Datasheet - EtherCAT Arduino Shield by Esmacat, EASE

1. Highlight

- EtherCAT Arduino Shield by Esmacat (EASE) connects Arduino boards, Arduino-like boards, and Arduino Shields.
- High speed communication (200Mbps, 200x faster than CAN bus) with an industrial standard protocol, EtherCAT, for high performance robotic applications
- Daisy chain connection and Power-over-EtherCAT (POE) simplifies topology of wiring.
- Free open-source EtherCAT Master, Esmacat Server Software, is provided.

2. Table of Contents

3. Overview

EtherCAT Arduino Shield by Esmacat (EASE) is an Arduino Shield with the form factor of Arduino UNO shields. EASE stacks onto Arduino boards or Arduino-like boards (a.k.a Base board). Base board can read and write a data packet from EASE via SPI, and the same data packet is also read and written by an EtherCAT Master via a standard EtherCAT protocol which is an industrial fieldbus for high performance robotics. Multiple EASE boards can be connected with Ethernet cables with a daisy-chain topology, and the power of the system is supplied over Ethernet cables with Power-over-EtherCAT (POE) technology. EASE bridges the data packets between an EtherCAT master and multiple Base boards. The high-speed communication of EtherCAT, which is 200 times faster than CAN-bus and 1,000 times faster than traditional RS232 communication, allows for the seamless integration and centralized control of multiple Base boards.

To get started with EASE, Esmacat provides EASE's Arduino library and a free open-source Windows and Linux EtherCAT Master on Esmacat's website (https://esmacat.com).

Since the communication of EASE is based on the standard 4-wire SPI protocol and EtherCAT protocol, any Arduino-like boards, other generic EtherCAT master, and EtherCAT slaves also can be connected with EASE.

