NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2022-2023

MA2012 - INTRODUCTION TO MECHATRONICS SYSTEMS DESIGN

November/December 2022 Time: 2 hours

INSTRUCTIONS:

1. This paper contains **FOUR (4)** questions and comprises of **TEN (10)** pages including **SIX (6)** pages of Appendices.
2. Answer **ALL** questions.
3. All questions carries equal marks.
4. This is a **CLOSED-BOOK** examination.

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1. Arduino UNO MCUs are used in the following scenarios.

(a) Sketch an interfacing circuit for each of the following digital sensors, as shown in Figure 1. You may use any pin of the MCU for interfacing.
   (i) Toggle Switch in an Active High configuration
   (ii) Slotted Opto Switch in an Active Low configuration
   (iii)Slotted Opto Switch in an Active High configuration

(9 marks)

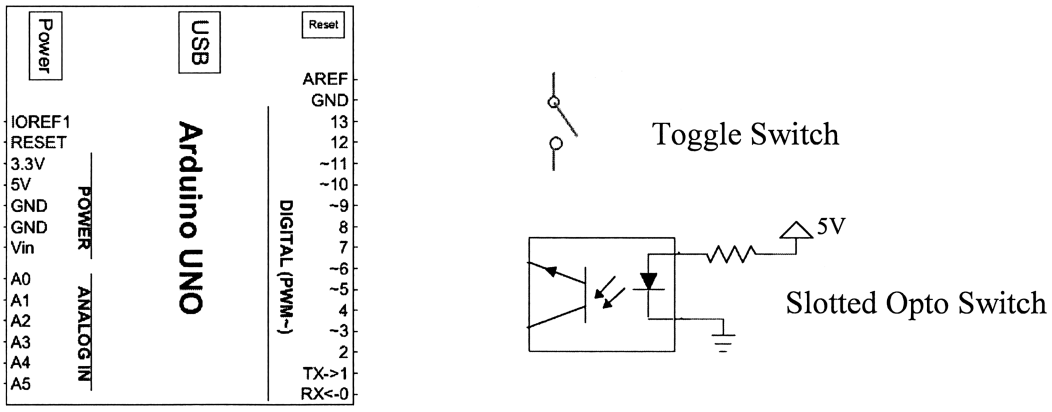


Figure 1 Interfacing Circuits with Digital Sensors

(b) Sketch an interfacing circuit for each of the following actuators, as shown in Figure 2. You may use any pin of the MCU for interfacing.
   (i) Solenoid
   (ii) Servomotor

(8 marks)

Note: Question 1 continues on page 2.
Figure 2 appears on page 2.

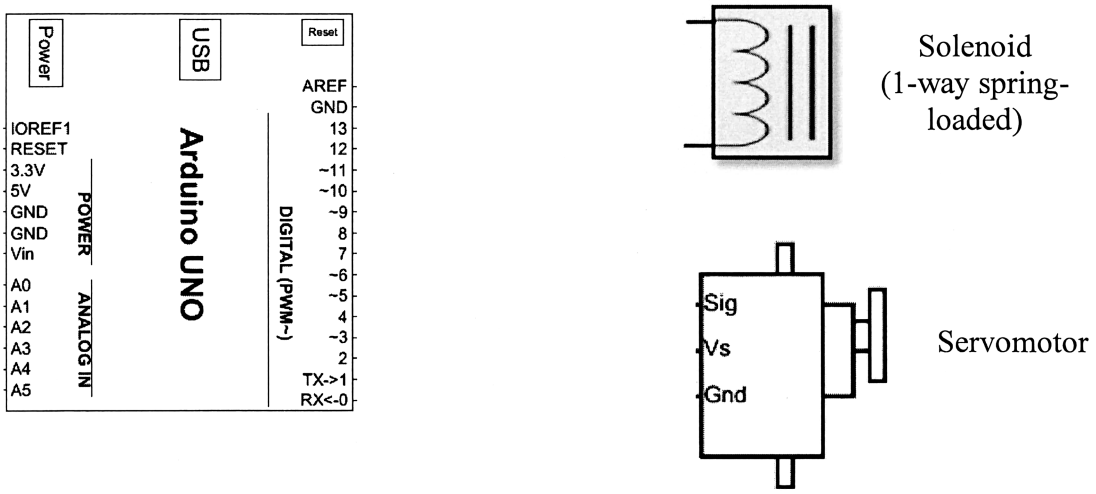


Figure 2 Interfacing Circuits with Actuator

(c) State TWO advantages of using a driver in an interfacing circuit to control an actuator.
(4 marks)

