Jaemi Hubo (KHR4) Users Manual

Daniel M. Lofaro

October 7, 2009

1 Overview

Welcome to the Hubo KHR4 reference manual. Through out this manual you will find information regarding the mechanical, electrical, and software operation of the Hubo KHR4 system.

1.1 Mechanical

The Hubo KHR4 has the following mechanical specifications: Page 15

- 6 DOF Per Leg
- 41 DOF Total
- Aluminum Frame
- High Gear Ratio Harmonic Drive Gear Boxes
- Maxon Brushless DC Motors

The gear ratios for the harmonic drive gear boxes can be found in Table 1.

Table 1: Harmonic Drive Gear Ratios

Joint	Harmonic Drive No
Hip Yaw	SHD 17 - 100:1
Hip Roll	SHD 20 - 160:1
Hip Pitch	SHD 20 - 160:1
Knee	SHD 20 - 160:1
Ankle Pitch	SHD 17 - 100:1
Ankle Roll	SHD 17 - 100:1
Trunk Yaw	SHD 14 - 100:1

Please refer to Appendix A.1 for the dimensions of the Hubo HKR4.

1.2 Electrical

Hubo KHR4 contains two primary x86 based computers, denoted as the *Head Computer* and the *Body Computer*, and multiple smart motor controllers. The Body Computer tells all of the motor controllers where to move

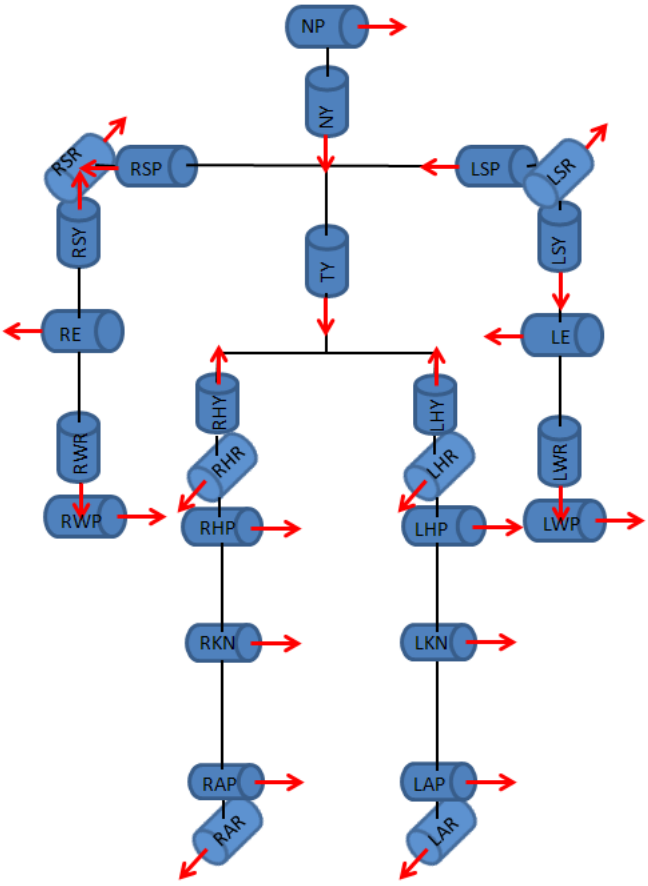


Figure 1: Hubo KHR4 Joint Direction

via communication over two 1MB/s CAN Buses, gathers sensor data from the Inertial Measurement Unit (IMU) and Force-Torque (FT) sensors. The Body Computer will then do all of the calculations to keep the Hubo KHR4 balanced properly.

1.2.1 Main Computers

Table 2 contains some of the specifications for the Hubo KHR4 Body Computer. Further Specifications can be found in Appendix A.3.

Table 2: Hubo HKR4 Body Computer Specifications

-	-
Name	PCM-3370
CPU	Pentium III 933MHz
Cache	512Kb
Chip Set	TwisterT + VT82C686B
BIOS	AWARD 256kb Flash BIOS
System Memory	512MB SDRAM
Watchdog Timer	1.6sec
Expantion	104-pin PC/104 and 120-pin PCI PC/104-Plus

Table 3 contains some of the specifications for the Hubo KHR4 Head Computer. Further Specifications can be found in Appendix A.2.

Table 3: Hubo HKR4 Head Computer Specifications

-	-
Name	PCM-3372
CPU	Pentium III 1.0GHz
Cache	128Kb
Chip Set	VIA CX700
BIOS	AWARD 4Mbit Flash BIOS
System Memory	1024Mb DD2533
Watchdog Timer	255 levels interval timer
Expantion	104-pin PC/104 and 120-pin PCI PC/104-Plus

1.2.2 Motor Controllers

The Hubo KHR4 motor controllers consists of three separate motor controllers.

- Single Channel Motor Controller/Driver
- Dual Channel Motor Controller/Driver
- Five Channel Motor Controller/Driver

Each of the motor drivers have the same basic firmware on them and take the same basic command however the single channel controller only supports a single motor with quadrature encoder and is used only for the waste. The dual channel supports two motors with quadrature encoders (2x200W) and is used for all of the leg joints and some of the upper body joints. The five channel supports five smaller motors each with a quadrature encoder which is used for the fingers on the right and left hands. All of the motor controllers support current feedback.

