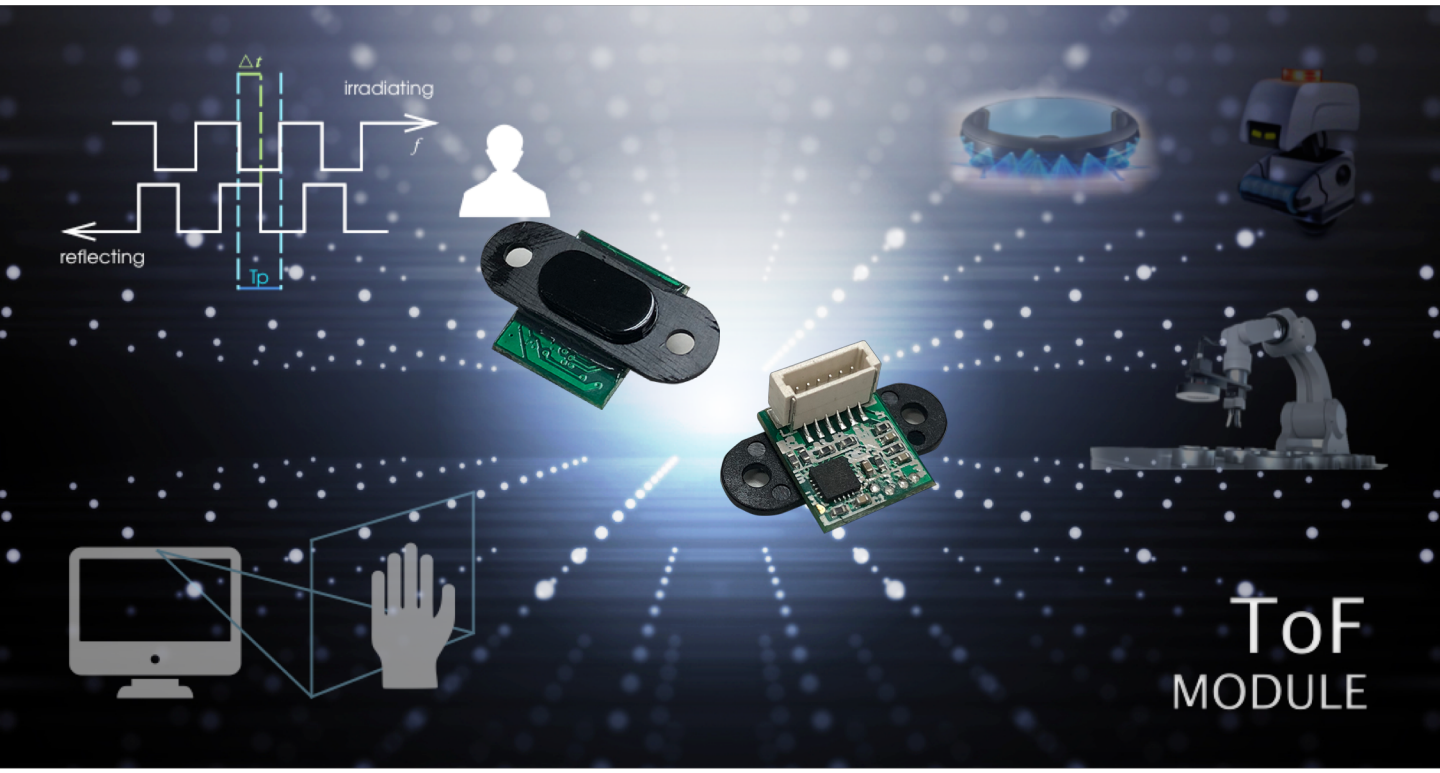
ToF Module MTOF171000C0 Application Notes



The high performance **MTOF171000C0** is a cost effective ToF(time –of –flight)Module system. Best-in-class distance measurement performance to a wide range of applications, including clean robot, tablets, Drone, and smart home applications.

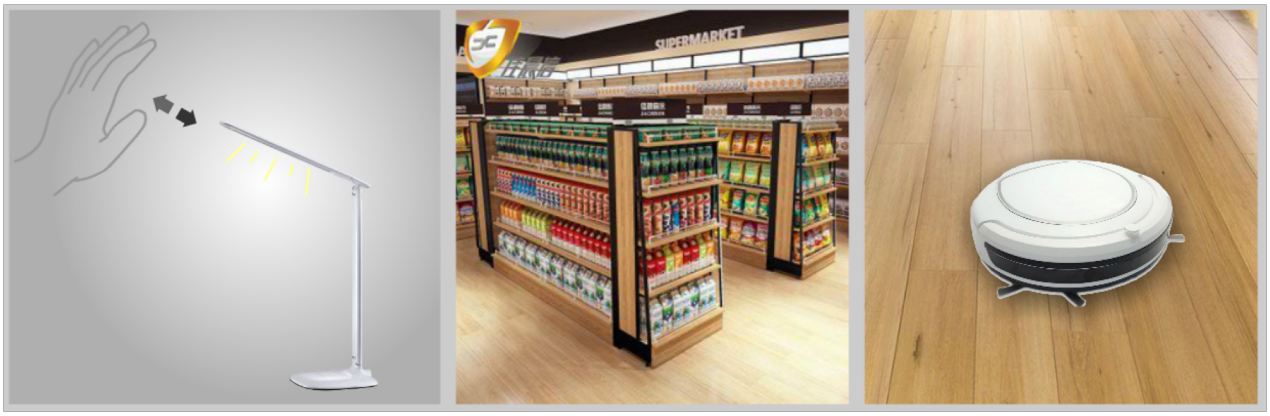
MTOF171000C0's time-of-flight sensing technology is realized by Sharp's original SPAD (Single Photon Avalanche Diodes) It enables accurate ranging result, higher immunity to ambient light and better robustness to work by special optical package design.
Please read this document before your design.

LEAD FREE

http://www.socle-tech.com/

Products Benefits

- 940nm emitter classified as class 1 under operation condition by IEC 60825-1:2014-3rd edition
- Long range absolute range measurement up to 1.2m
- High speed distance measurement response
- Advanced optical cross-talk compensation
- Easy to set
- No additional optical calibration requirement
- Single power supply
- Lead-free, RoHS compliant



Fundamental function

Features

- Working range : 2cm~120cm (White Card)
- Accuracy : +4% at 120cm (White Card)
- Sensor Board Dimension (mm) : 10 x 12 x 3.5
- Programmable for Customization
- Flexible Control Interface with Uart / I2C Selectable