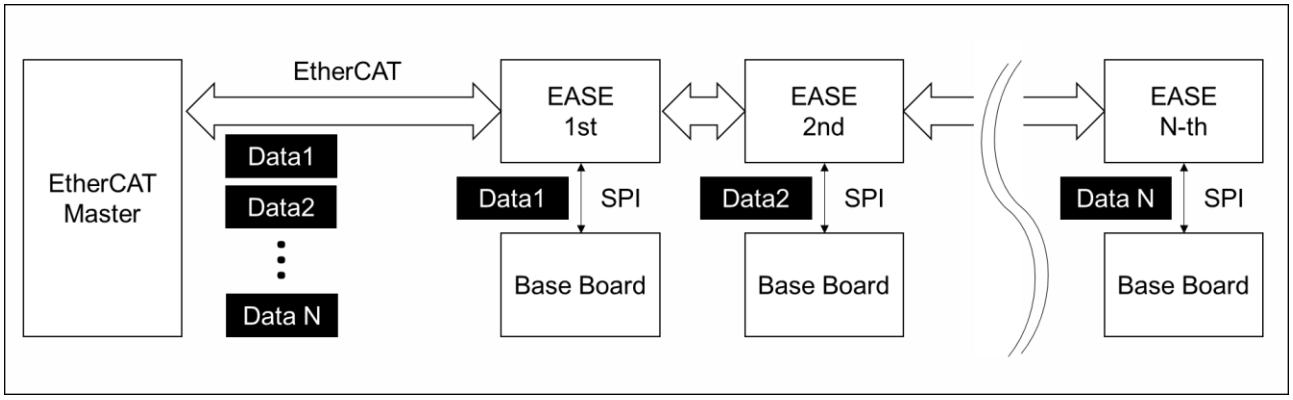
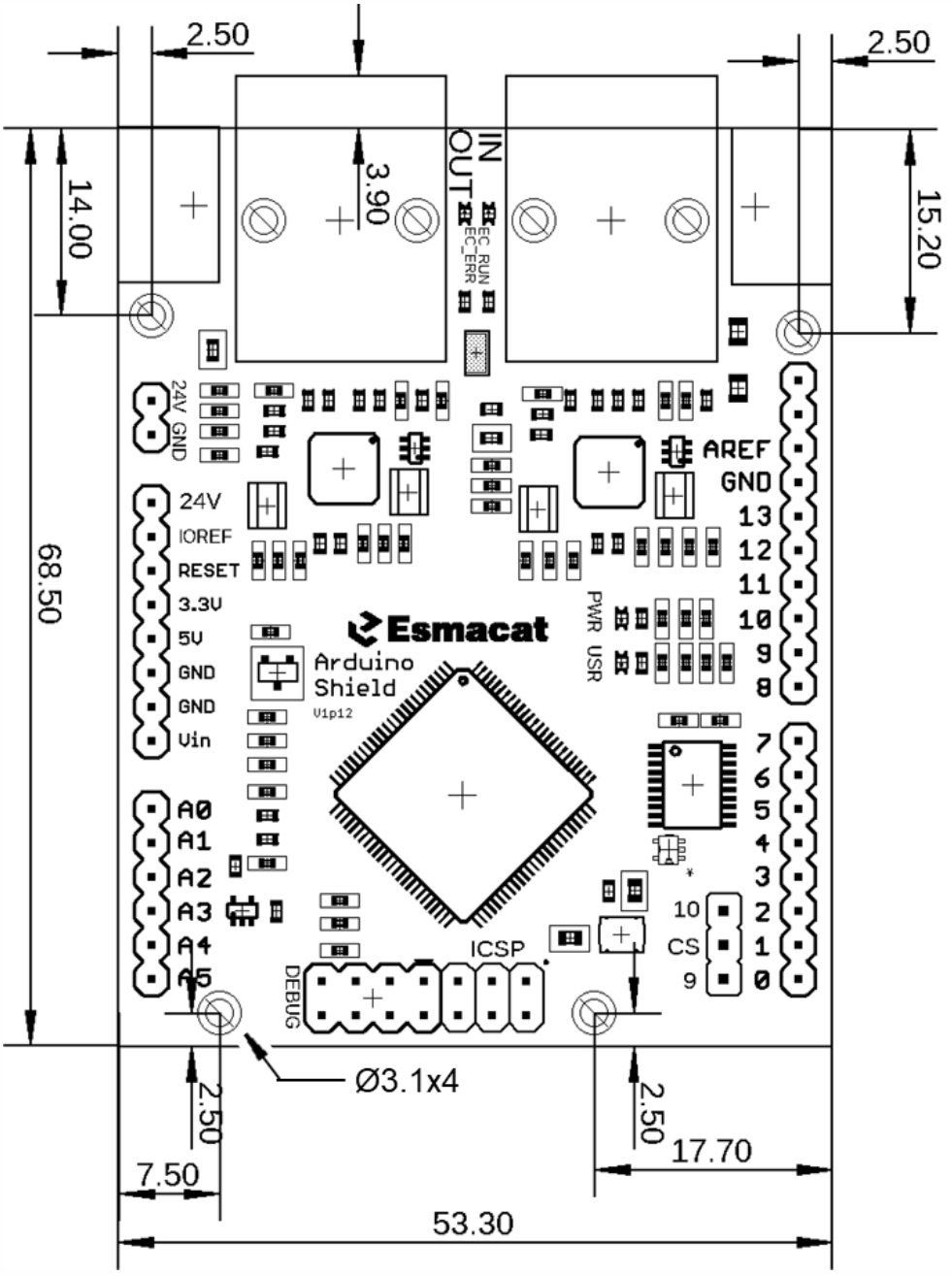


FIGURE 1. DATA FLOW BETWEEN ETHERCAT MASTER, EASE, AND BASE BOARD

4. Mechanical Dimension



- PCB board height from PCB top layer to the top of RJ45 connector: 14.4mm

FIGURE 2. DIMENSIONS OF ETHERCAT ARDUINO SHIELD BY ESMACAT (UNIT: MM)