1.3 Software

Hubo KHR4's Body Computer and Head Computer both run full versions of Windows XP updated to Service Pack 2. WARNING: Both systems must NOT be updated to Service Pack 3 for the time being due to the Wireless N drivers incompatibility with Service Pack 3.

1.3.1 Body Computer

The Body Computer's main operating system is Windows XP SP2 and the control is compiled using Visual Studios 6 (VS6) and Real Time Extensions 6.5 (RTX 6.5) by Ardence. The RTX system will be explained in greater detail in Section 3.1.

The purpose of the Body Computer is to give Hubo KHR4 a dedicated environment for its balancing controller.

The Body Computer does not have any .NET framework installed.

1.3.2 Head Computer

The Head Computer's main operating system is Windows XP SP2. The .NET framework 3.5 is currently installed. The purpose of this is so users

programing with Microsoft's Visual Studio 2008 can easily upload custom software.

The purpose of the Head Computer is to allow users to add human interaction without risking damaging the stability controller, i.e. the Body Computer.

2 Communication

The Hubo KHR4 has multiple communication methods. In short the *Body Computer* communicates with the motor drivers via two 1Mbps CAN Bus networks. The *Body Computer* can talk to the *Head Computer* via a serial RS232 level signal. Both of the *Body and Head Computers* talk to the *Base Station Computer* via a wireless 802.11n network connection.

2.1 Base Station Computer

The *Base Station Computer* connects to the *Body and Head Computers* via a Wireless 802.11n connection where the *Base Station Computer* is connected to the wireless router via a CAT-5e cable the *Body and Head Computers* are connected to the network via the 802.11n connection.

The *Base Station Computer* also acts as the network storage device for both the *Body and Head Computers*. The "Shared Documents" folder on the *Base Station Computer* is setup as the Z:_ drive on both the *Body and Head Computers*.

2.2 Body Computer

The *Body Computer* is the main computer for the Hubo KHR4. This computer communicates with all of the motor drivers via two 1Mbps CAN Buses. All of the lower body joints are located on one CAN Bus and all of the upper body joints are located on the other CAN Bus. The *Body Computer* is a PCM-3370 PC/104 computer. More information on the PCM-3370 can be found in Appendix A.3. All of the communication methods available on the *Body Computer* can be found in Table 4.

2.2.1 CAN Bus

The CAN Bus is a PCM-3680 Rev A.1 PC/104 Dual Port CAN Interface Module. Information regarding the PCM-3780 Rev A.1 CAN card can be found in Table 5 and in Appendix A.4.

2.2.2 RS232

The *Body Computer* contains two serial ports, COM1 and COM2. COM1 and COM2 are by default both connected to the *Head Computer* through

Table 4: Hubo KHR4 Body Computer On Board Communication

Number of Ports	Port Type
2x	USB1.1
1x	EIDE
1x	LPT
1x	RS-232/422/485 (COM1)
1x	RS232 (COM2)
1x	K/B
1x	Mouse
2x	CAN

internal connections.

2.2.3 Wireless

The *Body Computer* communicates with the Hubo network, called HuNet, via an 802.11n connection. The wireless configuration for the *Body Computer* can be found in Table 6.

2.2.4 Wired

The *Body Computer* can be plugged directly in to a 10/100 network and accessed. The *Body Computer* has a Static IP so it can be connected to via a network hub or directly via a crossover cable. The connection information can be found in Table **??**.

2.2.5 Digital I/O

2.3 Head Computer

2.3.1 RS232

2.3.2 Wireless

2.3.3 Wired

The *Head Computer* can be plugged directly in to a 10/100 network and accessed. The *Head Computer* has a Static IP so it can be connected to via

Table 5: PCM-3680 Rev A.1 PC/104 CAN Card Specifications

-	-
Ports	2
CAN controller	82C200
CAN transceiver	82C250
Signal support	CAN-L, CAN-H
Memory address	From C800H to EF00H
IRQ	3, 4, 5, 6, 7, 9, 10, 11, 12, 15
Isolation voltage	1000 VDC
Power consumption	+5 V @ 400 mA typical, 950 mA max.
Connectors	Dual DB-9 male connectors
Operating temperature	32 to 122 F (0 to 50 C)
PC/104 form factor	3.6" x 3.8" (90 mm x 96 mm)
Shipping weight	0.9 lb (0.4 kg)

a network hub or directly via a crossover cable. The connection information can be found in Table **??**.

