UNIVERSITY OF OSLO

FACULTY OF MATHEMATICS AND NATURAL SCIENCES

Guide for this written examination

Exam in: FYS4260 Microsystems and Electronic Packaging & Interconnection Technologies

Day of exam: Monday, June 4th, 2012

Exam hours: 09:00 – 12:00 (3 hours)

This examination paper consists of 6 page(s)

Appendices: No appendices

Permitted materials: None except the general allowed aids as for instance approved electronic calculators. For instance, tables and programmed data in calculators not allowed.

Make sure that your copy of this examination paper

is complete before answering.

Additional information:

Course responsible Per Øhlckers might not be present at University of Oslo on exam day but can be reached on cell phone 9590 3989. / Kursansvarlig Per Øhlckers vil kanskje ikke være tilstede på Universitetet i Oslo på eksamensdagen men kan nåes på mobiltelefon 9590 3989.

The test questions are given in Norwegian and English, and can be answered in either Norwegian or English. Use maximum 1 page for each question; that is for the sum of both the a) and the b) answers. Each question is equally weighed when grading the answers / Hvert spørsmål gis både med norsk og engelsk tekst. Besvarelsen kan gis valgfritt på norsk eller engelsk. Bruk maksimum 1 side på hver oppgave, dvs. summert for både a) og b) besvarelsen. Hvert spørsmål vektes likt ved bedømming av svarene.

Question 1: Trends/Wire Bonding/Failure Mode and Effect Analysis

Background information for question a): Figure 1 shows the tear down of the iPhone 3G S, where one can see that the battery is located at the bottom inside of the phone's housing, so that the entire phone must be dismounted to replace the battery. The designers have probably had good reasons for such a design, but the result is that it will be complicated and expensive to replace a defective battery, which is a Li-ion battery that has a typical lifespan of 3-400 charges or about 2 years of normal use. Maybe a bit exaggerated, we can say that the iPhone 3G S is not profitable to repair when the battery is worn out, giving the phone a typical lifetime of 2 years.

Fig 1: Sammenstilling av/Assembly of iPhone 3G S. Fra/From http://www.techspot.com/news/35215-isuppli-apples-iphone-3g-s-costs-179-to-make.html

Fig 2: Batteriskifte/Battery replacement for iPhone 4S. Fra/From http://www.ifixit.com/Guide/Installing-iPhone-4-Battery/3141/1

Additional comment: Battery replacement in the Apple 4S is greatly simplified, as Apple has, in retrospect, realized that this was a structural weakness. See Figure 2.

a. In general we see that more and more electronics products are constructed and manufactured in such a way that it becomes difficult or virtually impossible to repair them, for instance a remote control for a TV cannot be opened for repair because the cabinet parts are glued together, or to replace a defective battery in an Apple iPhone mobile phone is technically complex and expensive. Provide an analysis of this trend towards that electronics products are not repairable or difficult to repair and give 3 other examples of such products that are not designed for easy repair. Also, give an example of a product that is designed to be repair friendly and explain why.

Løsningsforslag:

Especially for consumer electronics with short time-to-market and the relatively high price pressure will favour low production costs with adequate performance over the reliability/life and repair-friendliness. This is often simple products that quickly are replaced with newer models or competing products. In this way the market accepts limited reliability/short life span, while also repairing quickly becomes no longer an option because the product is already out-dated. Etc., etc….. A large variations in possible answers here…… — Here, the student's capability for knowledge-based assessments are evaluated.

Spesielt for forbrukselektronikk med kort tid-til-marked, og relativt høyt prispress prioriteres lave produksjonskostnader med tilstrekkelig ytelse fremfor pålitelighet/levetid og reparasjonsvennlighet.

Dette er ofte enkle produkter som raskt erstattes med nyere modeller eller konkurrerende produkter. På denne måten aksepterer markedet begrenset pålitelighet/kort levetid, samtidig som reparasjon raskt blir uaktuelt fordi produktet blir utdatert. Etc., etc….. Stort spenn i mulige svar – her skal studentens evne til kunnskapsbasert refkesjon evalueres.

b. Describe the two main techniques for wire bonding, and explain how we can test that the wire bonding has been successful, both non-destructive and destructive. Make an FMEA analysis of the wire bonding process for a case in which the wire bonding was not strong enough. Calculate process capability for a wire bonding process where the wire breaking strength is to be between 40 and 70 mN, when the mean value is 51 mN and standard deviation is 5 mN. We assume that the statistical variations are normally distributed. Is this a process that is in control?