(d) Why is a driver not needed in the interfacing circuits for the above solenoid and servomotor? Give one reason each for solenoid and servomotor.
(4 marks)

2. A factory has two types of pressured chambers, Positive Pressure Chambers (differential pressure = 2.5 kPa when compared with a normal room) and Negative Pressure Chambers (differential pressure = –2.5 kPa). A pressure sensing device is to be developed to monitor the pressure of a chamber. The key component of the pressure measuring device is a XGZP6847 Pressure Sensor Module (datasheet is provided in Appendix A). The Pressure Sensor Module is powered by a 5 VDC source and is interfaced with an Arduino UNO MCU for measurement data acquisition.

(a) Sketch a circuit to interface the Pressure Sensor Module with an Arduino UNO MCU.
(6 marks)

(b) To save cost, it is desirable to develop one type of pressure sensing device to be used in both types of pressured chamber. Which models of the Pressure Sensor Module are suitable for this application? Explain your answer.
(4 marks)

(c) Among the models chosen in part (b), if you must maximize the device's sensing resolution, which one would you choose? Explain your answer.
(3 marks)

(d) The datasheet states that the offset and span changes linearly with the operating temperature at 0.03% of Full Scale per °C. During operation, if the temperature rises 30°C above the starting temperature, how will the sensing resolution of the device be affected? Explain your answer.
(5 marks)

Note: Question 2 continues on page 3.

(e) It is critical to maintain the pressure level in the pressured rooms to be within ±10% of the desired level. This criterion on sensing accuracy supersedes the cost consideration to go with only one type of sensor model. Which models of the Pressure Sensor Module would satisfy this new criterion for monitoring the pressure of the Positive and Negative Pressure Chambers? Explain your answer and show your calculation.

(7 marks)

3. An Arduino UNO MCU takes in reading from a network of 5 temperature sensors and shows the temperature readings in 5 displays. Each display is an array of 5 LEDs connected with the MCU serially via Software UARTs that requires 1 Tx and 1 Rx pins.

(a) The temperature sensors can be interfaced in either I2C or SPI serial communication protocol. Which protocol is more appropriate? Explain your answer.

(4 marks)

(b) Each temperature sensor has a measurement range of 0-50°C and it stores the reading in a 1-byte register within the sensor. The serial protocol of the sensor transmits the temperature reading to the MCU in a LSB First format. If the sensed temperature is 32°C, what is the data, in binary, that the MCU would receive?

(4 marks)

(c) The MCU sends a packet of data to the display in the following format:

1 Start bit (LOW), 5 data bits, 2 Stop bits (HIGH)

Determine the content of a transmitted packet from MCU to a display for a sensed temperature of 34°C, given the following display formats:

(i) If temperature is
- 0-5°C, all LEDs OFF;
- 6-15°C, LED 1 ON;
- 16-25°C, LEDs 1-2 ON;
- 26-35°C, LEDs 1-3 ON;
- 36-45°C, LEDs 1-4 ON;
- 46-50°C, all LEDs ON.

(4 marks)

(ii) Digital equivalent of temperature in 5-bit format (e.g. 0°C = 00000, 50°C = 11111). LED 1 displays MSB and LED 5 displays LSB.