2.3.4 Digital I/O

Table 6: Body Computer Wireless Configuration

-	-
SSID	HuNet
Frequency	2.4Ghz
Standard	802.11n
WPA2 Passkey	dasl1234
IP	192.168.0.102
Mask	255.255.255.0
Gateway	192.168.0.1
Domain	Hunet

Table 7: Body Computer Wired Configuration

-	-
Network	HuNet
Standard	10/100
IP (Static)	192.168.0.112
Mask	255.255.255.0
Gateway	192.168.0.1
Domain	Hunet

Table 8: Head Computer Wireless Configuration

-	-
SSID	HuNet
Frequency	2.4Ghz
Standard	802.11n
WPA2 Passkey	dasl1234
IP	192.168.0.103
Mask	255.255.255.0
Gateway	192.168.0.1
Domain	Hunet

Table 9: Head Computer Wired Configuration

-	-
Network	HuNet
Standard	10/100
IP (Static)	192.168.0.113
Mask	255.255.255.0
Gateway	192.168.0.1
Domain	Hunet

3 Timing

3.1 RTX

3.2 Body Computer

3.2.1 Hardware

3.2.2 Software

3.3 Head Computer

3.3.1 Hardware

3.3.2 Software

4 Sensors

4.1 IMU

4.2 Force-Torque

4.3 Encoders

4.4 Current Sensing

5 Motor Drivers

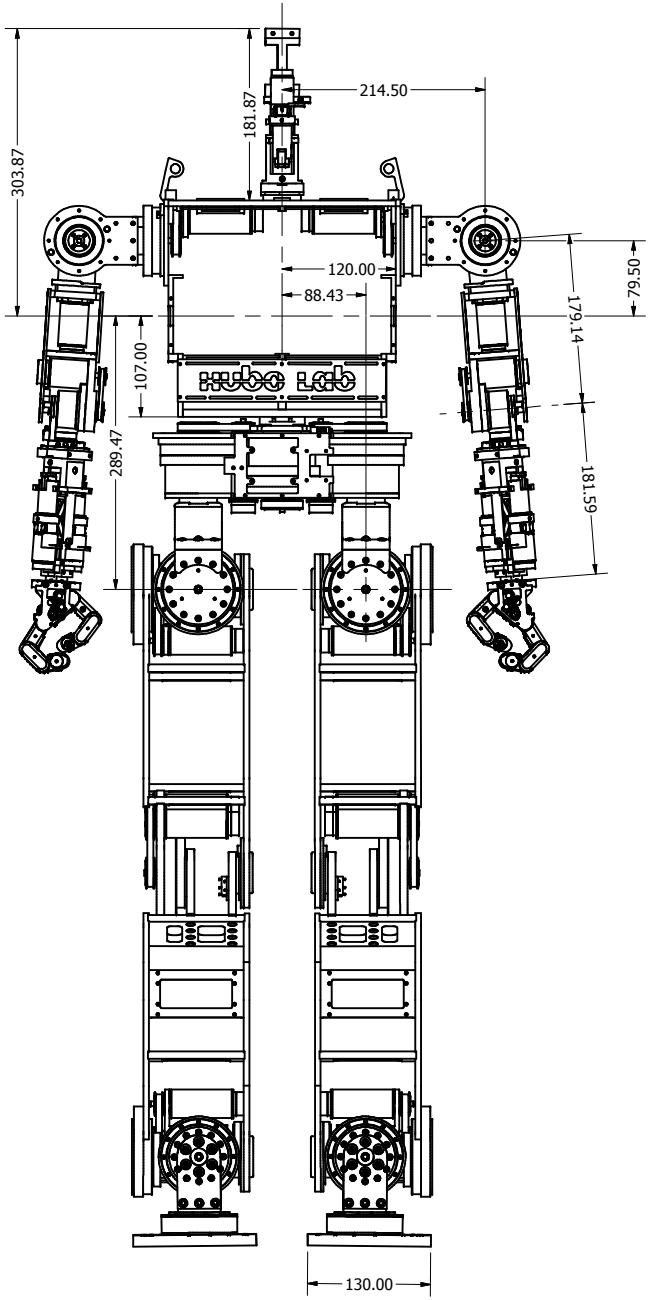
6 How To

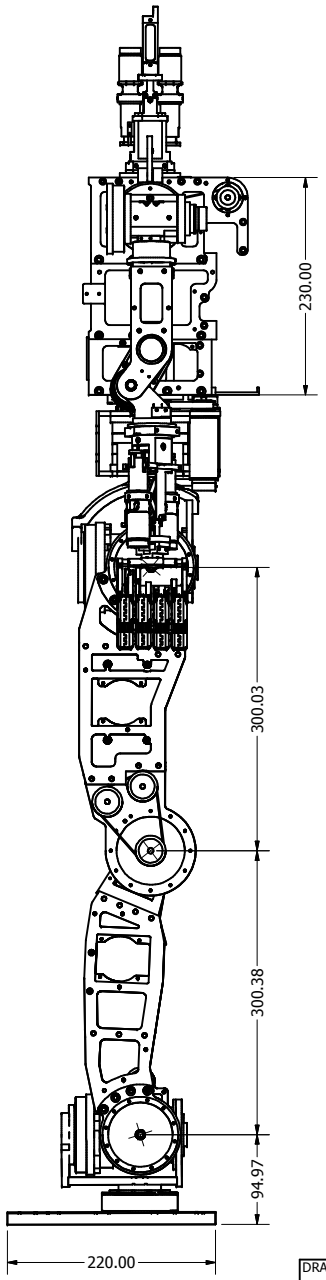
6.1 Upper Body Example: Raise Arm

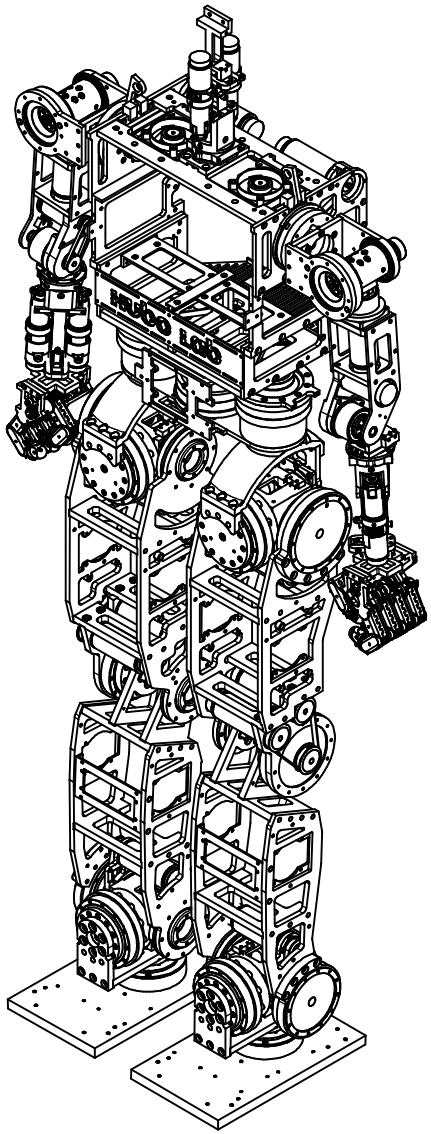
6.2 Lower Body Example: Raise Leg

A Appendix

A.1 Hubo KHR4 Dimensions





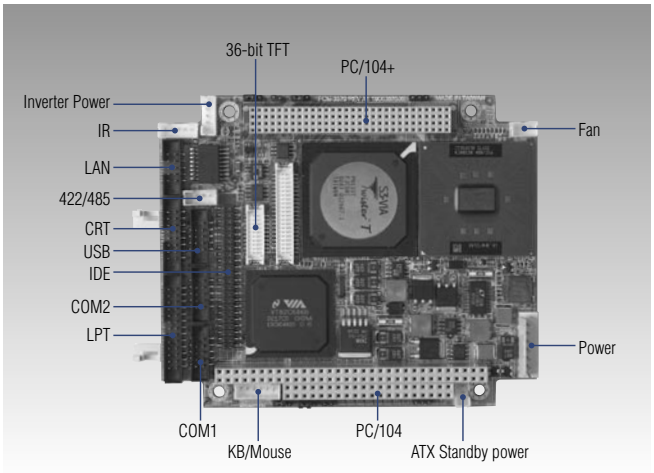


DRAWN RJG	9/23/2009	Drexel Autonomous Systems Lab
CHECKED		TITLE: JAEMI HUBO DIMENSIONS
QA		
MFG		
APPROVED		
SIZE C	DWG NO HUBO KHR-4 Rev_01	REV
SCALE	SHEET 1 OF 1	

A.2 Head Computer Specifications

PCM-3370

LV Intel® Pentium® III PC/104-Plus CPU Module