Formula help:

$$Cp = \frac{USL - LSL}{6\sigma} \qquad Cpk = \min\left(\frac{USL - \bar{x}}{3\sigma}, \frac{\bar{x} - LSL}{3\sigma}\right)$$

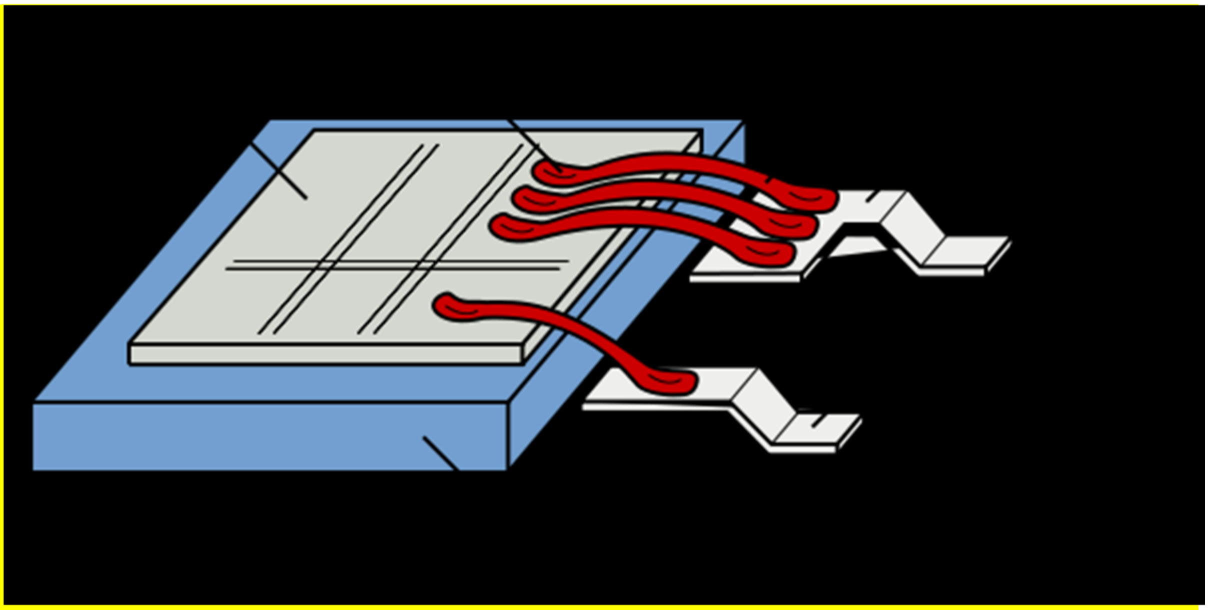
Løsningsforslag:

De to vanligste trådsveiseteknikken er kule – knipe trådsveising og knipe-knipe trådsveising. Se figur 2.6 i læreboka.

Tilleggskommentar: Spørsmålet er litt upresist, så de som svarer ved å angi to av de vanligste fysiske prosessene, dvs ultrasonisk og termokomprosjon, eller kombinasjonsprosessen termosonisk bør også få riktig for det! De som svarer ved å angi bruk av gull eller aluminium tråd, bør til en viss grad også belønnes. Se Ch. 3.3, side 3.40 til side 3.42.

The two most common wire bonding techniques are ball – wedge wire bonding and wedge - wedge wire bonding. See Figure 2.6 in the textbook.

Additional comment: The question is a bit also imprecise, so those who answer by listing two of the most common physical processes, i.e. ultrasonic and thermocompression, or the combination process thermosonic should also get proper acceptance for the answer! Those who answer use of alternatively gold or aluminium wire, should also be given some credit. See Ch. 3.3, page 3.40 to page 3.42.

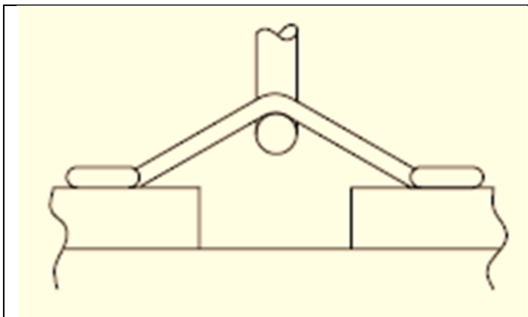


Bilde av kile-kile trådsveising/Graph of wedge-wedge wire bonding.

Bilde av kule trådsveising/Photo of a ball wire bond.