Pin define

Pin define
1 : VDD
2 : GND
3 : TXD
4 : RXD
5 : SCL
6 : SDA

Contents目錄

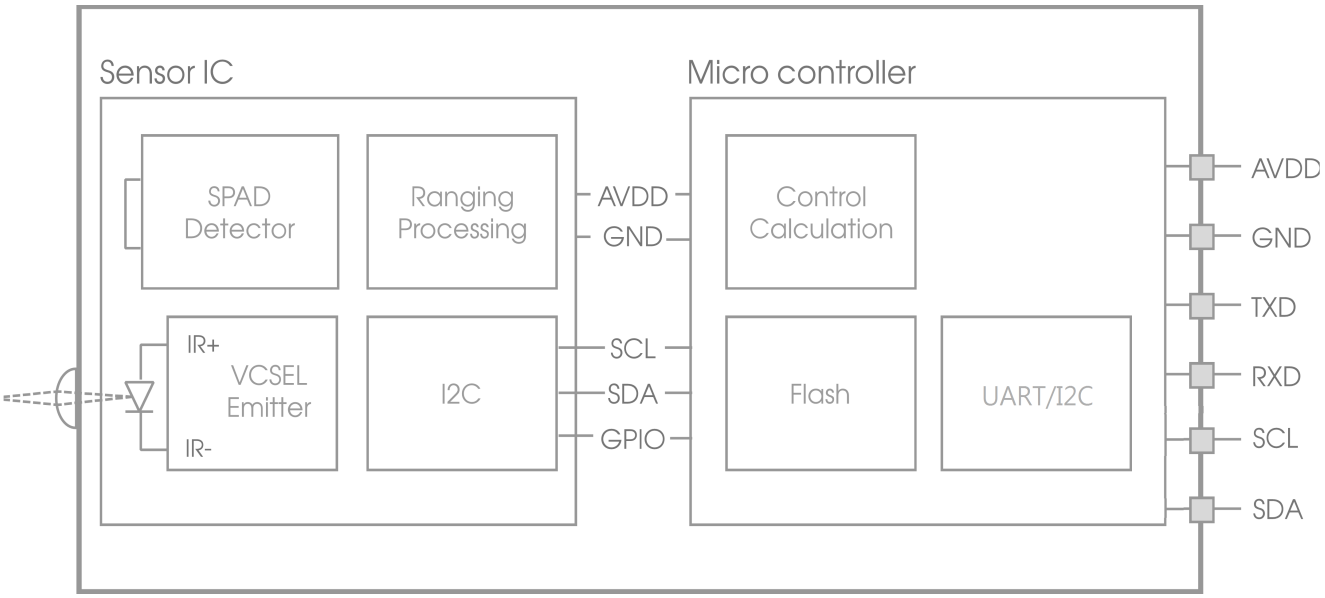
1. Overview 概述

MTOF171000C0 ToF module is easy using for customer’ s requirement, convenient setting for range measurement applications, this product can with the UART or I2C to be used as a control interface, for the details, please see this document.
MTOF171000C0 ToF module針對客戶使用需求，方便設定用於測距相關應用, 本產品可依據需求選擇透過 UART or I2C做控制介面使用，相關細節請見本文說明。

1.1 Technical specification技術規格

Parameter	Characteristics
MCU	8051
ToF Sensor	GP2AP01VT10F
FoV	25°
Operating temperature	-20 ~ 70℃
Power supply voltage	3.0V ~ 3.6V
Current consumption	30mA (at 3.0V)
Working Cycle time	33msec
Working Distance	2cm ~ 120cm (White card) 2cm ~ 70cm (Gray card)
Measurement Accuracy	±4% at 120cm (White card) ±7% at 70cm (Gray card)
Control Interface	UART / I2C Selectable
Sensor board Package	6pin / 10×12×3.5mm

1.2 System block diagram 系統架構

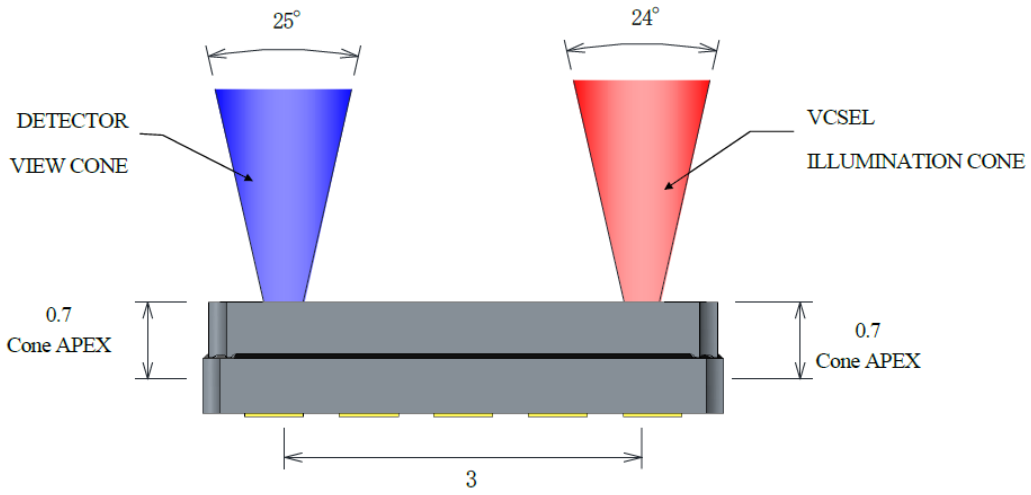


1.3 Device pin define 腳位定義

1:VDD: the power pin, power supplied from the control platform 3.3V to ToF Module
2:GND: ground pin , the same ground level with the control platform.
3:TXD: ToF Moudle data output terminal, which needs to connect to the data receiving end of the control platform UART interface, RXD port.
4:RXD: ToF Moudle data receiving terminal, need to connect to control platform UART interface data output port, TXD port
5:SCL: ToF Moudle serial clock pin, serial clock interface that needs to be connected to the I2C interface of control platform.
6:SDA: ToF Moudle serial data pin, serial data interface that needs to be connected to control platform I2C interface.
1：VDD : 電源接口端,由控制平台供電3.3v 給ToF Module
2：GND : Ground線,需要與控制平台同一個地的準位
3：TXD : ToF Moudle 資料輸出端,需要連接到控制平台UART介面的資料接收端, RXD端口
4：RXD : ToF Moudle 資料接收端,需要連接到控制平台UART介面的資料輸出端, TXD端口
5：SCL : ToF Moudle串列時鐘線, 需要連接到控制平台I2C介面的串列時鐘接口
6：SDA : ToF Moudle串列資料線, 需要連接到控制平台I2C介面的串列資料接口

1.4 Optical Characteristics 光學特性

The VCSEL Emitter terminal of the original ToF sensor is FOV 24°, and the Detector FOV is 25°. For detailed distribution of the light fields, please refer to the test data of chapter 5.
原ToF sensor的VCSEL發射端FOV 24°，接收端的FOV 25°。詳細的光場分布請參考第五章的資料。



2 System Development description 系統開發描述

2.1 System functional description 系統功能描述

This product has been integrated with optical, mechanical, electrical and distance measurement algorithms, and the optical correction has been adjusted in the factory. The users do not need to consider the difference of optical integration and assembly between different parts, it is easy to use in the product application immediately. The control interface supports the UART/I2C interface at present. As long as the command line is executed, the distance measurement related operation can be carried out.
本產品已進行光、機、電、測距算法等功能整合，並在出廠時執行過光學校正,使用者不需再考慮光學整合與組裝差異問題，方便立即用於產品應用。控制介面部分，目前支持介面為UART/I2C介面,只要依據指令，就可以進行測距工作。

2.2 Peripheral circuit design周邊電路設計

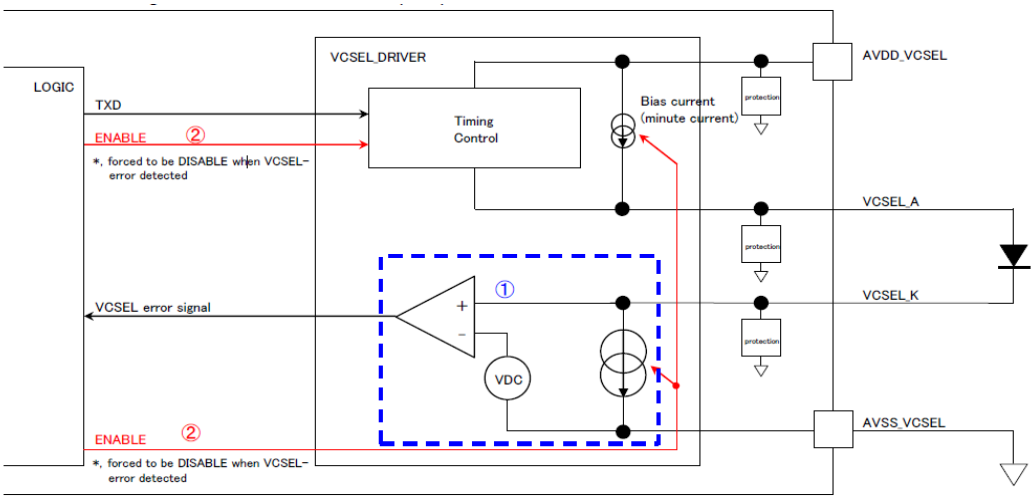
VCSEL fail safe circuit 激光失誤時之安全線路

① Monitoring mode (below blue part) 正常運行模式(藍色)