Features

- ULV Intel® Celeron® 400/650 MHz Fanless, LV Pentium® III 800/933 MHz
- Chipset: VIA® VT8606/TwisterT and VT82C686B
- VGA/LCD controller with optimized Shared Memory Architecture (SMA)
- 4 x AGP VGA/LCD & LCD controller up to 1024 x 768
- +5 V and +12 V power supply required
- 10/100Mbps PCI Ethernet interface, supports wake-on-LAN
- COM2 (5 V) supports power line connected on pin 9
- PC/104 and PC/104-Plus expansion connector
- Support for CompactFlash® Card (CFC) Type I Socket
- 1.6 sec – interval Watchdog timer
- 1 SODIMM socket supports up to 512 MB SDRAM

Specifications

General

CPU	Onboard ULV Intel Celeron 400/650 MHz Fanless, or LV Pentium III 933 (800 MHz optional)
2nd Cache Memory	256 KB on ULV Celeron/512 KB on Pentium III
System Chipset	VIA VT8606/TwiserT + VT82C686B
BIOS	AWARD® 256 KB Flash BIOS
System Memory	1 x SODIMM socket, supports up to 512 MB SDRAM
Power Management	Supports Advanced Power Management
SSD	Supports CompactFlash Card Type I
Watchdog Timer	1.6 sec – interval Watchdog timer, set up by software, jumperless selection, generates system reset or IRQ11
Expansion Interface	104-pin 16-bit PC/104 module connector and 120-pin PCI PC/104-Plus module connector

I/O

I/O Interface	1 x EIDE, 1 x LPT, 1 x RS-232/422/485, 1 x RS232, 1 x K/B, 1 x Mouse
USB	2 Universal Serial Bus 1.1 compliant ports
IrDA	Share with COM2, transfer rate up to 1.15 Mbps
I/O Expansion	Support for + 5 V FAN, speed detect connector, Heat, Fan speed