5. Connector, Jumper, and LED

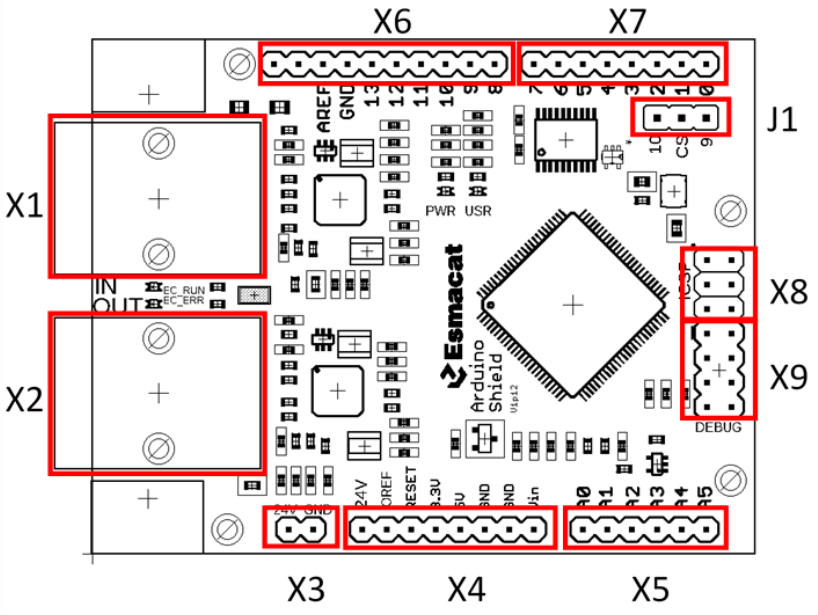


FIGURE 3. CONNECTORS AND JUMPER OF EASE

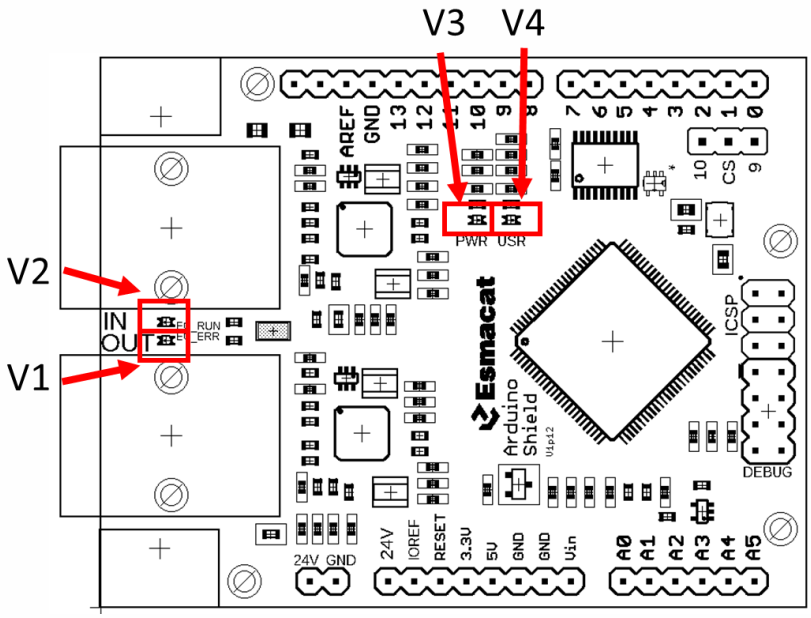


FIGURE 4. LEDS OF EASE

5.1. EtherCAT IN/OUT Connector, X1/X2

X1 is for EtherCAT communication with the previous EtherCAT board or an EtherCAT master and for the board's power supply. X2 is for EtherCAT communication with the next EtherCAT boards and also supplies 24 VDC power to the boards that follow (See Section 8). The connector is a RJ45 connector which is a standard connector of Ethernet communication.

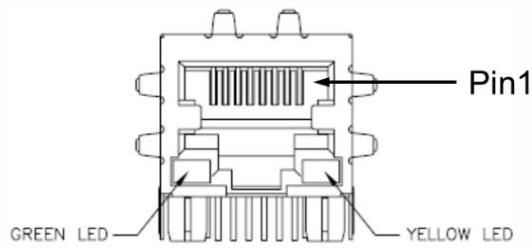


FIGURE 5. X1/X2 ETHERCAT IN/OUT RJ45 CONNECTOR

Pin number	Pin name
1	TX+
2	TX-
3	RX+
4	24 VDC
5	24 VDC
6	RX-
7	DGND
8	DGND

TABLE 1. ETHERCAT IN/OUT CONNECTOR PINOUT

CAUTION: After a POE injector with a 24VDC power supply unit, the Ethernet cable carries 24VDC. Thus, the user must not plug the Ethernet cable into a non-POE compatible device. For more detail information, please contact Esmacat technical support (https://esmacat.com/pages/contact-us).

5.2. 24VDC Power Supply Connector, X3

X3 provides 24VDC to other electric components such as an Arduino Shield. The connector consists of generic male pins with 0.1 inch pitch, which is same as typical Arduino shields.

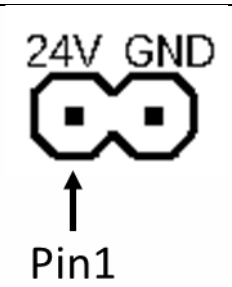


FIGURE 6. X3, 24VDC POWER SUPPLY CONNECTOR

Pin number	Pin name
1	24 VDC
2	GND

TABLE 2. PINOUT OF X3

5.3. Power Connector, X4

X4 is for the power pins of EASE, Arduino base boards (Base board), Arduino-like base boards (also Base board,) and Arduino Shields. The pinouts are identical except Pin 1 providing 24VDC for other electric devices. EASE supplies 9VDC to the Arduino boards through VIN pin to minimize the wiring between multiple Arduino boards. The connector consists of generic male pins with 0.1inch pitch, which is same as typical Arduino shields.