(6 marks)

(iii) Digital equivalent of differential temperature versus 25°C, e.g. Differential Temperature = Measured Temperature - 25°C.
- LED 1: 0 ≡ Negative and 1 ≡ Positive;
- LED 2-5: Digital equivalent of differential temperature

(7 marks)

4. You are to design the control system of a road-railway junction, as shown in Figure 3.

Use two or more Arduino UNO MCUs to design the system with the following components:

a) Two sets of Red-Amber-Green LED Traffic Lights.
b) Four pairs of Red-Green LED Pedestrian Lights.
c) Four push buttons to activate Pedestrian Lights.
d) A wireless RF communication module that receives signal from sensors 1 km away for incoming train.
e) Four DC motors to lower & raise gantry bars
f) Two alarms to warn cars and pedestrians of incoming train.
g) Two flashing LED lights on top of the gantry pillars to warn cars and pedestrians of incoming train.
h) Two pressure sensors, one in each direction, to detect vehicles beating the red light.

i) Two cameras, one in each direction, to take picture of the rear of the vehicle which beats the red light.

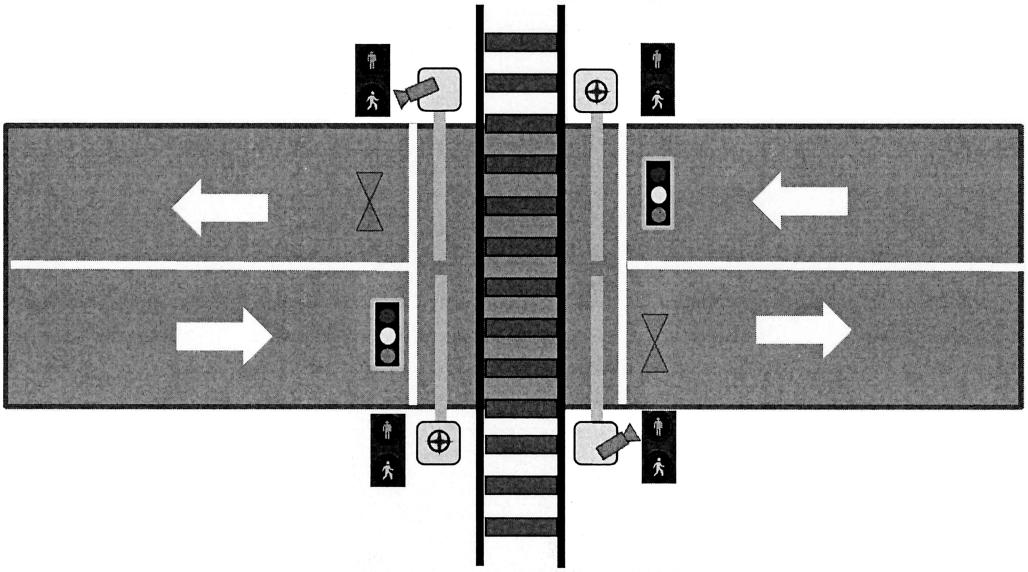


Figure 3 Road-Railway Junction

Sketch a schematic block diagram to show your design of the control systems for this application. Indicate and describe clearly in your diagram all the mechatronic components (Arduino UNO MCU, sensors, actuators, I/O devices, interfacing devices, power sources, etc.) and their relationships to each other. You may make appropriate assumptions to add new components (e.g. switches, drivers, etc.), but you need to state them clearly.

Your answer needs to specify only the component type. Information on the make and model of components are not required.

(25 marks)

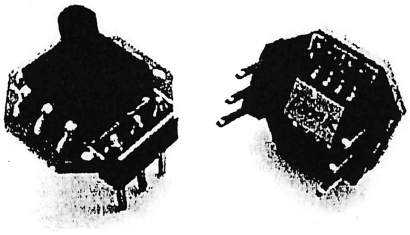
CFSensor

Only for MEMS Silicon Based Piezoresistive Pressure Sensor Solutions from Die to Package

XGZP6847 Pressure Sensor Module

Features

- Ranges: -100kPa～0kPa...1000kPa(-15PSI ~0PSI...150PSI)
- Perfect Accuracy(±1.0%) of full scale
- Gage,Vacuum Type
- For Non-corrosive gas or dry air
- Calibrated,Amplified analog output
- Temp. Compensated:0℃～+85℃(32℉ ~+185℉)
- Direct application,Low Cost.