Ethernet

Chipset	Realtek RTL8139D 10/100 Mbps
Speed	10/100Base-T
Interface	1 x RJ-45

Display

Chipset	*VIA VT8606 4X AGP controller, supporting CRT PCM-3370F: 18/24/36 bit TTL interface PCM-3370E: 18/24 bit TTL interface and 36 bit dual channel LVDS

Mechanical and Environmental

Dimension (L x W)	96 x 115 mm
Weight	0.162 kg (with heat sink)
Operating Temperature	0 ~ 60° C
Operating Humidity	0% ~ 90% relative humidity, non-condensing

Power

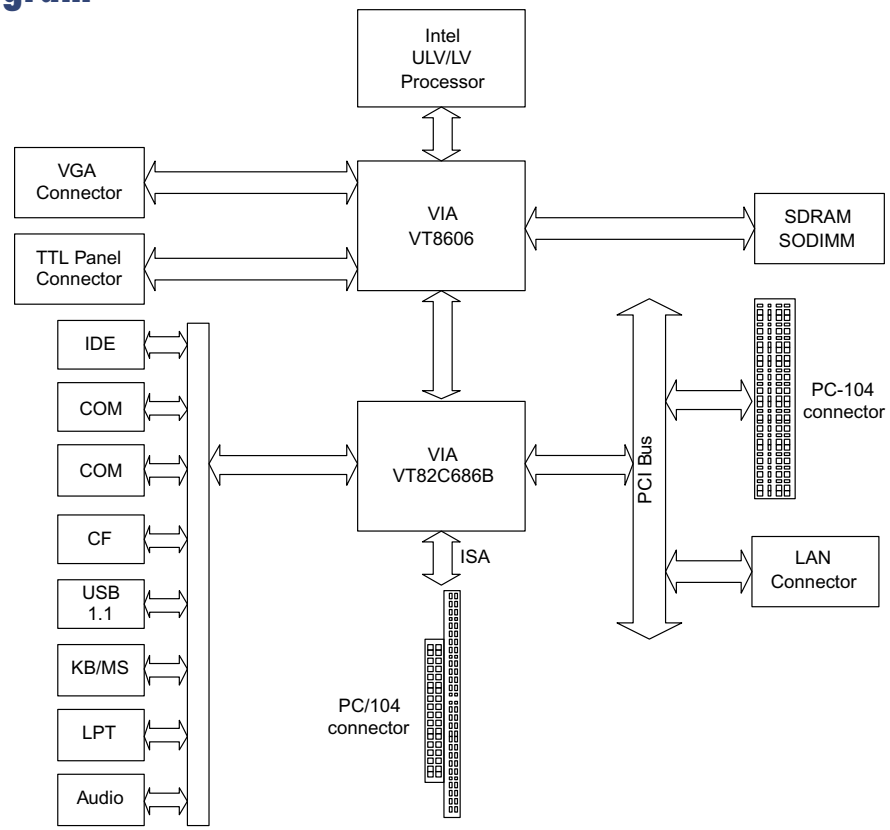
Power Supply Voltage	+5 V ±5%, +12 V ±5%	
Power Consumption	Typical:	2.43 A @ +5 V (ULV Celeron 400 MHz CPU) 2.83 A @ +5 V (ULV Celeron 650 MHz CPU) 3.50 A @ +5 V (LV Pentium III 933 MHz CPU) 0.02 A @ +12 V (ULV Celeron 400 MHz CPU) 0.02 A @ +12 V (ULV Celeron 650 MHz CPU) 0.02 A @ +12 V (LV Pentium III 933 MHz CPU)
	Max:	2.47 A @ +5 V (ULV Celeron 400 MHz CPU) 2.97 A @ +5 V (ULV Celeron 650 MHz CPU) 3.99 A @ +5 V (LV Pentium III 933 MHz CPU) 0.06 A @ +12 V (ULV Celeron 400 MHz CPU) 0.06 A @ +12 V (ULV Celeron 650 MHz CPU) 0.08 A @ +12 V (LV Pentium III 933 MHz CPU)

Packing List

1 x PCM-3370 SBC	
1 x KB/Mouse Y-Cable	(p/n:1700060202)
1 x Y-Cable external cable	(p/n:1703060053)
1 x VGA Cable	(p/n:1701160150)
1 x Ethernet RJ-45 Conn. conversion cable	(p/n:1701100202)
1 x IDE Cable	(p/n:1701440350)
1 x COM Port Cable	(p/n:1700100250)
1 x LPT port cable	(p/n:1700260250)
1 x Wire ATX Power	(p/n:1703200380)
1 x Startup manual	
1 x CD-ROM (Manual, Driver, Utility)	