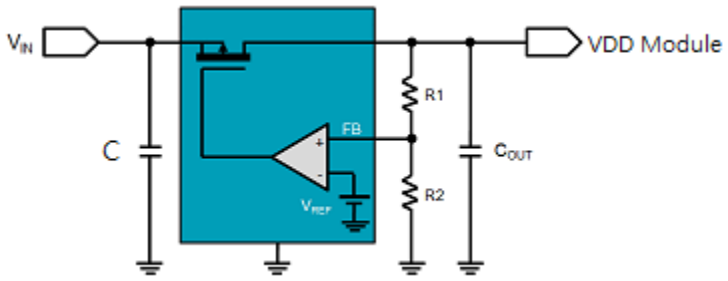
Voltage level of VCSEL_K is predictable under normal operation.
This node is always monitored and compared with internal threshold, and judged in every operation cycle.
在正常運行下VCSEL_K的電壓階級是可預測的。
該節點一直被監測並與內部閾值進行比較，且在每個操作週期中進行判斷。

② Shutdown mode (below red part) 關機模式(紅色)

Once abnormal condition detected, VCSEL DRIVER block, including all of the current sources below, It is automatically shut down and also TXD signal is disabled in the timing controller. This monitoring function is tested for every chip at wafer sort.
運作時，對晶圓的每個晶片排序進行了監控功能測試。一旦檢測到異常狀態，VCSE驅動模塊，包括所有的電源會被自動關閉，並且在定時控制器中TXD訊號被禁用運作。



In order to use this product with more effectively, it is suggested that overload protection circuit should be designed on the power supply block of the main platform. The proposed circuit examples are as follows:
為有效使用本產品，建議在應用平台供電部分，可以設計過載保護電路，相關建議電路範例如下:



2.3 Control interface

UART Serial Port

For the UART control interface, please read the related settings and examples before use the MTOF171000C0.
有關控制介面,如下為UART 操控介面的相關資料。使用MTOF171000C0前請先詳細閱讀相關設定與範例。

Port Setting

1. Bits per Second : 9600
2. Data Bits : 8
3. Parity : None
4. Stop bits : 1
5. Flow Control : None

Command/Data Transmission Format

Data(HEX)	Description
55	1st Identification Byte
AA	2nd Identification Byte
CMD	Command
CMD_DAT/ADDR	Data / Register
LEN	Data Length
DAT0	Data 0
DAT1	Data 1
…	…
DATn	Data n，n=LEN
CHKSUM	Check Sum（The TWO Identification Byte are not included ）

Serial Port Command List

Instruction

Command Name	Instruction(HEX)	Feature Function
CMD_RD_SEN_REG	D1	Read the ToF sensor register
CMD_WR_SEN_REG	51	Write the ToF sensor register
CMD_RD_MM	D3	Distance measure data(reply the "8888" when abnormal status)
CMD_CALI_XTALK	FA	XTALK Calibration
CMD_CALI_OFS	FB	OFFSET Calibration
CMD_WR_OFS	7C	Write the OFFSET value
CMD_WR_XTALK	7D	Write the XTALK value
CMD_RD_VAR	F0	Get the Module status information, for the Engineering debug
CMD_RESET	F5	Sensor Reset

Example

Command Name	Send instruction	Return instruction	Command Name
CMD_RD_SEN_REG	55 AA D1 3B 01 0D	55 AA D1 3B 01 0F 1C	To get the TOF sensor DEVICE ID
CMD_WR_SEN_REG	55 AA 51 00 01 C0 12	55 AA 51 00 01 C0 12	To Write "0xC0" into TOF Sensor Register COMMAND_00H
CMD_RD_MM	55 AA D3 00 02 D5	55 AA D3 00 02 01 02 D8	To Get the Distance Measurement value, ex. 0x0102=258mm
CMD_CALI_XTALK	55 AA FA 00 02 D5	55 AA FA 00 04 Hs Ls Hx Lx chksum	HsLs : the result after Calibration HxLx :the Calibration data
CMD_CALI_OFS	55 AA FB 00 04 FF	55 AA FB 00 04 Hs Ls Ho Lo chksum	HsLs : the result after Calibration HoLo :the Calibration data
CMD_WR_OFS	55 AA 7C 00 02 Ho Lo chksum	55 AA 7C 00 02 Ho Lo chksum	offset value with Big Endian
CMD_WR_XTALK	55 AA 7D 00 02 Hx Lx chksum	55 AA 7D 00 02 Hx Lx chksum	xtalk value with Big Endian
CMD_RD_VAR	55 AA F0 00 20 10	the Module status information, for the Engineering debug	the Module status information, for the Engineering debug
CMD_RESET	55 AA F5 00 00 F5	55 AA F5 00 00 F5	System Reset

The Command/Data Transmission seen as executed finish, when the next Byte be triggerred delay more than 10ms

Command Example

Command/命令	Send / 發送	Return / 返回	Description / 說明
CMD_RD_MM	55 AA D3 00 02 D5	55 AA D3 00 02 01 02 D8	Return the Distance measurement 0x0102=258mm 返回距離值0x0102=258mm

Execution Example 執行範例

1. ToF Module power on
2. Waiting for the system init. 300~500ms
3. The main platform send the command CMD_RD_MM, D3
   Ex, Send "55 AA D3 00 02 D5"
4. Waiting for the measuring data reply, the period for the reply will depend on the environment status , about 16~33us
5. ToF Module return the distance measure result

Ex, "55 AA D3 00 02 01 02 D8", the "01 02 " is the distance data 0x0102 = 258mm

1. 供電ToF Module
2. 等待系統初始化結束約 300~500ms
3. 控制平台發送開始測距指令CMD_RD_MM, D3
   Ex, 發送 "55 AA D3 00 02 D5"
4. 等待測距資料回覆,回覆時間將依據場景而有差異,約16~33us
5. ToF Module在測距程序處理完畢後,回覆測距結果

Ex, "55 AA D3 00 02 01 02 D8", 其中 " 01 02 "為測距結果0x0102 = 258mm

I2C Bus

For the I2C control interface, please read the related settings and examples before use the MTOF171000C0.
有關控制介面,如下為I2C 操控介面的相關資料。使用MTOF171000C0前請先詳細閱讀相關設定與範例。

I2C Setting

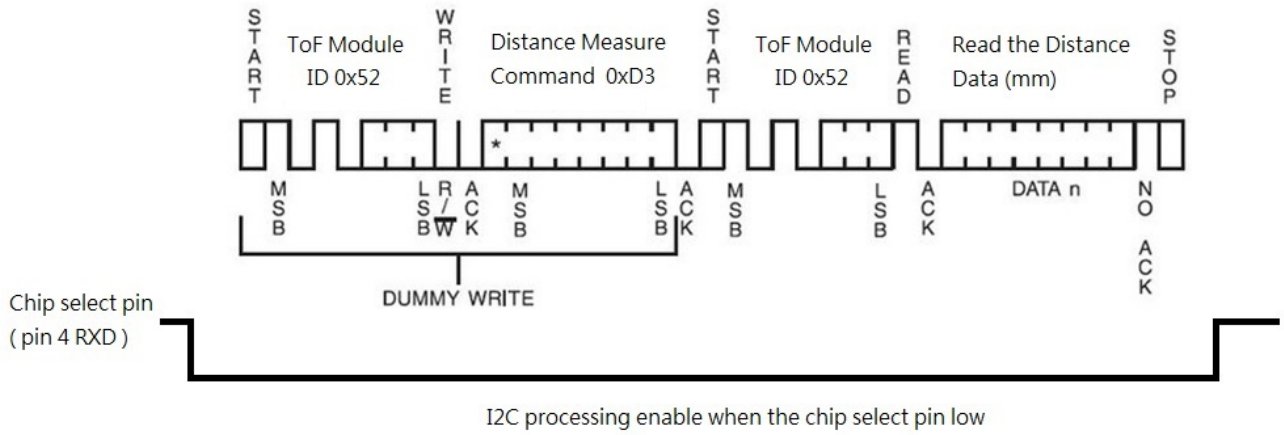
1. Module ID : 0x52
2. Data Bits : 8
3. Module Select pin : RXD
4. Control : I2C Standard mode 100 kbit/s

