be set to Enable/Disable.

- Timing Unit: system clock (10ns)

- Timer Length: 32 bits

The setting range is $0 \sim (2^{32}-1)$ times the system clock. The timer can be set to generate an interrupt to the system at the end of timing.

(2) Watchdog Timer

- Timing Unit: the timing length set by the timer

- Watchdog Timer Length: 32 bits

25

The setting range is $0\sim(2^{32}-1)$ times the timing unit. The user must clear the watchdog timer and set its value to zero before watchdog timeout. Upon watchdog timeout, IMP-6000S will automatically generate a system reset signal to clear all the state registers of the hardware and restore the registers to their initial states (the length of the reset signal is configurable).

2.9. Reset

The Reset function not only allows the system to be reset with the hardware switch provided on IMP-6000S, but also allows the user to use software to reset the DAC, ADC, PCL(position control loop), PGE, LIO, RIO, and the peripherals of IMP-6000S either individually or as a whole.

Chapter 3 Hardware Installation

3.1. Basic Installation

A. Wire the adapter(s) to be used (IMP-6000S-1: universal adapter, IMP-6000S-2: dedicated adapter, IMP-6AB: analog/digital conversion adapter) according to the "IMP-6000S-1/2 IMP-6AB Hardware User Manual".

B. If the Ethernet function is desired, connect the Ethernet cable to the RJ45 connector of IMP-6000S.

C. If the remote I/O function is desired, connect the optical fiber transmission cable to the optical fiber connector socket of IMP-6000S.

D. If the RS232 function is desired, connect the RS232 cable to the RS232 connector of IMP-6000S.

E. Connect external +5V or +24V power to IMP-6000S.

F. Make sure that IMP-6000S and its peripheral modules are grounded properly. Also make sure that IMP-6000S and its peripheral modules are at the same reference potential to avoid system damage at start-up due to different reference potentials.

G. For the operation method in the standalone mode, please refer to the "IMP Series Standalone Mode User Guide".
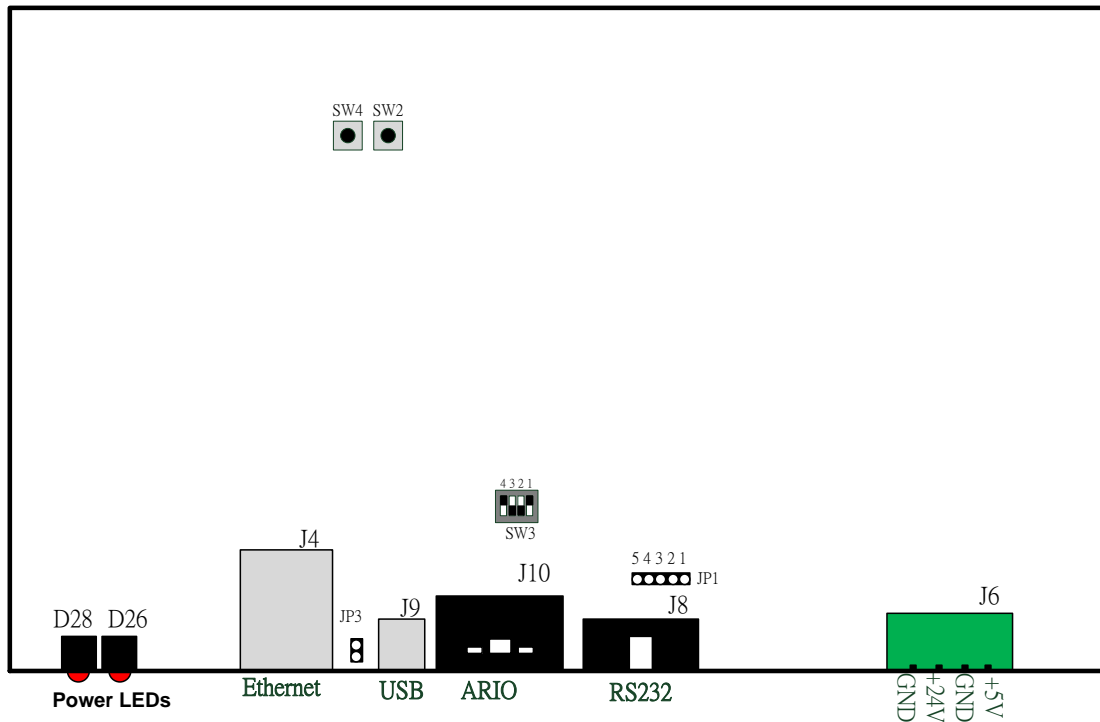
3.2. Board Layout

Fig. 3-1 Diagram of IMP-6000S Board Layout

Jumper	Function	Note
JP1	RS232 device mode setting	Default setting: Standard mode (refer to 3.3 Pin Assignments of Connectors)
JP3	USB master/slave mode setting	Open-circuit mode: OTG device mode Short-circuit mode: Host mode Default setting: Open-circuit

Switch	Function	Note
SW2	Hardware reset (PROG)	
SW3	Hardware boot mode setting	Default setting:
SW4	System reset (RESET)	

Indicator lamp	Function	Note
D28	24V power LED	
D26	5V power LED	

Note: SW3 is used to set the boot mode and should not be changed arbitrarily; otherwise, the system cannot boot up normally.