Trådsveising kan testes ved teste bruddstyrken av en trådsveising – se figuren nedenfor.

Wire bonding can be controlled by testing the ultimate strength of a wire bond – see graph below.



Figur: Prinsipp for å måle bruddstyrken av en trådsveising.

Graph: Principle of measurement of ultimate strength of a wire bond.

Beregninger av produksjonsgodhetsindekser: / Calculation of process capability indexes:

Cp = (70–40)/6*5 = 1

Cpk = (51-40)/3*5 = 0,73

Prosessen er ikke kontroll. Prosessen akkurat i kontroll hvis vi greier å sentrere middelverdien, dvs forbedre/øke styrken, men generelt har da prosessen også for stor vilkårlig variasjon også, fordi eksakt sentrering er vanskelig å oppnå

The process is not in control. The process will be just within in control if we manage to properly centre the mean, i.e. improve/increase the strength, but overall, the process also has too large random variation, because exact centering is difficult to achieve.

Oppgave 1: Trender/Trådsveising/Feilmode- og effektanalyse

Bakgrunn for spørsmål a): Figur 1 ovenfor viser sammenstillingen av iPhone 3G S, hvor en kan se at batteriet ligger helt underst i telefonkabinettet, slik at hele telefonen må demonteres for å skifte batteri. Konstruktørene har sikkert hatt gode grunner for en slik design, men resultatet er at det blir komplisert og kostbart å skifte et defekt batteri, som er et Li-ione batteri som har en typisk levetid på 3-400 ladninger eller ca 2 års normal bruk. Satt på spissen kan vi si at iPhone 3G S ikke er lønnsom å reparere når batteriet er utslitt, noe som gir telefonen en typisk levetid på 2 år.

Tilleggskommentar: Batteriskifte i Apple 4S er sterkt forenklet, så Apple har nok i ettertid innsett at dette var en konstruksjonssvakhet. Se figur 2 ovenfor.

a. Generelt ser vi at flere og flere elektronikkprodukter konstrueres og fremstilles på en slik måte at det blir vanskelig eller tilnærmet umulig å reparere, som f.eks. at en fjernkontroll for et TV ikke lar seg åpne for reparasjon fordi dekslet er limt sammen, eller at det å skifte et defekt batteri i en Apple iPhone mobiltelefon er teknisk komplisert og kostbart. Gi en analyse av denne trenden til at elektronikkprodukter er ureparerbare eller vanskelig å reparere, og gi 3 andre eksempler på slike produkter som ikke er konstruert for enkel reparasjon. Gi også et eksempel på et produkt som er konstruert reparasjonsvennlig og begrunn hvorfor.

b. Beskriv de to viktigste teknikkene for trådsveising, og forklar hvordan vi kan teste at trådsveisingen har blitt vellykket, både ikke-destruktivt og destruktivt. Foreta en FMEA-analyse av trådsveiseprosessen for et tilfelle hvor trådsveisingen ikke er sterk nok. Beregn prosessdugeligheten når bruddstyrken skal være mellom 40 og 70 mN, når middelverdien er 51 mN og standardavviket er 5 mN. Vi antar at variasjonene statistisk er normalfordelt. Er dette en prosess som er i kontroll?

Formelhjelp:

$$Cp = \frac{USL - LSL}{6\sigma} \qquad Cpk = \min\left(\frac{USL - \bar{x}}{3\sigma}, \frac{\bar{x} - LSL}{3\sigma}\right)$$

Recommended number of pages for this problem is 1-2 handwritten pages. / Anbefalt omfang på besvarelsen av denne oppgaven er 1-2 håndskrevne sider.

Question 2: Comparison of substrate technologies

a. The choice of assumed best substrate technology for an electronic product involves a consideration of several factors, where the technical characteristics and production costs may be the most important. Set up a comparison table as shown below, and fill in for respectively printed wiring board technology, high temperature thick film technology and flexible circuit board technology.