Only two data bus lines and one module select pin are required, a serial data line (SDA) and a serial clock line (SCL) and a module select pin (RXD).
The I2C Standard mode upto 100 kbit/s, with 8-bit oriented bidirectional data transfers.
For the multi modules control, master dumps data to the selected ToF Module with the module select pin (RXD) at low.
需要兩個資料傳輸信號線與一個模組選擇腳位，包括序列資料信號線(SDA)與序列時鐘信號線，以及一個模組選擇腳位(RXD)。
此為標準I2C 模式設計，速度達100kbit/s，8位元雙向資料傳遞。
為了滿足多模組控制的設計，主控平台可以下拉模組選擇腳位(RXD)信號並搭配序列資料傳輸，來控制欲控制的ToF 模組。

Command Instruction

Command Name	Instruction(HEX)	Feature Function
CMD_RD_MM	D3	Distance measure data(reply the "8888" when abnormal status)
CMD_RESET	F5	Sensor Reset

Operation Sequence



Execution Example 執行範例

The Command sequence for the Ranging :

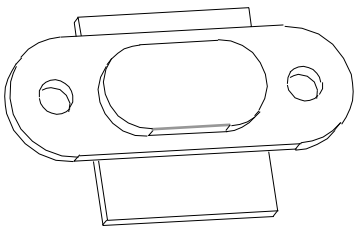
1. Pull Low the Module select pin
2. Master send START
3. Master send I2C addr 0x52 (7bit) with the read/write select 0 (1bit) ,waiting for ACK
4. Slave send ACK
5. Master send I2C command 0xD3 (8bit) ,waiting for ACK
6. Slave send ACK
7. Master send START
8. Master send I2C addr 0x52 (7bit with the read/write select 1 (1bit) ,waiting for ACK
9. Slave send ACK
10. Slave send data (2Bytes) reply the ranging result(mm)
11. Master send ACK
12. Master send STOP
13. Pull High the Module select pin

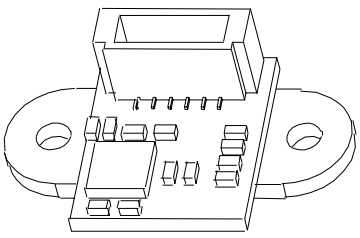
測距指令信號通信流程：

1. 下拉模組選擇腳位
2. Master發送START
3. Master發送I2C addr 0x52 (7bit) 和讀寫選擇位 0 (1bit) ，等待ACK
4. Slave發送ACK
5. Master發送I2C 讀取測距資料命令 0xD3 (8bit) ，等待ACK
6. Slave發送ACK
7. Master發送START
8. Master發送I2C addr 0x52 (7bit) 和讀寫選擇位 1 (1bit) ，等待ACK
9. Slave發送ACK
10. Slave發送data (2Bytes) ，回覆測距結果(mm)
11. Master發送ACK
12. Master發送STOP
13. 上拉模組選擇腳位

3 Design and Application 設計與應用

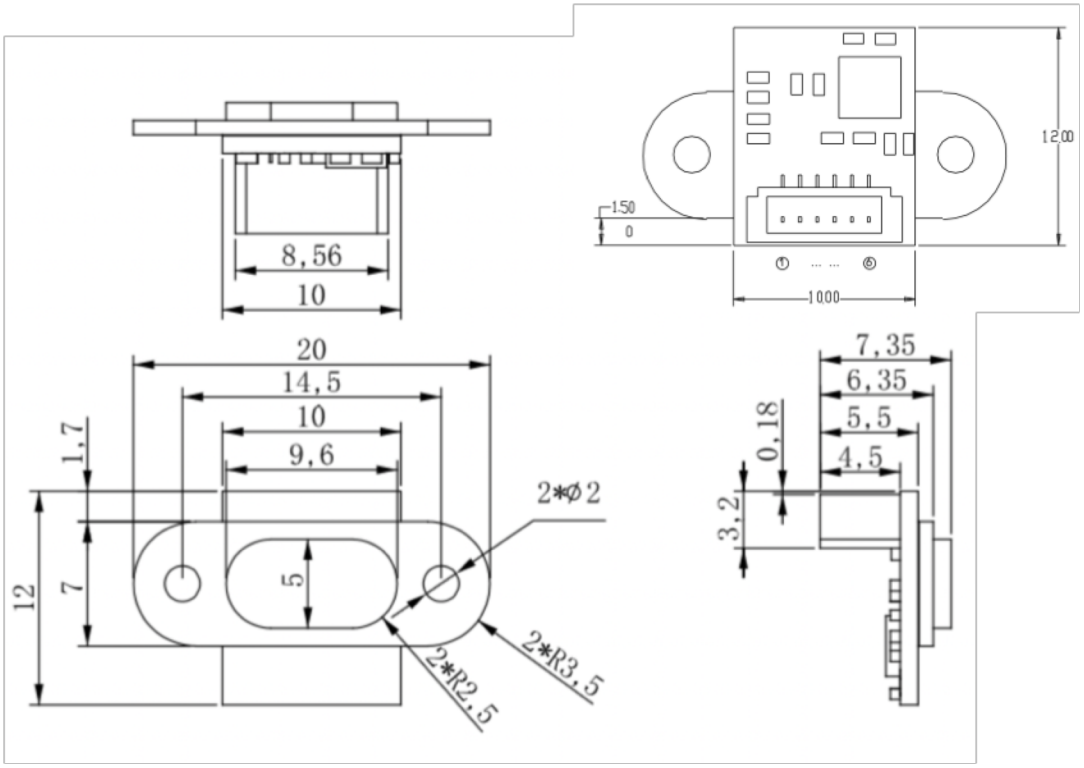
3.1 OUTLINE design 機構外觀





Module OUTLINE

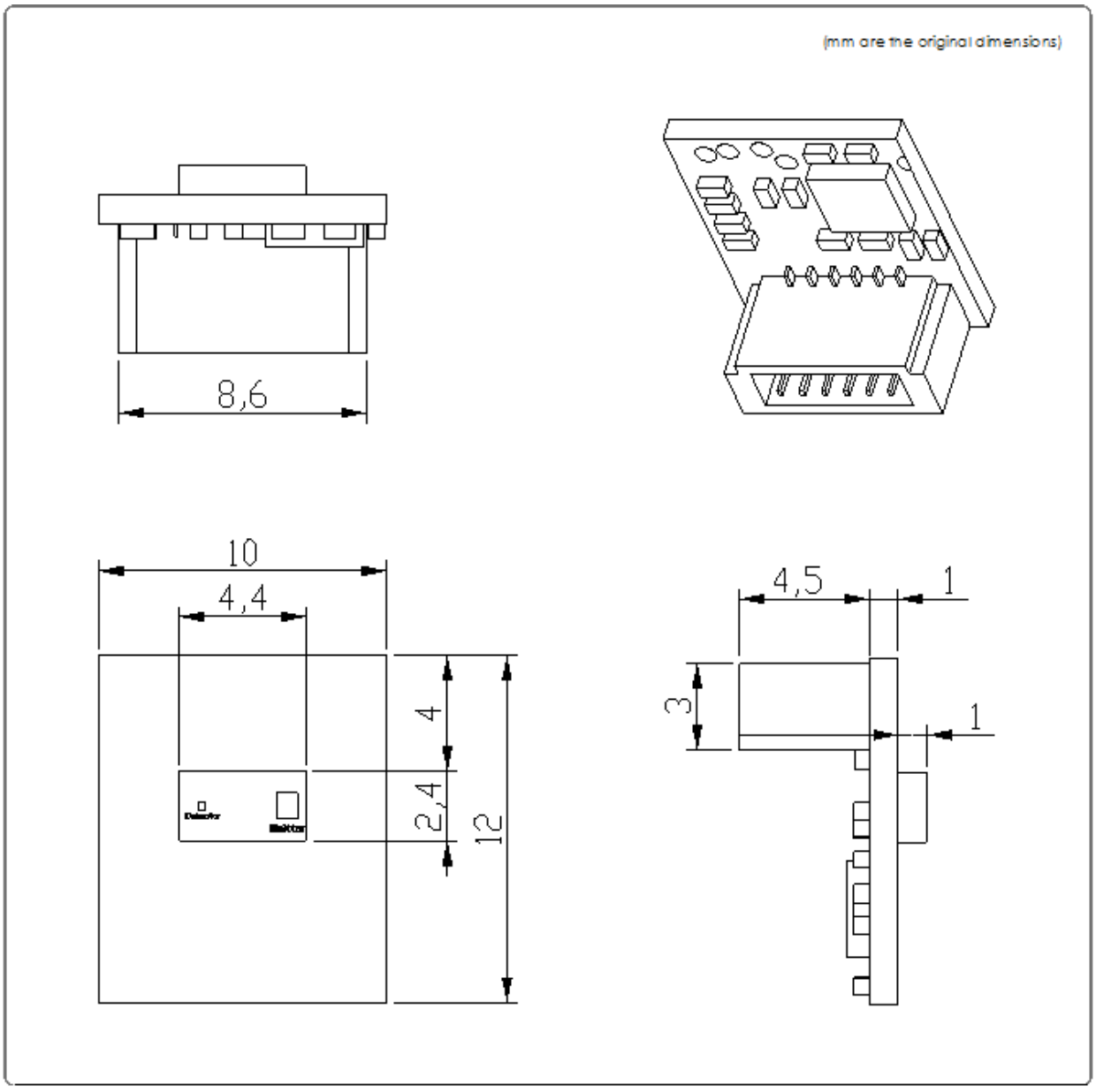
(mm are the original dimensions)