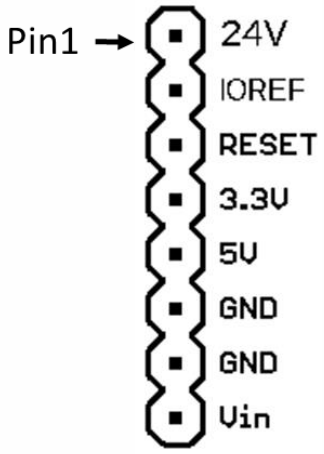


FIGURE 7. X4, POWER CONNECTOR

Pin number	Pin name	Description
1	24 VDC	24VDC from POE
2	IOREF	IOREF voltage of Base board
3	RESET	Reset pin for Base board
4	3.3V	Provided from Base board
5	5V	Provided from Base board
6	GND	Shared GND
7	GND	Shared GND
8	VIn	9VDC from EASE

TABLE 3. PINOUT OF X4

5.4. Analog Input Connector, X5

X5 bypasses the pins of Analog input connectors of Base board. The connector consists of generic male pins with 0.1inch pitch, which is the same as typical Arduino shields.

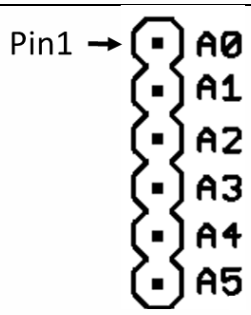


FIGURE 8. X5, ANALOG INPUT CONNECTOR

Pin number	Pin name	Description
1 - 6	A0 – A5	Directly connecting the corresponding pins of Base board

TABLE 4. PINOUT OF X5

5.5. Communication Connector, X6

EASE communicates with Base board through X6 with SPI. P13, P12 are P11 are used for SPI and P10 or P9 can be selected for the chip selector of SPI, which allows another shield to use the other pin. The other pins bypass the pins of Base board. The connector consists of generic male pins with 0.1inch pitch, which is the same as typical Arduino shields.

FIGURE 9. X6, COMMUNICATION CONNECTOR

Pin number	Pin name	Description
1,2,3,4	SCL, SDA, AREF, GND	Directly connecting the corresponding pins of Base board
5	P13, SPI CLK	SPI CLK, EASE communicates with Base board via SPI
6	P12 SPI MISO	SPI MISO, EASE communicates with Base board via SPI
7	P11 SPI MOSI	SPI MOSI, EASE communicates with Base board via SPI
8	P10 SPI CS	SPI Chip Selector, EASE uses either P10 or P9 for SPI, which is selected by Jumper 1.
9	P9 SPI CS	
10	P8	Directly connecting the corresponding pins of Base board

TABLE 5. PINOUT OF X6

5.6. GPIO Connector, X7

X7 bypasses the pins of Digital connectors of Base board. The connector consists of generic male pins with 0.1inch pitch, which is same with typical Arduino shields.

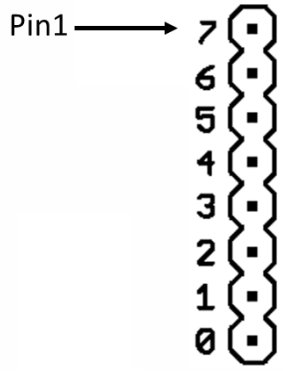


FIGURE 10. X7, COMMUNICATION CONNECTOR

Pin number	Description
1-7	Directly connecting the corresponding pins of Base board

TABLE 6. PINOUT OF X7

5.7. ICSP, X8

X8 bypasses the pins of of Base board. The connector consists of generic male pins with 0.1inch pitch, which is same with typical Arduino shields.

FIGURE 11. X8, ICSP CONNECTOR

Pin number	Description
1-6	Directly connecting the corresponding pins of Base board

TABLE 7. PINOUT OF X8

5.8. Debug Connector, X9

X9 is only for the debug of EASE. Do not use this connector

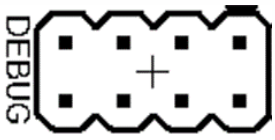


FIGURE 12. X9, DEBUG CONNECTOR

Pin number	Description
1-8	Do not use these pins. Only for debugging purposes.