Characteristics	Printed Circuit Board Technology	High Temperature Thick Film Technology	Flexible Circuit Board Technology
Typical substrate material	FR4 Epoxy-glass	Alumina (Al2O3 + additives like glass)	Polyimide
Typical material for conductor lines	Copper/Plated copper	Copper, gold or alloys of silver-palladium printing	Copper/Plated copper

		pastes.	
Pattern definition technique	Photolithograpics with dry film photoresist and polymer masks	Screen printing, sometimes stencil printing	Usually screen printing. In high volumes, roll to roll screen printing is sometimes used.
Possibility for integrated resistors and capacitors in the substrate (yes/no)	No	Yes	No
Suitability for high-speed operation *= poor **= medium ***= premium	**	** (*** also OK)	*
Typical application area(s)	Generic workhorse technology for most applications:	High temperature/high reliability/medium miniaturisation	Applications with dynamic or static bending
Production costs *= low **= medium ***= high	*	**	*

Table 1. Comparison table for substrate technologies. /

b. Based upon the findings in the above table, explain which technology would be a good choice for the electronics for the space sonde “Rosetta”, which is a research space sonde made by the European Space Agency (ESA). It was launched on March 2nd, 2004 with an “Atlas 5G” Payload Rocket from Kourou in Guyane Française, to observe the asteroids “Steins” (passed the Earth in 2008) and “Lutetia” (2010). A picture of the sonde shown to the left below, with a polar projection image of the “Lutetia” asteroide to the right.

Fig 3: A picture of the space sonde “Rosetta” sonde / Et bilde av romsonden “Rosetta”

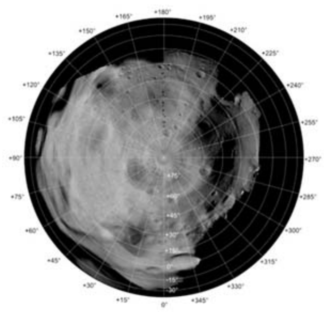


Fig 4: Polar projection image of “Lutetia” / Polarprojeksjon av “Lutetia”

Suggested answer:

High temperature thick film technology with its high packaging density and corresponding low weight, high temperature range, high thermal conductivity, acceleration/vibration robustness, high life time and high reliability would be a good choice among the 3 technologies mentioned in Q.2.a. In addition, speed capability could sometimes be needed.

Oppgave 2: Sammenligning av substratteknologier

a. Å velge beste substratteknologi for et elektronikkprodukt er en avveiing av flere forhold. Tekniske egenskaper og produksjonskostnader er kanskje de viktigste. Lag en sammenlikningstabell som vist under og fyll inn for hhv rigide kretskort teknologi, høytemperatur tykkfilmteknologi og fleksible kretskort teknologi.

Egenskaper	Rigide kretskort-teknologi	Høytemperatur tykkfilmteknologi	Fleksible kretskort-Teknologi
Typisk substratmateriale			
Typisk materiale for lederbaner			
Mønsterdefinisjons-teknikk			
Mulighet for å integrere motstander og kondensatorer i kretskortet (ja/nei)			
Egnethet for høyhastighetsoperasjon *= dårlig **= middels ***= godt			
Typisk(e) anvendelsesområde(r)			
Produksjonskostnad *= lav **= middels ***= høy			

Tabell 1. Sammenligningstabell for substrat-teknologier.

b. Basert på tabellen over, begrunn hvilken teknologi som ville være naturlig å velge for elektronikk til romsonden "Rosetta", som er en forskningsromsonde laget av den europeiske romfartsorganisasjonen ESA. Den ble skutt opp 2. mars 2004 med en "Atlas 5G" bærerakett fra Kourou i Guyane Française for observere asteroidene "Steins" (passerte jorden i 2008) og Lutetia (2010). Sonden til venstre i figur 1 overfor, til høyre en polarprojeksjon av asteroiden"Lutetia".

Recommended number of pages for this problem is 1-2 handwritten pages. / Anbefalt omfang på besvarelsen av denne oppgaven er 1-2 håndskrevne sider.

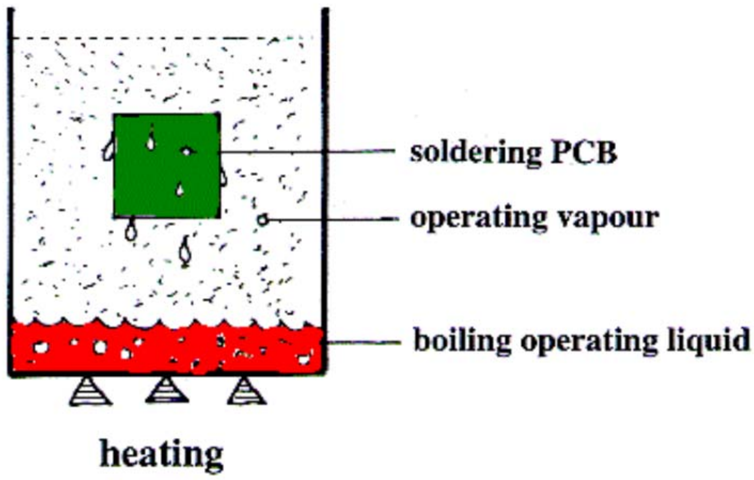
Question 3: Reflow soldering

a) Explain the basics principles of vapour phase soldering for reflow soldering in surface mount technology for assembly of printed circuit boards. This is best done by combining text and graphical presentations.