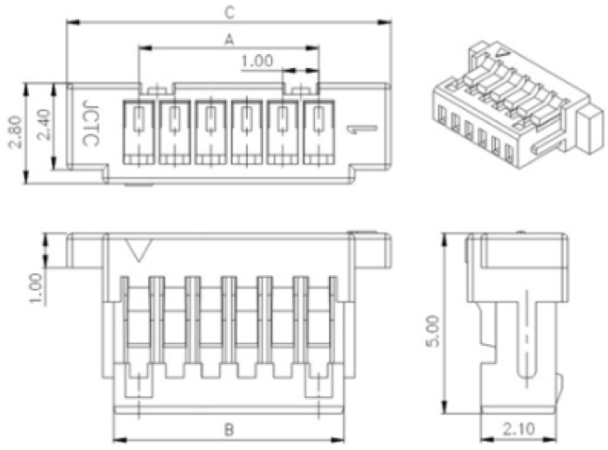
No.	Pin name
①	VDD
②	GND
③	TXD
④	RXD
⑤	SCL
⑥	SDA

Gross weight : 0.7g

PCBA OUTLINE



Recommend Connector



Dimensional Information:

A	B	C
5.00	6.40	9.00

*Suitable JCTC 11002 series Terminal
*Mates with JCTC 11002 series single row Wafer

3.2 Outer Cover suggestion 外蓋設計建議

With the Optical impact, the outer cover should not be attached to the appearance of the ToF Module, because the outer cover will cause the reflection or crosstalk of the rays, which will affect the operation of the ranging function.
If the outer cover must be added, please confirm that the IR penetration rate of the outer cover is over 90% at least, and the AR coating must be made on both sides of the lens, and the outer cover must be attached to the lens surface of the MTOF171000C0.
In addition, if there is a printed texture on the outer cover, please confirm that the block of the VCSEL Emitter and the Receiver will not have a texture area, and the block must have no pattern with the single color.
因光學限制,不可以有外蓋加在ToF Module外觀, 因外蓋會造成射線的反射或串擾，影響測距功能的運作。
如果必須加裝外蓋，請確認該外蓋的IR 穿透率至少90%以上，且雙面都必須做AR 鍍膜，而外蓋必須平貼於MTOF171000C0的lens上面。
此外，如果外蓋上面有印刷圖示，請確認在發射端與接收端上區塊，不可以有花紋切換區，這區塊必須為單一顏色且無紋路。

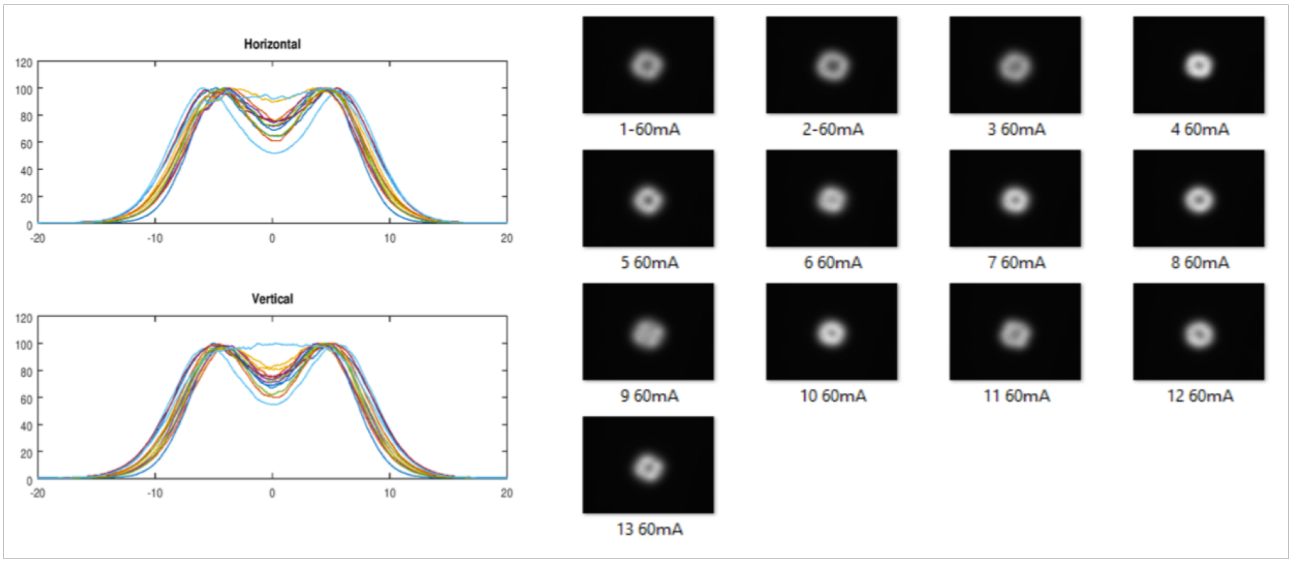
3.3 Ambient light impact 環境光干擾問題

Because that the outdoor ambient light is the full spectrum light wave, the placement design needs to avoid the ambient light direct into the detector of the MTOF171000C0, otherwise it will cause the problem of unanticipated ranging.
It is suggested that the module can be reduced to the inside of the mechanism so that it can also help prevent environmental light interference. For the design of internal contraction, the space limit of the light field should also be taken into consideration. The FoV of MTOF171000C0 is 25 degrees. If there is interference in the round-trip space of the optical path, it may also affect the precision of distance measurement. So we suggest that there is enough space to be designed. If there is a limit in space, the inner edge of the proposed MTOF171000C0 can be painted black, so as to reduce the optical path back and forth in the space interference.
因為戶外環境光為全頻段波長，所以使用環境需要避開外界光直射，否則會造成無法預期的測距問題。
建議可以把模組內縮到機構裡面，這樣對於預防環境光干涉也有幫助。對於內縮的設計，也要考慮到光場的空間限制，MTOF171000C0的FoV為25°，如果光路往返空間中有干擾，也可能對於測距精度有影響，所以我們建議要有足夠空間的設計。如果空間上必須有限制，建議放置MTOF171000C0的內緣可以塗上黑色，這樣可減少光路往返於內緣空間的干擾影響。