All product specifications are subject to change without notice

Board Diagram



Ordering Information

Part No.	CPU	L2 Cache	Chipset	CRT	LVDS	TTL	10/100	USB 1.1	RS-232	RS-422/485	LPT	CF	KB/MS	PCI-104 connector	PC/104 connector	Thermal Solution	Operation Temp.
PCM-3370F-R0A1E	LV Pentium III 933 Mhz	256 KB	VIA8606+ 686B	Yes	--	36 bit	1	2	2	*Option	Yes	Yes	Yes	Yes	Yes	Active	0 ~ 60°C
PCM-3370F-M0A1E	ULV Celeron 650 Mhz	256 KB	VIA8606+ 686B	Yes	--	36 bit	1	2	2	*Option	Yes	Yes	Yes	Yes	Yes	Passive	0 ~ 60°C
PCM-3370F-J0A1E	ULV Celeron 400 Mhz	256 KB	VIA8606+ 686B	Yes	--	36 bit	1	2	2	*Option	Yes	Yes	Yes	Yes	Yes	Passive	0 ~ 60°C
PCM-3370Z-J0A1E	ULV Celeron 400 Mhz	256 KB	VIA8606+ 686B	Yes	--	36 bit	1	2	2	*Option	Yes	Yes	Yes	Yes	Yes	Passive	-20 ~ 80°C
PCM-3370Z1-J0A1E	ULV Celeron 400 Mhz	256 KB	VIA8606+ 686B	Yes	--	36 bit	1	2	2	*Option	Yes	Yes	Yes	Yes	Yes	Passive	-30 ~ 70°C
PCM-3370E-R0A1E	LV Pentium III 933 Mhz	256 KB	VIA8606+ 686B	Yes	36 bit	24 bit	1	2	2	*Option	Yes	Yes	Yes	Yes	Yes	Active	0 ~ 60°C
PCM-3370E-M0A1E	ULV Celeron 650 Mhz	256 KB	VIA8606+ 686B	Yes	36 bit	24 bit	1	2	2	*Option	Yes	Yes	Yes	Yes	Yes	Passive	0 ~ 60°C
PCM-3370E-J0A1E	ULV Celeron 400 Mhz	256 KB	VIA8606+ 686B	Yes	36 bit	24 bit	1	2	2	*Option	Yes	Yes	Yes	Yes	Yes	Passive	0 ~ 60°C

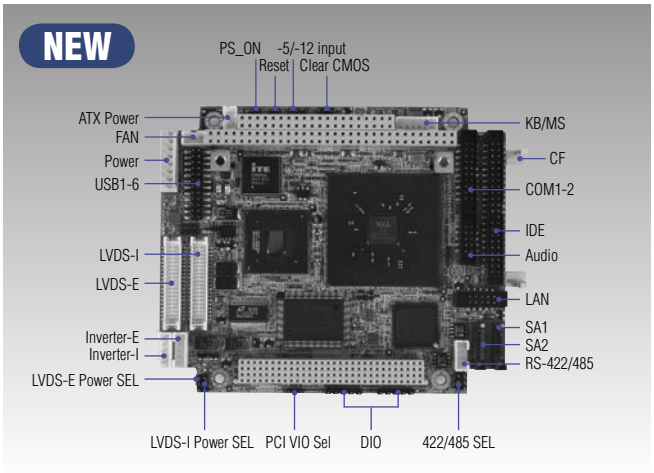
Optional Accessories

- **RS-422/485 cable** (p/n:1703040257)
- **12cm USB cable** (p/n:1703100121)
- **26cm USB cable** (p/n:1703100261)

A.3 Body Computer Specifications

PCM-3372

VIA Eden™ (V4) + CX700 PC/104-Plus CPU Module



Features

- VIA Eden™ (V4) 400/600 MHz and ULV1.0 GHz processor; VIA C7 2.0 GHz processor
- Supports DDR2 memory
- Supports 10/100 Base-T Ethernet
- 48-bit TFT LCD LVDS interface
- Supports one RS-232, one RS-232/422/485, and six USB 2.0 ports
- PC/104 and PC/104-Plus expansion connector
- Support audio function compliant with HD
- Support for CompactFlash® card type I

Specifications

General

- **CPU** — VIA Eden (V4) processor for 400/600 MHz and ULV1.0 GHz; VIA C7 2.0 GHz processor
- **2nd Cache Memory** — 128 KB on Processor
- **System Chipset** — VIA CX700
- **BIOS** — AWARD® 4 Mbit Flash BIOS
- **System Memory** — 200-pin SODIMM socket, supports DDR2 SDRAM, to 128/256/512/1024Mb. DDR2 533/400 SDRAM
- **Power Management** — ACPI supported, APM1.2
- **SSD** — Supports CompactFlash Card Type I
- **Watchdog Timer** — 255 levels interval timer, setup by software.
- **Expansion Interface** — 104-pin 16-bit PC/104 module connector and 120-pin PCI PC/104-Plus module connector
- **Battery** — Lithium 3 V/196 mAH

I/O

- **I/O Interface** — 1 x EIDE, 1 x RS-232/422/485, 1 x RS232, 1 x K/B, 1 x Mouse. 2 x SATA
- **USB** — 6 x USB 2.0
- **Audio** — Supports HD Audio stereo sound
- **GPIO** — 8-bit general purpose (4 Input/4 Output)