TABLE 8. PINOUT OF X9

5.9. Jumper, J1

The user can select which pin of Base board to be used as the CS pin for SPI communication between EASE and Base board. This jumper prevents potential conflict of using the same SPI CS pin if stacked Arduino Shields on EASE need SPI communication.

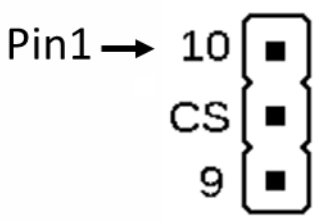


FIGURE 13. J1, JUMPER CS PIN SELECTOR

Pin number	Pin name	Description
1	P10	Connected to P10 of Connector X6
2	CS	This pin is used as CS for SPI communication between EASE and Base board
3	P9	Connected to P9 of Connector X6

TABLE 9. PINOUT OF X9

5.10. EtherCAT Status LED, V1 and V2

V1 is a green LED that shows the “RUN” status of EtherCAT communication. V2 is a red LED that shows the “ERROR” status of EtherCAT communication. V1 and V2 can be used for the diagnosis of the EtherCAT communication, and the signals of V1 and V2 can be interpreted as shown in Table 10.

LED	Color	Pattern	Status
V1, RUN	green	off	Init
		flashing	Pre-Operational
		single flash	Safe-Operational
		on	Operational
		flickers	Bootstrap
V2, ERROR	red	off	-

		flashing	Err-Operational No Communication

TABLE 10. INTERPRETATION OF V1 AND V2 LEDS

5.11. Power LED, V3

V3 is a green LED that shows if the board is stably powered by POE. When the LED is on, the power is supplied.

5.12. User LED, V4

V4 is a yellow LED that is controlled by the user. It can be controlled by the SPI communication between EASE and Base board.

6. SPI Communication between EASE and Base Board

Base board reads eight 16-bit integers and write eight 16-bit integers of EASE via an SPI protocol. The data packet including the integers are also read and written by EtherCAT Master via EtherCAT protocol. Therefore, EASE bridges this data packet between Arduino and EtherCAT Master for the 8 integers for input and 8 integers for output. The flow of the data packet is illustrated in Figure 14.

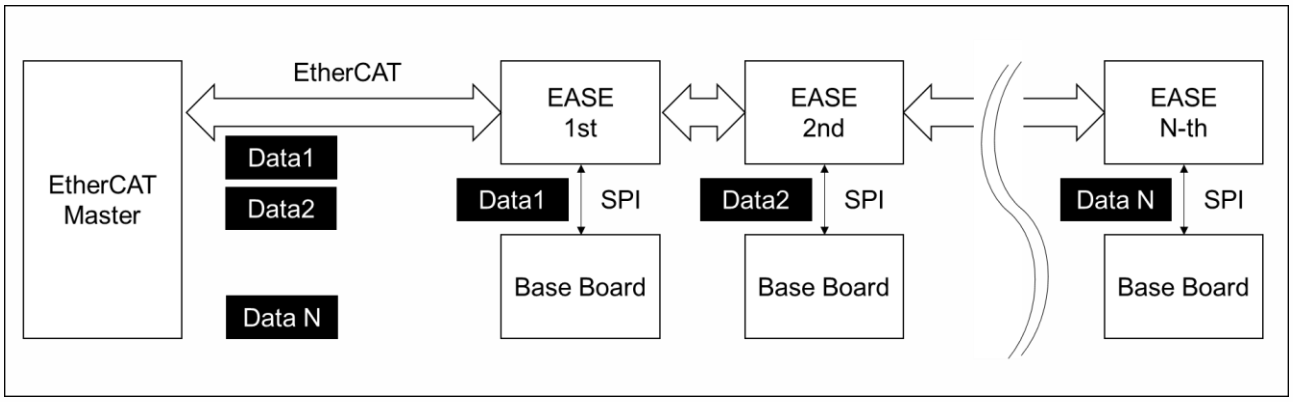


FIGURE 14. DATA FLOW BETWEEN ETHERCAT MASTER, EASE, AND BASE BOARD

EASE uses the standard 4 wire connection consisting of MOSI, MISO, CS and SCK. The operation of SPI starts when CS pins set down. In the SPI protocol with EASE, the SCK pin needs to be 0 at idle condition, and the data is shifted in and out on the falling edge of the data clock signal. If Arduino Board is the SPI Master, the SPI mode needs to be set “SPI_MODE1”.

The bits of MOSI and MISO are defined in Table 11, and the sequence and timing of CS, SCK, MISO, and MOSI are shown in Figure 15 and Figure 16.