3.4 Multi Module Design 多模組設計

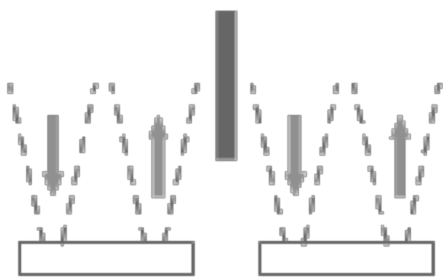
The design with two or more ToF Modules also needs to consider about the problem of mutual interference, which may occur if been started simultaneously. It is suggested that to switch the operation, to start the ranging operation one by one. Or in mechanism design, to place the two modules as far as possible, so that the light field will not have overlapping area. Or put the partition between the two MTOF171000C0, it can also effectively prevent the interference with each other.
對於兩個或以上ToF Module運作的設計,也需要考慮到互相干擾的問題，如果同時啟動，可能會有互相干擾問題發生。建議可以切換操作的方式來使用，一次啟動一個模組做測距動作。或是在機構設計上儘量拉開兩個MTOF171000C0空間，使光場不會有重疊區域。或是兩個MTOF171000C0中間加上隔板，也可以有效防止互相干擾的問題發生。

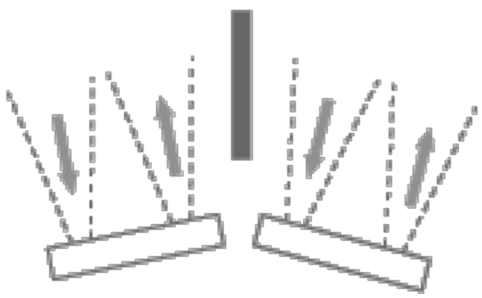
光場資料 Ray field information



The Full Ray field diameter at the distance with 3mm/5mm/8mm :

3mm – 1.28mm
5mm – 2.13mm
8mm – 3.40mm





4. Demo Kits介紹

4.1.Getting Started with Arduino

The Arduino Software (IDE) allows you to write programs and upload them to your board.
Below we use Arduino 2560 as an example:

1.Install the Arduino Desktop IDE : https://www.arduino.cc/en/Guide/HomePage
To get step-by-step instructions select one of the following link accordingly to your operating system.

Windows(https://www.arduino.cc/en/Guide/Windows)
Mac OS X(https://www.arduino.cc/en/Guide/MacOSX)
Linux(https://www.arduino.cc/en/Guide/Linux)
Portable IDE (Windows and Linux) (https://www.arduino.cc/en/Guide/PortableIDE)

(Reference: https://www.arduino.cc/en/Guide/HomePage)

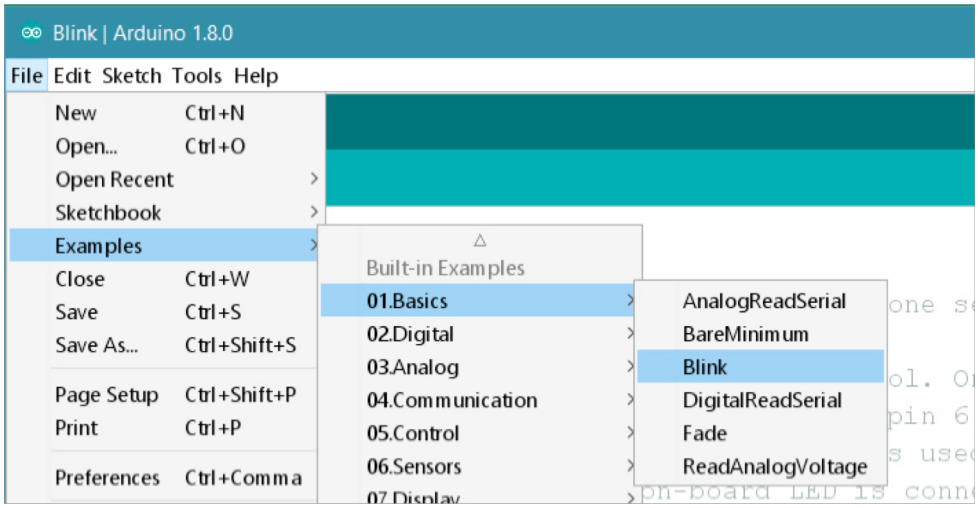
2.Use your Arduino Mega 2560 on the Arduino Desktop IDE
(https://www.arduino.cc/en/Guide/ArduinoMega2560)

2.1 Connect your board

The USB connection with the PC is necessary to program the board and not just to power it up. The Mega2560 automatically draw power from either the USB or an external power supply. Connect the board to your computer using the USB cable. The green power LED (labelled PWR) should go on.

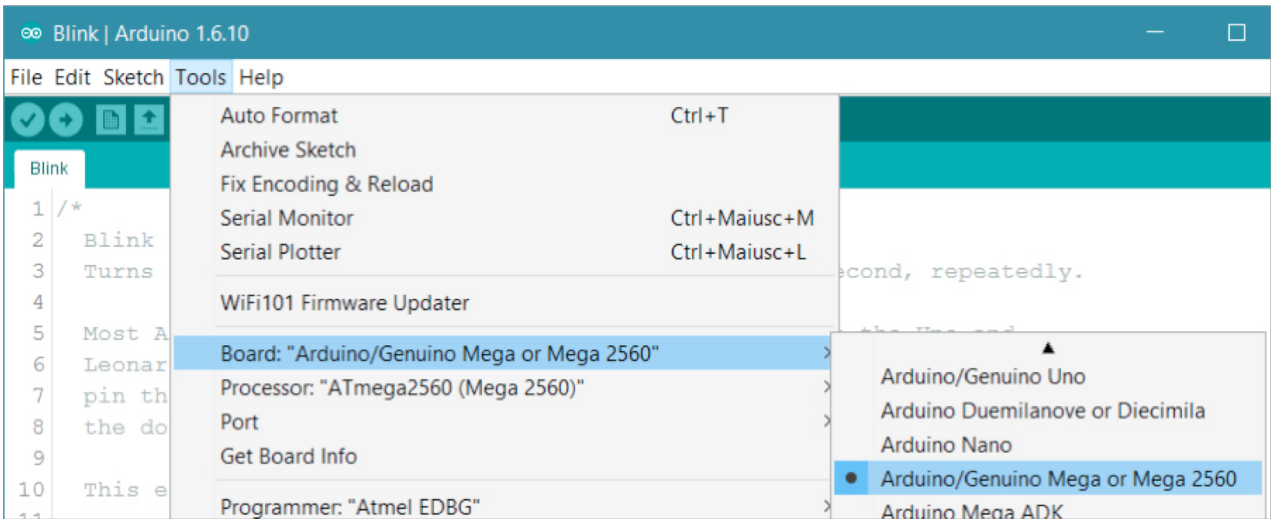
2.2 Open your first sketch and test

Open the LED blink example sketch: File > Examples >01.Basics > Blink.