Ethernet

- **Chipset** — Intel 82551ER
- **Speed** — 10/100Base-T
- **Interface** — 1 x internal box header

Display

- **Chipset** — VIA CX700
- **Memory Size** — Optimized Shared Memory Architecture, supports 64 MB frame buffer using system memory
- **Resolution** — CRT display Mode
  pixel resolution up to
  1920 x 1440 x 32 bpp at 85 Hz
  1600 x 1200 x 16 bpp at 100 Hz and,
  up to 1024 x 768 x 32 bpp at 60 Hz for TFT LCD
  LCD Interface
  24/48 bit LVDS interface
  Dual Independent Display
  CRT + LVDS, LVDS+LVDS (optional)

Mechanical and Environmental

- **Dimension (L x W)** — 96 mm x 115 mm
- **Weight** — 0.162 kg (with heat sink)
- **Operating Temperature** — 0 ~ 60° C (32 ~ 140° F)
- **Operating Humidity** — 0% ~ 90% relative humidity, non-condensing

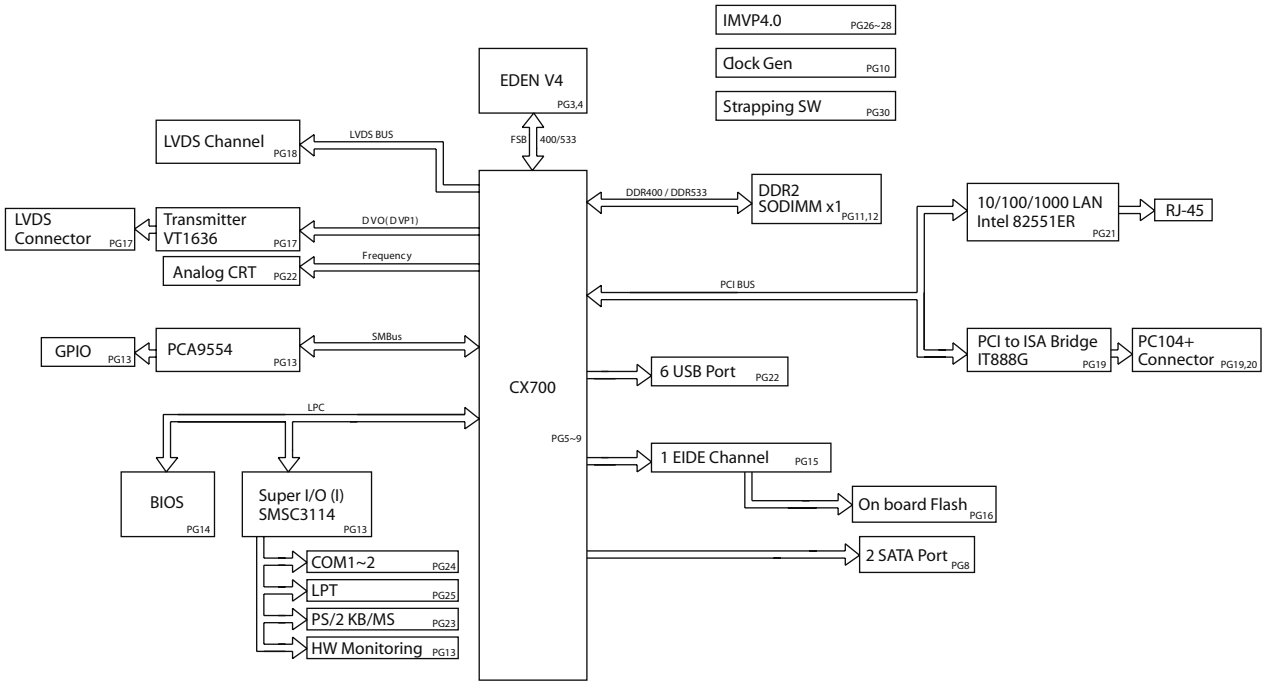
Power

- **Power Supply Voltage** — AT/ATX, +5 V ± 5%, +12 V ± 5% (Optional) (5 V only, 12 V optional for PC104 add on card and LCD inverter)
- **Power Consumption** — Typical: +5 V 1.45 A
  +12 V 0.02 A
  MAX: +5 V 2.63 A
  +12 V 0.03 A
  (Eden ULV1.0GHz with 512M RAM)

Packing List

- **1 x PCM-3372 SBC**
- **1 x Wire AT Power cable** (p/n:1703080104)
- **1 x Audio cable** (p/n:1703100152)
- **1 x Wire ATX power** (p/n:1703200380)
- **1 x Two COM cable** (p/n:1701200180)
- **1 x RS-422/485 COM cable** (p/n:1703040157)
- **1 x Keyboard/Mouse cable** (p/n:1703060053)
- **1 x Y cable (for KB/MS extention)** (p/n:1700060202)
- **1 x Ethernet RJ-45 Conn. conversion cable** (p/n:1701100202)
- **1 x IDE cable** (p/n:1701440350)
- **1 x VGA cable** (p/n:1700000898)
- **1 x USB cable (bracket type with two USB ports)** (p/n:17000000897)
- **1 x SATA cable** (p/n:1700071000)
- **1 x Startup manual**
- **1 x CD-ROM (Manual, Driver, Utility)**