MOSI /MISO	Bit sequence	Bit Name	Description
MOSI	0	C1	0: Write 1: Read
	1	C0	0: this bit needs to be always Low. 1: Do not send 1. The high bit is reserved.
	2-4	A2-A0	Index of the integer in PDO at Single Shot mode 000: IN_GEN_INT0 for Read, OUT_GEN_INT0 for Write 001: IN_GEN_INT1 for Read, OUT_GEN_INT1 for Write 002: IN_GEN_INT2 for Read, OUT_GEN_INT2 for Write 003: IN_GEN_INT3 for Read, OUT_GEN_INT3 for Write 004: IN_GEN_INT4 for Read, OUT_GEN_INT4 for Write 005: IN_GEN_INT5 for Read, OUT_GEN_INT5 for Write 006: IN_GEN_INT6 for Read, OUT_GEN_INT6 for Write 007: IN_GEN_INT7 for Read, OUT_GEN_INT7 for Write
	5	L0	0: User LED off 1: User LED on
	7-8	X	Does not matter
	9-24	O15-O0	Data packet to write. MSB comes first. If C1 is 1, these bits do not matter.
MISO	0-8	X	Does not matter

	9-24	I15-I0	Data packet to read. MSB comes first. If C1 is 0, these bits do not matter.

TABLE 11. DEFINITION OF MISO AND MOSI BITS IN SPI COMMUNICATION

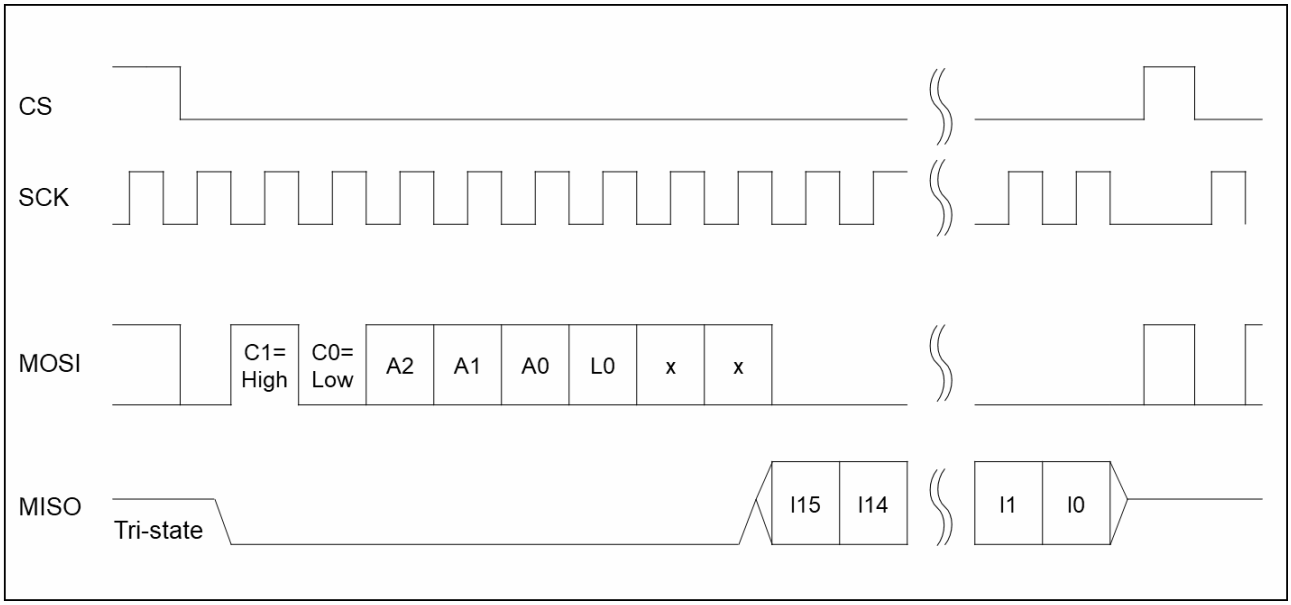


FIGURE 15. SINGLE 16BIT DATA READ OF EASE VIA SPI

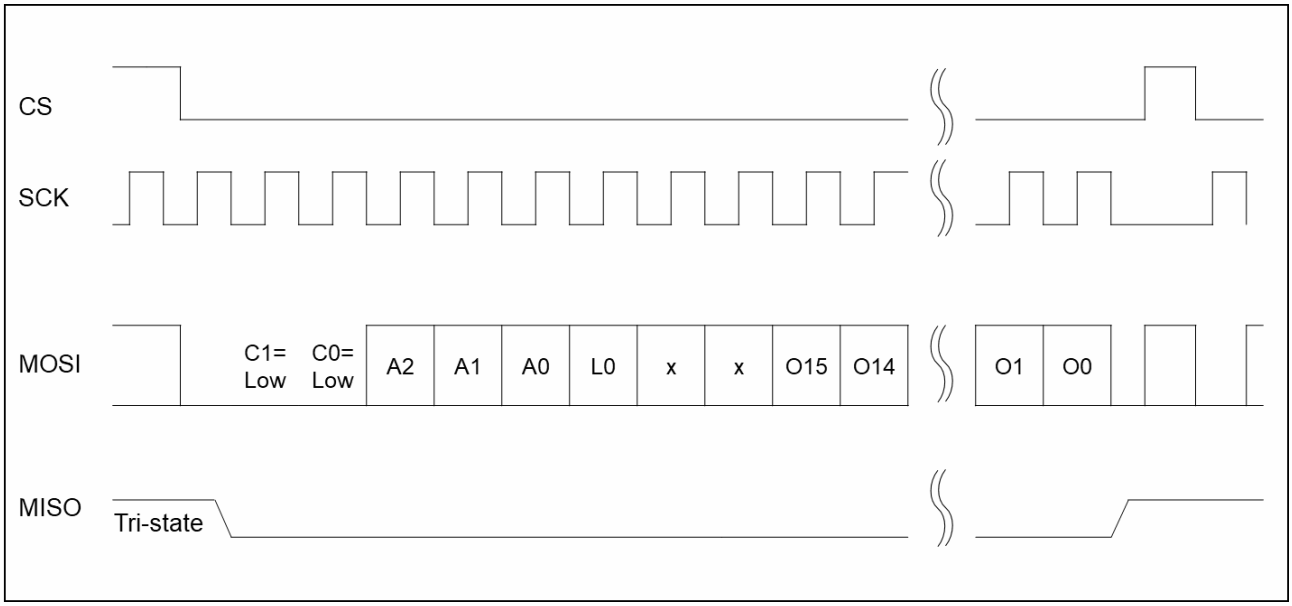


FIGURE 16. SINGLE 16BIT DATA WRITE OF EASE VIA SPI

7. EtherCAT Communication between EASE and EtherCAT Master

The eight 16-bit integers for input and eight 16-bit integers for output of EASE are read and written by EtherCAT Master via CAN-Over-EtherCAT (COE) protocol of EtherCAT.

The EtherCAT slave information of EASE has been defined in the EEPROM of EASE, and shows a list of important items of EASE.

Item	Data	Comment
Vendor_Name	Harmonic Bionics, Inc.	Developer of EASE
Vendor_ID	0x0062696F	Registered at EtherCAT Technology Group (ETG)
Group_Name	EtherCAT Arduino Shield by EASE	