Applications

■ For Medical equipment field, such as therapy equipment, breathing machine, oxygen generating equipment,monitor,alcohol tester.etc.

■ For Sport and fitness equipment field,such as massage,air spring bed,etc.

■ For Home appliance field, such as washing machine,active oxygen water machine beer machine,coffee machine, etc.

■ For Other fields, such as air pump,emergency lamp, dust collector, HVAC and pneumatic device etc.

Introduction

XGZP6847 is a prefect silicon pressure sensor module offering a ratiometric analog interface for reading pressure over the specified full scale pressure span and temp.range.

The XGZP6847 incorporates a silicon piezoresistive pressure sensor(XGZP SOP6) and an on-board Application Specific Integrated Circuit(ASIC) under PC board in a DIP8 package.

The XGZP6847 is fully calibrated and temperature compensated for offset,sensitivity, temperature and non-linearity,so XGZP6847 pressure sensor module satisfy the prefect repeatability,linearity, stability and sensibility, which can be applied directly in medical equipment, fitness machine,home electronics,and other pneumatic devices etc.

XGZP6847 pressure sensor module is for high volume application at an affordable cost and perfect performance.

Custom calibrations(excitation voltage,output voltage,and pressure range) are available.

Performance Parameter

Unless otherwise specified, measurements were taken with a supply voltage of 5 Vdc at a temperature of 25±1℃ and humidity ranging from 25%~85

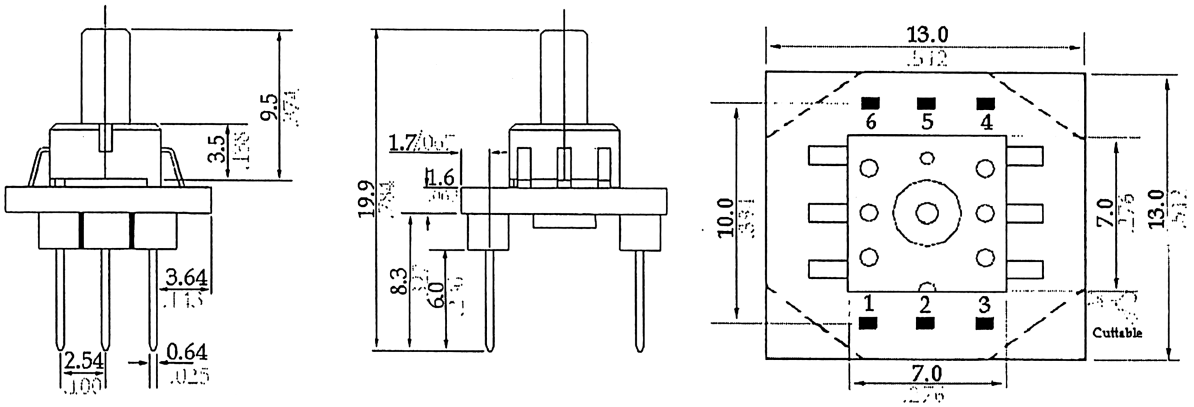
Item	Data	Unit
Output Signal	0.5-4.5	V
Accuracy	±1.0	%Span
TSO(Temp. Coefficient of Offset)	±0.03	%FS/℃
TCS(Temp. Coefficient of Span)	±0.03	%FS/℃
Long Term Stability(1year)	±2	%Span
Over Pressure	2X (≤500kPa)	Rated
	1.5X(≥500kPa)	
Compensation Temp.	0 ~ 85/32 ~ 176	℃/℉
Ambient Temp.	-20 ~ 100/-4 ~ 212	℃/℉
Storage Temp.	-40 ~ 125/-40 ~ 257	℃/℉

Pressure Range (100kPa=0.1MPa=1bar≈14.5PSI)

Pressure Range（kPa）	Model
0 ~ 10	XGZP6847010KPG
0 ~ 20	XGZP6847020KPG
0 ~ 40	XGZP6847040KPG
0 ~ 100	XGZP6847100KPG
0 ~ 200	XGZP6847200KPG
0 ~ 500	XGZP6847500KPG
0 ~ 700	XGZP6847700KPG
0 ~ 1000	XGZP6847001MPG
-100 ~ 0	XGZP6847100KPGN
-30 ~ 0	XGZP6847030KPGN
-20 ~ 0	XGZP6847020KPGN
-40 ~ 40	XGZP6847040KPGPN
-100 ~ 100	XGZP6847100KPGPN