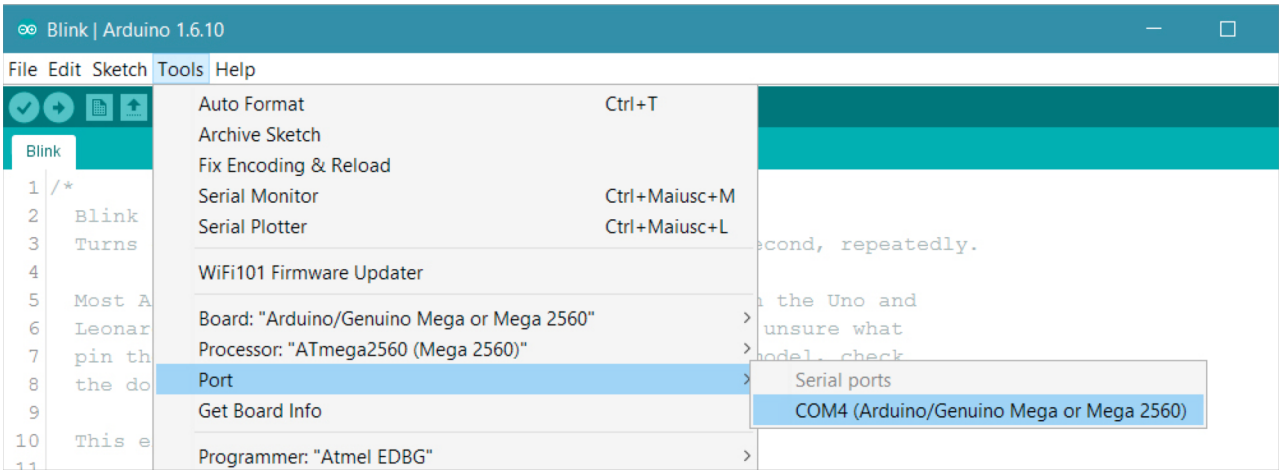


2.3 Select your board type and port

You'll need to select the entry in the Tools > Board menu that corresponds to your Arduino or Genuino board. You have a Mega2560, therefore it has an ATmega2560 microcontroller, selected by default as processor.

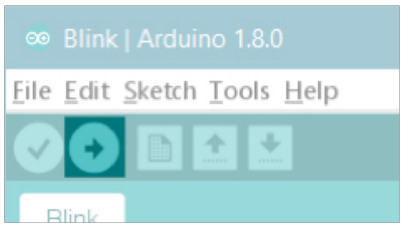


Select the serial device of the board from the Tools | Serial Port menu. This is likely to be COM3 or higher (COM1 and COM2 are usually reserved for hardware serial ports). To find out, you can disconnect your board and re-open the menu; the entry that disappears should be the Arduino or Genuino board. Reconnect the board and select that serial port.



2.4 Upload the program

Now, simply click the "Upload" button in the environment. Wait a few seconds - you should see the RX and TX leds on the board flashing. If the upload is successful, the message "Done uploading." will appear in the status bar.



2.5 Run code

A few seconds after the upload finishes, you should see the pin 13 (L) LED on the board start to blink (in orange). If it does, congratulations! Your board is up-and-running.

1.Open file:

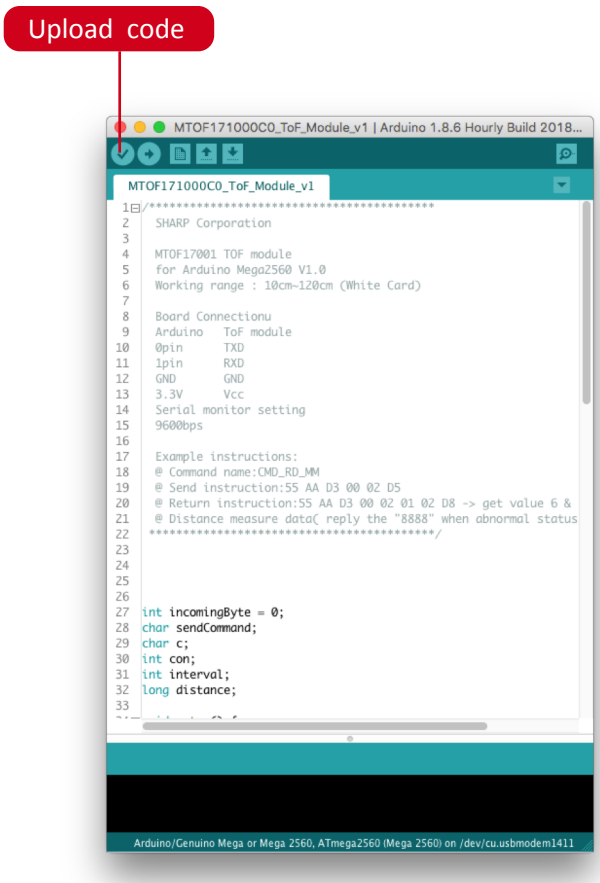
Folder path:

Arduino -> MTOF17001_ToF_Modulexxxx -> MTOF17001_ToF_Modulexxxx.ino

*red xxx is version

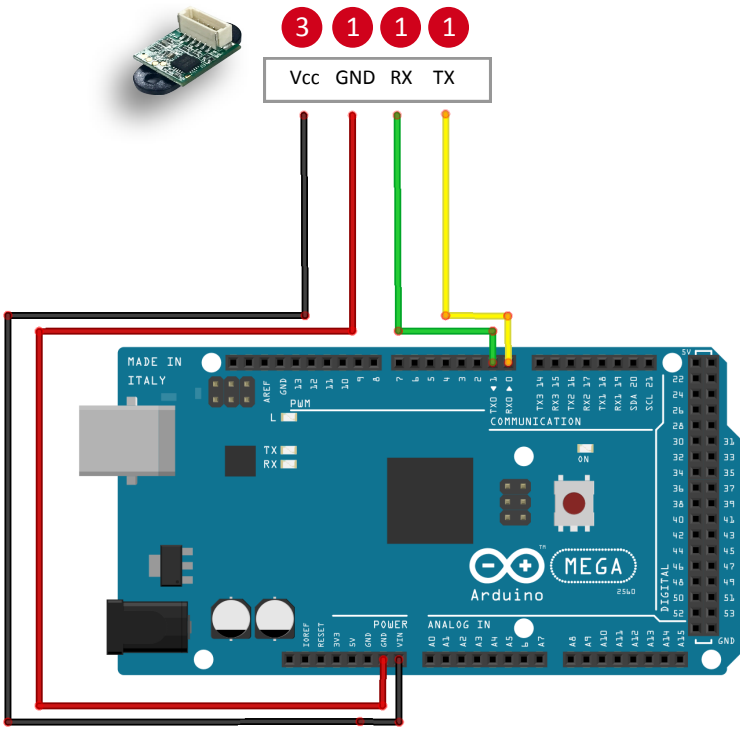
2.Connect Arduino

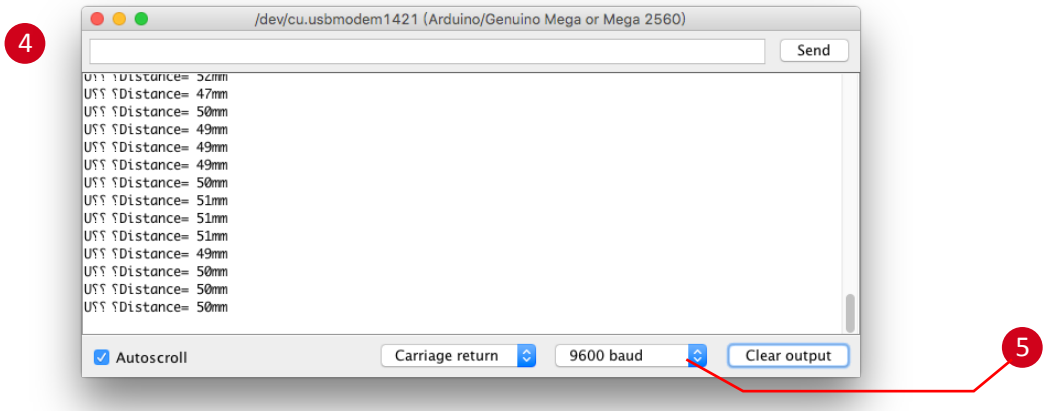
3.Upload the code



4.2.Connect sensor to Arduino

1. Connect Tx(Sensor) to Rx(Arduino), Connect Rx(Sensor) to Tx(Arduino), Gnd
2. Open serial window
3. Connect Vcc
4. Data show in serial window
5. Set Baud rate to 9600 and you can see the data