3.3. Pin Assignments of Connectors

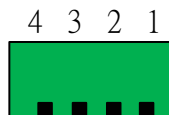● **Pin Assignments of Power Connector:**

Refer to the figure below:

Fig. 3-2 Diagram of Power Connector Socket

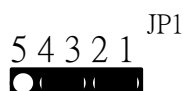| Pin number	1	2	3	4
Name	VCC	GND	+24V	+24VGND

● **Pin Assignments of RS232 Connector:**

Refer to the figure below:

Fig. 3-3 Diagram of RS232 Connector Socket

The connector can work in a **Null modem mode** or a **Reverse mode**, depending on the JP1 setting, as explained in more detail below.

Null modem mode: Pin1 and Pin2 of JP1 are shorted, and so are Pin3 and Pin4.

Name	Pin number	Description	Reference
Rx	2	Serial data received by IMP-6000S from a computer	GND
Tx	3	Serial data transmitted from IMP-6000S to a computer	GND
GND	5	GND	

Standard mode: Pin1 and Pin2 of JP1 are shorted, and so are Pin3 and Pin4.

JP1
5 4 3 2 1

Name	Pin number	Description	Reference
Tx	2	Serial data transmitted from IMP-6000S to a computer	GND
Rx	3	Serial data received by IMP-6000S from a computer	GND
GND	5	GND	

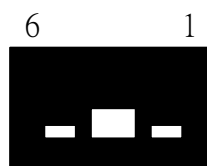●**Pin Assignments of ARIO Optical fiber Connector:**

Refer to the figure below:

Fig. 3-4 Diagram of ARIO Optical fiber Connector Socket

Name	Pin number	Description	Reference
Rx	1	Serial data transmitted from IMP-ARIO / IMP-ARIO64 (Slave) to IMP-6000S (Master)	GND
Tx	6	Serial data transmitted from IMP-6000S (Master) to IMP-ARIO / IMP-ARIO64 (Slave)	GND
VCC	3, 5	VCC	GND
GND	2, 4	GND	

3.4. Remote Input/Output (RIO) Wiring (IMP-ARIO / IMP-ARIO64 (Optical) is optional)

As shown in Fig. 3-5, IMP-6000S and IMP-ARIO / IMP-ARIO64 (Optical) are connected via an optical fiber transmission interface, which advantageously features resistance to interference and enhanced transmission accuracy. IMP-6000S is connected to the IMP-ARIO / IMP-ARIO64 (Optical) module(s) through an optical fiber transmission cable.

While connecting, please note that each IMP-ARIO / IMP-ARIO64 (Optical) has a previous connector and a Next connector. When connecting the first IMP-ARIO / IMP-ARIO64 (Optical) (slave0), for example, its previous end must be connected to IMP-6000S, and its Next end, to the Previous end of the second IMP-ARIO / IMP-ARIO64 (Optical) (slave1). The same rule applies to all the ARIO boards to be connected.
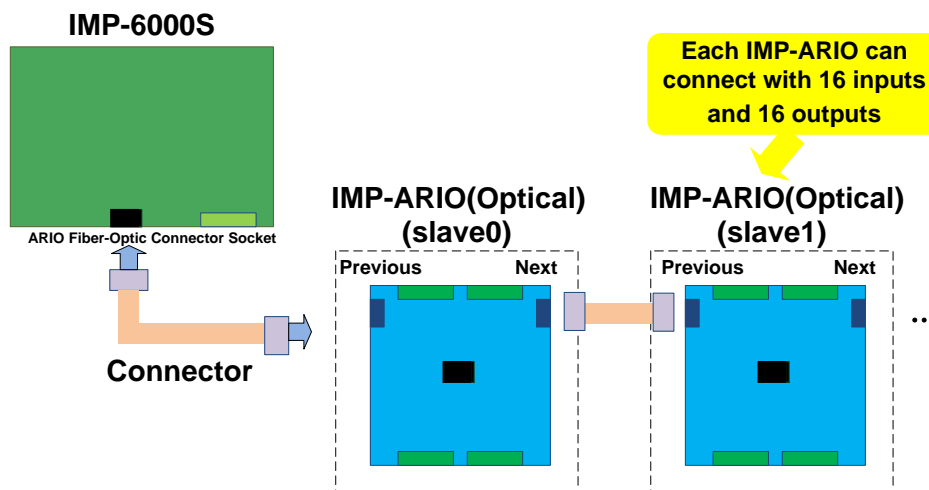
Fig. 3-5 Diagram of the Connection between IMP-6000S and IMP-ARIO / IMP-ARIO64 (Optical)