-100 ～ 700	XGZP6847700KPGPN
Available for more custom pressure range	

Dimension (Unit:mm/Inch)



Electric Connection

1	2	3	4	5	6
N/C	Vdd	GND	Vdd	OUT	GND

NOTE:

1,N/C Pins must be left floating

2,Soldering of lead Pins:250'C for 5 sec max.

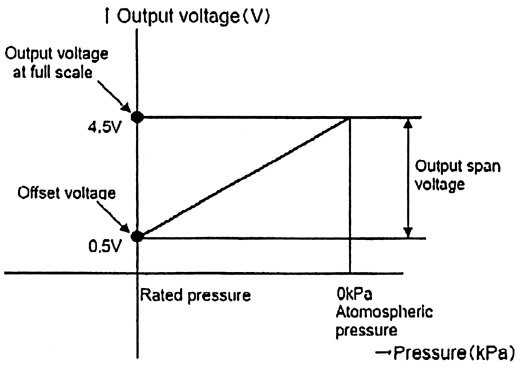
Notes:

1.Attention that the medium should be compatible with the pressure parts.

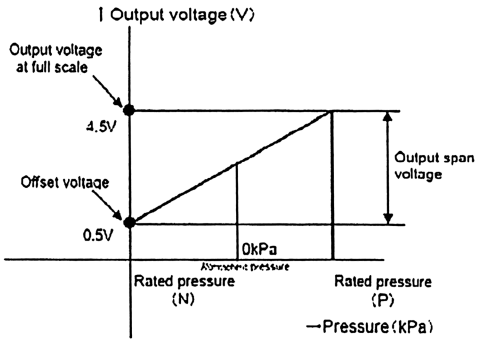
2.Please contact us if special request on parameter and application.

XGZP6847 Output VS.Pressure

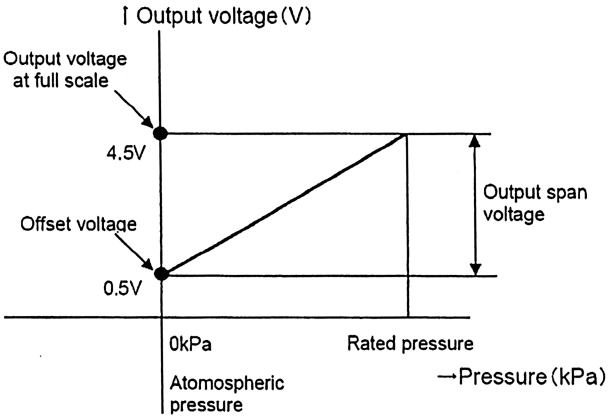
Model	100KPGN	030KPGN	020KPGN
Output(V)	Pressure (kPa)		
0.5	-100	-30	-20
1.5	-75	-22.5	-15
2.5	-50	-15	-10
3.5	-25	-7.5	-5
4.5	0	0	0



Model	040KPGPN	100KPGPN	700KPGPN
Output(V)	Pressure (kPa)		
0.5	-40	-100	-100
1.5	-20	-50	100
2.5	0	0	300
3.5	20	50	500
4.5	40	100	700



Model	010KPG	020KPG	040KPG	100KPG	200KPG	500KPG	700KPG	001MPG
Output (V)	Pressure (kPa)							
0.5	0	0	0	0	0	0	0	0
1.5	2.5	5	10	25	50	125	175	250
2.5	5	10	20	50	100	250	350	500
3.5	7.5	15	30	75	150	375	525	750
4.5	10	20	40	100	200	500	700	1000



Notes:

■ Mounting

Adopting land on the PC board for ensuring the sensor is securely fixed.

■ Soldering

Due to its small size, the thermal capacity of the pressure sensor is low.Therefore, take steps to minimize the effects of external heat.