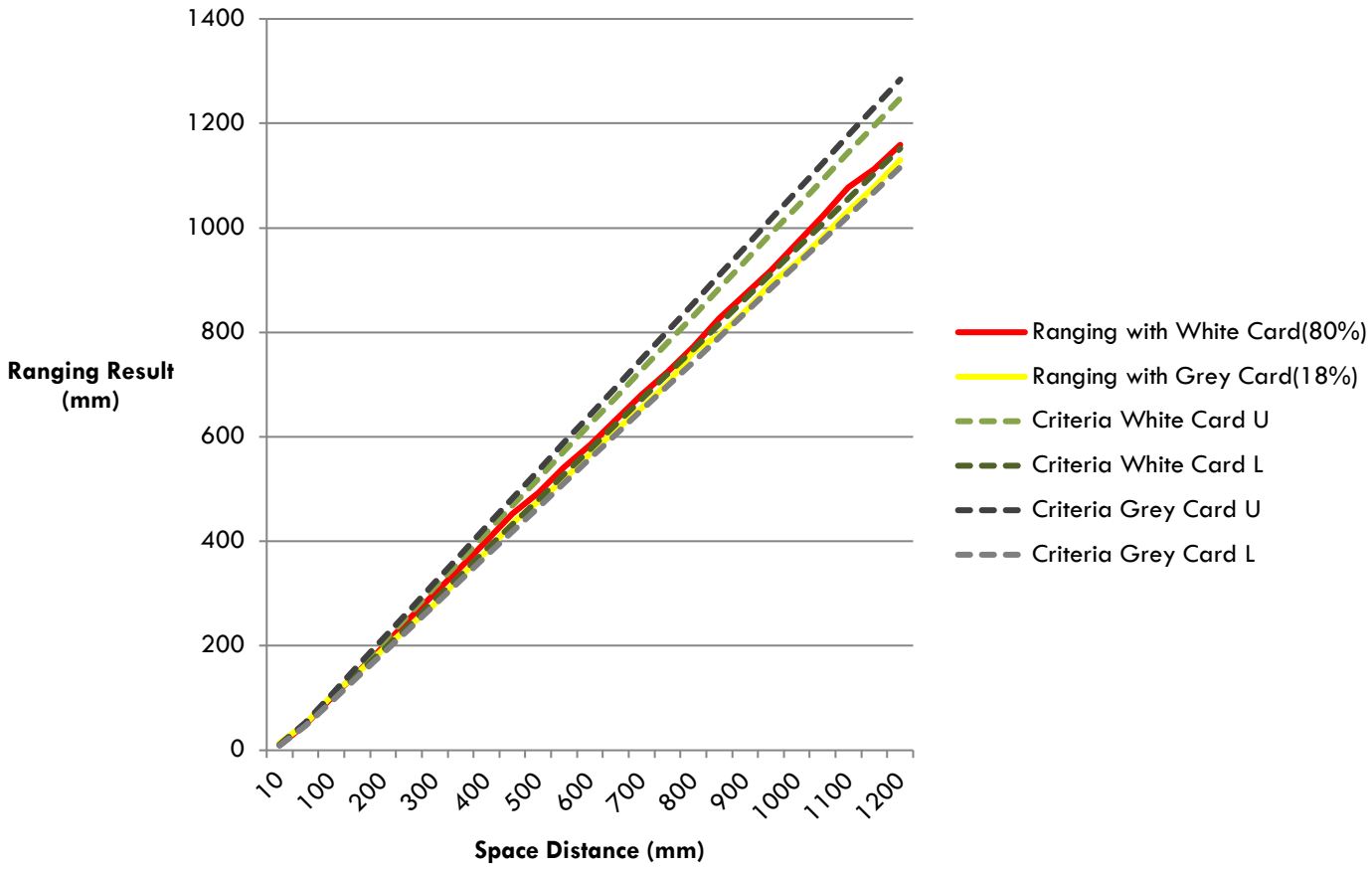


5 Performance Description 性能描述

5.1 Accuracy Result 精確度結果

Condition Description:
(1) test in the dark room
(2) read data with single trigger, and take 10 times average value for each distance

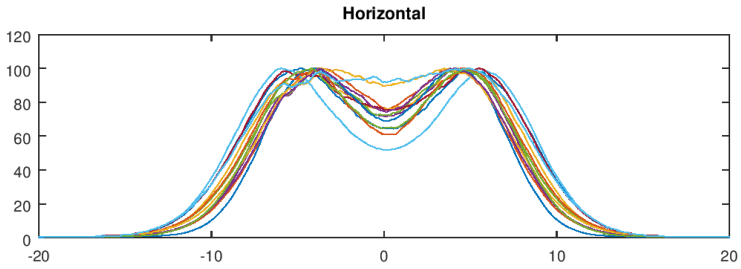
條件描述：
(1)於暗房中
(2)以單筆trigger做資料讀取，每個距離測10次取平均值

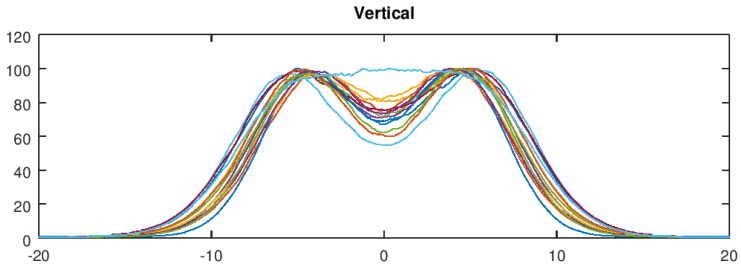


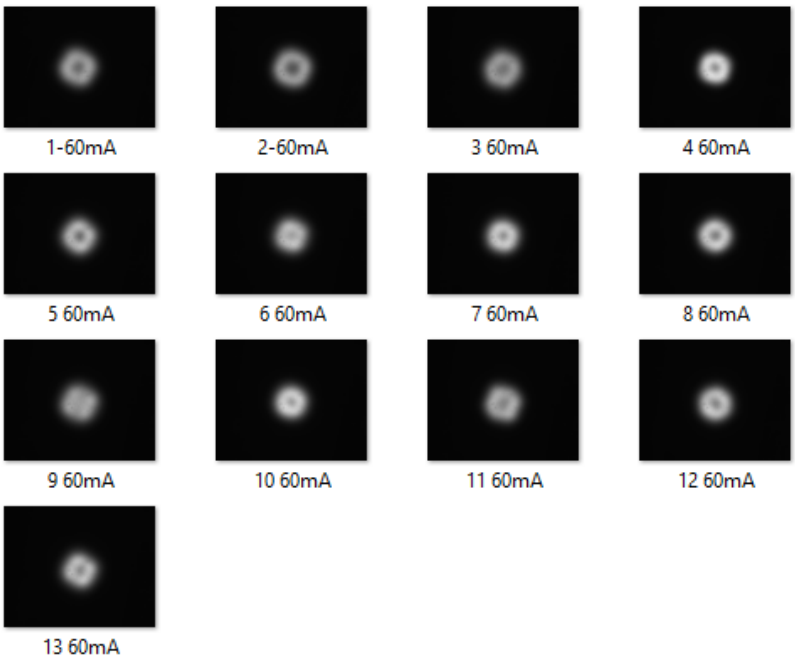
5.2 VCSEL Ray light field 激光光場

Condition Description:
(1)test in the dark room
(2)Catch the data by Infrared Energy Detection Camera (FLIR CM275)
(3)read data with single trigger, and take 10 times average value for part

條件描述：
(1)於暗房中
(2)以Infrared Energy Detection Camera (FLIR CM275)擷取
(3)以單筆trigger做資料讀取，每個模組測10次取平均







	MIN	MAX	
FOV 1/e^2	15	25	degree
DIP	0	35	%

Ray field SPEC

5.3 Angle impact of distance detection 角度對距離影響

With the same reflectivity condition, it is possible that there is a distance error on the location of the object, and the correlation error is as follows. The base object at the distance 800mm with 80% surface reflection.
在同樣反射率條件下，有可能因為物件所在位置而有距離上的誤差，相關誤差值如下, 測試物基準為 800mm, 80% 反射率.

6 Revision History 版本更新

Version	Modification	Date
V1.311	1st version release	2018/07/30
V1.335	Modify the Serial instruction	2018/08/17

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