Device_Name	EtherCAT Arduino Shield by EASE	
Product_Code	0x00090101	

TABLE 12. ETHERCAT SLAVE INFORMATION OF EASE

The 16 integers that are communicated between EASE and EtherCAT Master are mapped in the object dictionary of Process Data Objects (PDO) as defined in Table. Although EASE provides the data packet in the form of an integer data type since the integer is one of the most commonly used data types, the user can convert the integer variable into Boolean, Double, or other data types with simple bit operations.

PDO Address	Data Type	Object Name	Size (bit)	Access
0x6001	INT	IN_GEN_INT0	16	Read Only
0x6002	INT	IN_GEN_INT1	16	Read Only
0x6003	INT	IN_GEN_INT2	16	Read Only
0x6004	INT	IN_GEN_INT3	16	Read Only
0x6005	INT	IN_GEN_INT4	16	Read Only
0x6006	INT	IN_GEN_INT5	16	Read Only
0x6007	INT	IN_GEN_INT6	16	Read Only
0x6008	INT	IN_GEN_INT7	16	Read Only
0x7001	INT	OUT_GEN_INT0	16	Read/Write
0x7002	INT	OUT _GEN_INT1	16	Read/Write

0x7003	INT	OUT _GEN_INT2	16	Read/Write
0x7004	INT	OUT _GEN_INT3	16	Read/Write
0x7005	INT	OUT _GEN_INT4	16	Read/Write
0x7006	INT	OUT _GEN_INT5	16	Read/Write
0x7007	INT	OUT _GEN_INT6	16	Read/Write
0x7008	INT	OUT _GEN_INT7	16	Read/Write

TABLE 11. PDO MAPPING IN EASE

8. Power Supply

The EASE and other Esmacat slaves are powered by POE technology (Figure 17). That is the logic power of EASE and Base board is supplied through Ethernet cables with a passive POE injector. After the POE injector, Ethernet wire pin 4 and 5 are connected to 24 VDC and Ethernet wire pin 7 and 8 are connected to 0 VDC. For the pinouts of RJ45 connector, refer Table 1. The configuration of the logic power supply is illustrated in Figure 18.