Damage and changes to characteristics may occur due to heat deformation.

Use a non-corrosive resin type of flux.

Since the pressure sensor is exposed to the atmosphere, do not allow flux to enter inside.

▼ Manual soldering

□Set the soldering tip from 260 to 300°C (30W), and solder for no more than 5 seconds.

□Please note that output may change if the pressure is applied on the terminals when the soldering.

□Thoroughly clean the soldering iron.

▼ SMD soldering

□Please keep the SMD solder bath temperature no higher than 260°C/500°F. When soldering, heat should be applied no longer than five seconds.

□When mounting onto a PCB of low thermal capacity, please avoid SMD soldering as this may cause heat deformity.

▼ Solder reworking

□Finish reworking in one operation.

□For reworking of the solder bridge, use a soldering iron with a flat tip. Please do not add more flux when reworking.

□Please use a soldering iron that is below the temperature given in the specifications in order to maintain the correct temperature at the tip of the soldering iron.

□Too much force on the terminals will cause deformation and loss in effectiveness of the solder. Therefore, please avoid dropping and careless handling of the product.

□Please control warping of the PCB within 0.05 mm of the sensor width.

□When cut folding the PCB after mounting the sensor, take measures to prevent stress to the soldered parts.

□The sensor terminals are designed to be exposed, so contact of the terminals with metal shards and the like will cause output errors. Therefore, please be careful and prevent things such as metal shards and hands from contacting the terminals.

□To prevent degradation of the PCB insulation after soldering, please be careful not to get chemicals on the sensor when coating.

□Please consult us regarding the use of lead-free solder.

■ Cleaning

▼ Since the pressure sensor chip is exposed to the atmosphere, do not allow cleaning fluid to enter inside.

▼ Avoid ultrasonic cleaning since this may cause breaks or disconnections in the wiring.

■ Environment

▼Please avoid using or storing the pressure sensor chip in a place exposed to corrosive gases (such as the gases given off by organic solvents, sulfurous acid gas, hydrogen sulfides, etc.) which will adversely affect the performance of the pressure sensor chip.

▼Since this pressure sensor chip does not have a water-proof construction, please do not use the sensor in a location where it may be sprayed with water, etc.

▼Avoid using the pressure sensors chip in an environment where condensation may form. Furthermore, its output may fluctuate if any moisture adhering to it freezes.

▼The pressure sensor chip is constructed in such a way that its output will fluctuate when it is

exposed to light. Especially when pressure is to be applied by means of a transparent tube, take steps to prevent the pressure sensor chip from being exposed to light.

▼Avoid using the pressure sensor chip where it will be susceptible to ultrasonic or other high-frequency vibration.

■ Quality check under actual loading conditions

To assure reliability, check the sensor under actual loading conditions. Avoid any situation that may adversely affect its performance.

■ Other handling precautions

▼That using the wrong pressure range or mounting method may result in accidents.

▼The only direct pressure medium you can use is dry air. The use of other media, in particular, corrosive gases (organic solvent based gases, sulfurous acid based gases, and hydrogen sulfide based gases, etc.) and media that contains moisture or foreign substances will cause malfunction and damage. Please do not use them.

▼The pressure sensor chip is positioned inside the pressure inlet. Never poke wires or other foreign matter through the pressure inlet since they may damage the chip or block the inlet. Avoid use when the atmospheric pressure inlet is blocked.

▼Use an operating pressure which is within the rated pressure range. Using a pressure beyond this range may cause damage.

▼Since static charge can damage the pressure sensor chip, bear in mind the following handling precautions.

□When storing the pressure sensor chips, use a conductive material to short the pins or wrap the entire chip in aluminum foil. Plastic containers should not be used to store or transport the chips since they readily become charged.

□ When using the pressure sensor chips, all the charged articles on the bench surface and the work personnel should be grounded so that any ambient static will be safely discharged.

▼Based on the pressure involved, give due consideration to the securing of the pressure sensor DIP type and to the securing and selection of the inlet tube.

END OF PAPER

MA2012 INTRODUCTION TO MECHATRONICS SYSTEMS DESIGN

Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.