Suggested answer:

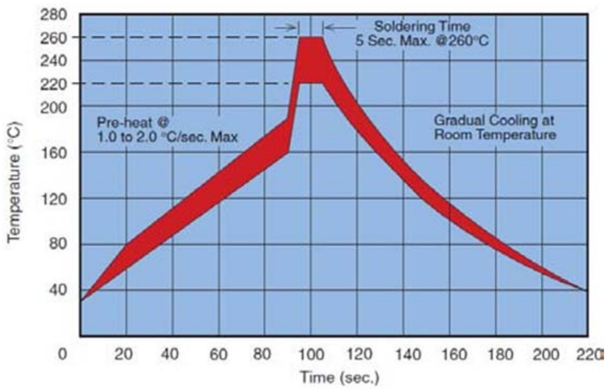
From: http://www.adauto.co.uk/VPOverview.pdf:

The principle of Vapour Phase or Condensation soldering, involves immersing a populated PCB into a vapour, which has been created by a liquid with a specific boiling point. In the case of leadfree alloys, which generally have melting points of 217º or 221ºC, fluid used would typically have a boiling point of 230ºC. The heat of the PCB and components, when immersed in the vapour, can never exceed the boiling point of the liquid; this completely eliminates any risk of overheating. Any fluid residue on the PCB evaporates; the PCB cools prior to exiting the machine. Working with an assured maximum temperature of just 230ºC for lead free alloys provides the least possible risk of any damage to boards or components.



(Figure from: www2.fz-juelich.de/zel/datapool/page/160/SMDPART2.pdf

A typical temperature profile:



Heat transfer to the PCB is accomplished almost irrespective of the shape, colour and thermal mass involved. For example, it is possible to solder such disparate items as a 0.5 mm thick PCB and an 18-layer board simultaneously. Both will get sufficient heat for soldering but neither will overheat. The Delta T will always be less than 5ºC. Using VP reflow the physically defined and unchangeable heat transfer of the condensing vapour means that there are no variations in the process as long as the physical properties remain the same. This ensures consistent repeatability and reproducibility; the only requirement is the presence of vapour

See also Ch. 7.3.2, page 7.19 to 7.23:

b) Set up a table with alternative methods for reflow soldering in surface mount technology for assembly of printed circuit boards, where vapour phase soldering is one of the alternative methods. Make a comparison list in the table with 2 advantages and 2 disadvantages for each soldering method. Specifically, explain why vapour phase soldering is not in widespread industrial use, but mostly used for laboratory prototyping work like your own surface mount technology project.

Suggested answer:

The question could favourably stipulate that 3 or methods should be given. Some students listed wave soldering as one method, which is wrong, beacause it is not a reflow soldering process.

See 7.3.2, page 7.13 to 7.23:

Oppgave 3: Omsmelte lodding

a) Forklar basisprinsippene for dampfaselodding brukt ved omsmeltelodding ved montasje av overflatemontasje teknologi kretskort. Dette gjøres best ved å kombinere bruk av tekst og grafiske presentasjoner.

b) Lag en tabell med alternative metoder for omsmeltelodding i overflatemontasje-teknologi for montasje av kretskort, hvor dampfaselodding er en av de alternative metodene. Lag en sammenligningsliste i tabellen hvor 2 fortrinn og 2 ulemper for hver loddemetode settes opp. Forklar spesielt hvorfor dampfaselodding ikke er i omfattende industrielt bruk, men benyttes mest for laboratoribasert prototypefremstilling, slik ditt eget overflatemontasje-teknologi prosjekt.

Recommended number of pages for this problem is 1-2 handwritten pages. / Anbefalt omfang på besvarelsen av denne oppgaven er 1-2 håndskrevne sider.