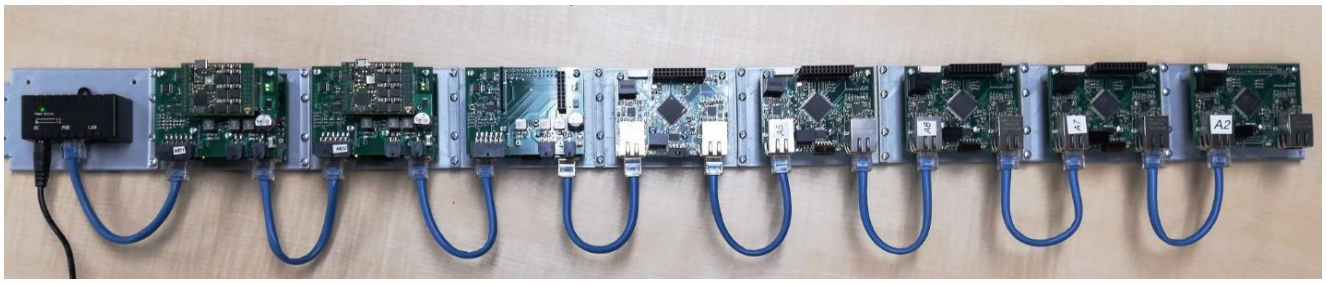


FIGURE 17 EXAMPLE OF AN DAISY CHAIN CONNECTION OF ESMACAT SLAVES FOR ETHERCAT COMMUNICATION AND POWER SUPPLY WITH POE

In the idle condition of Esmacat slaves, one slave device consumes approximately 2W (100mA at 24V, power consumption varying on the operation conditions). The user needs to select a 24V power supply unit that can supply sufficient powers of all Esmacat slaves connected through a daisy chain. If the user wants to use a high-current power supply unit, the user needs to confirm if Ethernet cable can carry the current. If additional power is needed, a user can connect another POE injector as shown in Figure 18.

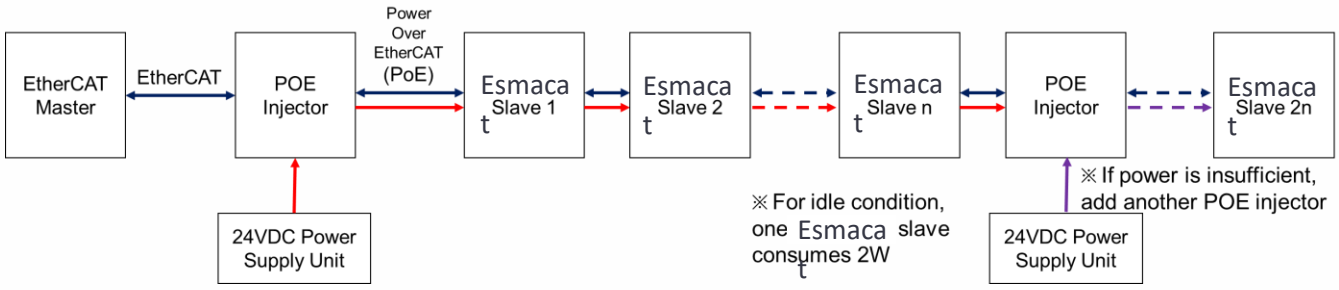


FIGURE 18 LOGIC POWER SUPPLY VIA POE

9. List of Figures and Tables

10. Legal Disclaimer

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Arduino is the trademark of Arduino AG

11. Contact Information

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12. Version History

Version	Release date	Author/ Reviewer	Changes
v0p95	October 11th 2019	YY/NA	• The first beta version document.
V0p96	October 17th 2019	YY/NA	• Description of Continuous mode has been deleted. • Grammar errors have been corrected.

			• The dimension of the holes of the board has been added in the mechanical dimension figure.
V1p00	December 20th 2019	YY/NA	• Logo has been changed into Esmacat • The format has been updated based on Format Instruction and Template of Esmacat Document v0p91 • Author and reviewer sections of Version History have been added based on *Format Instruction and Template of Esmacat Document v0p91*