Board Diagram



Ordering Information

Part No.	CPU	Chipset	L2 Cache	CRT	TTL	LVDS	10/100	USB2.0	RS-232	RS-232/ 422/485	LPT/KB/ MS	SATA	CF	Audio	PC/104+ connector	Thermal Solution	Operation Temp.	Embedded OS
PCM-3372F-J0A1E	VIA Eden (V4) 400 MHz	CX700	128 KB	Yes	--	48-bit	1	6	1	1	Yes	2	Yes	Yes	Yes	Passive	0 ~ 60° C	optional
PCM-3372F-M0A1E	VIA Eden (V4) 600 MHz	CX700	128 KB	Yes	--	48-bit	1	6	1	1	Yes	2	Yes	Yes	Yes	Passive	0 ~ 60° C	optional
PCM-3372F-S0A1E	VIA Eden (V4) ULV 1.0 GHz	CX700	128 KB	Yes	--	48-bit	1	6	1	1	Yes	2	Yes	Yes	Yes	Passive	0 ~ 60° C	optional
PCM-3372F-U0A1E	U0A1E VIA C7 2.0GHz	CX700	128 KB	Yes	--	48-bit	1	6	1	1	Yes	2	Yes	Yes	Yes	Passive	0 ~ 60° C	optional

A.4 CAN Card Specifications

PCM-3680 PC/104
Dual Port CAN Interface Module

Jumper Setting

The PCM-3680 is a special purpose communication card that brings the Control Area Network to your PC. With the built-in CAN controller, the PCM-3680 provides bus arbitration and error detection with automatic transmission repeat function. This drastically avoids data loss and ensures system reliability. The on-board CAN controllers are located at different positions in the memory. You can run both CAN controllers at the same time, independently. The PCM-3680 operates at baud rates up to 1 Mbps and can be installed directly into the expansion slot of your PC.

Control Area Network

The CAN (Control Area Network) is a serial bus system especially suited for networking "intelligent" I/O devices as well as sensors and actuators within a machine or plant. Characterized by its multi-master protocol, real-time capability, error correction, high noise immunity, and the existence of many different silicon components, the CAN serial bus system, originally developed by Bosch for use in automobiles, is increasingly being used in industrial automation.

Direct Memory Mapping

The PCM-3680 is assigned with memory address, which allows direct access to the CAN controller. This is the simplest and fastest way of programming any board in a PC because the board is regarded as standard RAM.

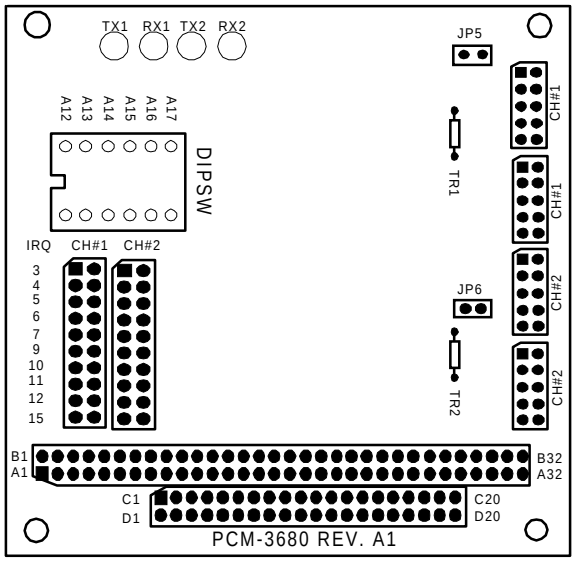
Optical Isolation Protection

On-board optical isolators protect your PC and equipment against damage from ground loops, increasing system reliability in harsh environments.

Specifications

- **Ports**: 2
- **CAN controller**: 82C200
- **CAN transceiver**: 82C250
- **Signal support**: CAN-L, CAN-H
- **Memory address**: From C800H to EF00H
- **IRQ**: 3, 4, 5, 6, 7, 9, 10, 11, 12, 15
- **Isolation voltage**: 1000 V_{DC}
- **Power consumption**: +5 V @ 400 mA typical, 950 mA max.
- **Connectors**: Dual DB-9 male connectors
- **Operating temperature**: 32 to 122° F (0 to 50° C)
- **PC/104 form factor**: 3.6" x 3.8" (90 mm x 96 mm)
- **Shipping weight**: 0.9 lb (0.4 kg)

Features

- Operates 2 separate CAN networks at the same time
- High speed transmission up to 1 Mbps
- 16 MHz CAN controller frequency
- Takes a 4 KB address space, 40 base address adjustable in steps from C800H up to EF00H
- Optical isolation protection of 1000 V_{DC} ensures system reliability
- Wide IRQ selection for each port includes: IRQ 3, 4, 5, 6,7, 9, 10, 11, 12, 15
- LED indicates Transmit/Receive status on each port
- Direct memory mapping enables speedy access to the CAN controllers
- C library and examples included

Jumper & Switch Locations