Question 4: Micromachined devices and packages

SYMBOLS	DIMENSIONS IN MILLIMETERS		
	MIN	NOM	MAX
A	0.85	0.90	0.95
A1	0.00	0.02	0.05
b	0.18	0.25	0.30
c	---	0.20 REF	---
D	3.90	4.00	4.10
D2	2.65	2.70	2.75
E	3.90	4.00	4.10
E2	2.55	2.60	2.65
e	---	0.50	---
f (e-b)	---	0.25	---
K	0.25	0.30	0.35
L	0.30	0.35	0.40
L1	0.35	0.40	0.45

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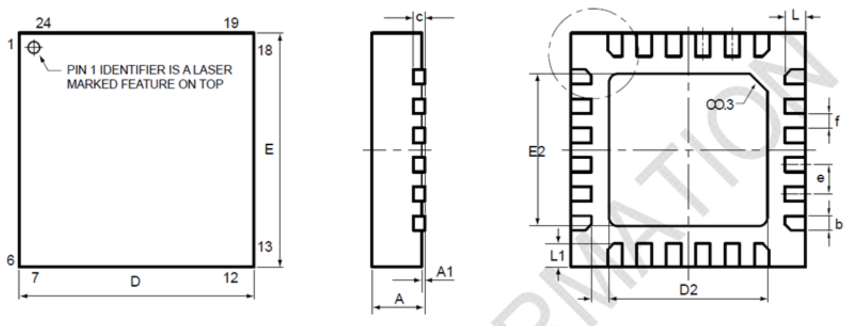

Fig 5: From the datasheet of The MPU-6000 from InvenSense is a 6-axis MotionTracking Device (Inertia Measurement Unit - IMU)

a. The MPU-6000 from InvenSense is a 6-axis MotionTracking Device (Inertia Measurement Unit - IMU) designed for the low power, low cost, and high performance requirements of smartphones, tablets and wearable sensors. Pictures from the data sheet are shown above in figure 5. What kind of package is used for this MEMS-sensor? Propose two different methods which could be used for electrical and mechanical bonding this sensor to a PCB substrate. The lead material is NiPdAu (nickel-palladium-gold).

Suggested answer:

See Ch.4.5.3: This is a LLCC; LeadLess Chip Carrier. Alternative electrical and mechanical bonding of this sensor to a PCB substrate:

1. Reflow soldering. See Ch. 7.3.2, page 7.13 to 7.19.
2. Socket mounting for easy replacement.
3. Gluing with isotropic conductive adhesive. Refer to ppt on adhesives.
4. Gluing with anisotropic conductive adhesive. Refer to ppt on adhesives.
5. Thermode or impulse soldering. See Ch. 7.3.2, page 7.23 to 7.25.

b. When using such MEMS IMU components in plastic packages, PCB mounting and assembly can cause package stress. This package stress in turn can affect the output offset and its value over a wide range of temperatures. What causes this stress? How can it be reduced or avoided?

Suggested answer:

Here, a subjective assessment can be given. Some suggestion:

1. Thermal stress due to thermal mismatch due to different coefficients of expansion for the package and the PCB, both because of temperature variations, thermal cycling and temperature increases due to power dissipations. Can be minimised by better matching of coefficients of thermal expanions, for instance with metal core printed wiring board. Also dissipation power generated temperature differences can be minimised by better thermal conductance or better heat removal, for instance with forced air cooling.
2. Also external forces on the PCB assembly can set up stresses in the package leading to stress induced errors. This can be minimised with more rigid assembly or stress isolation designed into the PCB, the package, or the chip itself.

Oppgave 4. Mikromaskinerte komponenter og pakke/innkapsling

a. MPU-6000 fra InvenSense er en 6-akse bevegelsessensor (Treghets Måle Enhet - TME) designet for bruk i produkter med krav til lav effekt, lav kost og høy ytelse som smarttelefoner, lesebrett og sensorer i klær. Figur 5 over er hentent fra databladet. Hva for pakke/innkapsling er benyttet for denne MEMS-sensoren? Foreslå to forskjellige metoder som kan benyttes for elektrisk og mekanisk bonde denne sensoren til et mønsterkort. Komponentens ben er av NiPdAu (nikkel-palladium-gull).

b. Når slike MEMS TME'er settes inn i en plast kapsel, kan sammenstilling og lodding på mønsterkort forårsake pakkestress. Dette pakkestresset kan igjen innvirke på utgangssignalets offset og dets verdi over et større temperaturområde. Hva forårsaker dette stresset? Hvordan kan dette reduseres eller unngås?

Anbefalt omfang på besvarelsen av denne oppgaven er 1-2 håndskrevne sider./ *Recommended number of pages for this problem is 1-2 handwritten pages.*

----- End / Slutt-----