POLITECNICO DI TORINO
ESAMI DI STATO PER L'ABILITAZIONE ALLA PROFESSIONE DI INGEGNERE DELL'INFORMAZIONE

I Sessione 2015 - Sezione A

Settore dell'Informazione

Prova pratica del 22 luglio 2015

Il candidato svolga uno a scelta fra i seguenti temi proposti.
Gli elaborati prodotti dovranno essere stilati in forma chiara e ordinata. L'ordine e la chiarezza espositiva costituiranno elementi di valutazione.

Tema n. 1

Il freezing detto anche acinesia paradossa, congelamento o più semplicemente blocco motorio è un disturbo che insorge nel corso dell'evoluzione della malattia di Parkinson di cui costituisce un sintomo indipendente generalmente resistente alla terapia con levodopa.

Il freezing è definito come brusca e repentina incapacità di movimenti volontari. Questo fenomeno può verificarsi all'inizio o nel corso della marcia, nell'attraversare passaggi stretti o nei cambiamenti di direzione.

La stimolazione uditiva ritmica (RAS) è stata introdotta come strumento di assistenza per il freezing. La RAS consiste in un ticchettio ritmico che viene attivato al rilevamento di un episodio di freezing tramite accelerometri. Questa tecnica permette di aiutare il paziente a proseguire o riprendere un'andatura costante. Il solo uso di accelerometri ha però mostrato limiti per predire un evento di freezing. La latenza di rilevamento (decimi di secondi nel migliore dei casi) non consente di evitare completamente l'evento di freezing.

Risultati in letteratura hanno mostrato alterazioni dei segnali EEG, EMG, ECG e della reazione vincolare al terreno durante l'analisi del cammino prima di un evento di freezing. Sulla base di tali risultati si vuole sviluppare un sistema indossabile multimodale per la predizione e prevenzione di eventi di freezing.

Il candidato
1. Progetti e descriva la struttura complessiva del sistema
2. Sulla base delle scelte progettuali effettuate discutere la classificazione del dispositivo medico e gli aspetti normativi.
3. Selezioni due delle grandezze elettrofisiologiche/meccaniche acquisite dal sistema definito al punto 1 e descriva i dettagli dei sottosistemi per l'acquisizione di questi segnali (trasduttore, sue caratteristiche, banda passante, frequenza di campionamento etc)
4. Selezioni un sottosistema del punto 2 e per questo progetti la catena di condizionamento ed amplificazione a livello di schema elettrico (amplificatore da strumentazione, condizionamento mediante filtri, filtro anti-aliasing ecc....).

Tema n. 2

Si consideri un motore a corrente continua alimentato da un amplificatore di potenza ideale PWM (Pulse Width Modulation) che pone in rotazione un carico inerziale tramite un riduttore di velocità, secondo lo schema di Figura 1.

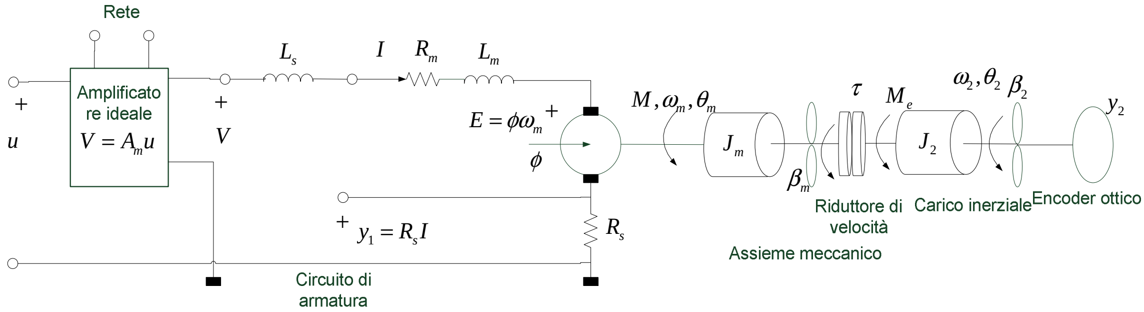

Figura 1: schema elettromeccanico.

Il riduttore di velocità è affetto da un'elasticità torsionale (non in Figura) tale che la coppia M_e trasmessa al carico si esprime come $M_e = K\left(\theta_m / \tau - \theta_2\right)$. Si parli di riduttore ideale se si trascura tale elasticità e di riduttore reale altrimenti.

Le variabili in Figura 1 sono le seguenti. Corrente del motore I, tensione di comando u, tensione di alimentazione V, forza controelettromotrice E, velocità e posizione angolare dell'albero motore ω_m, θ_m, velocità e posizione angolare del carico ω_2, θ_2, coppia motrice M, coppia di uscita del riduttore M_e, misura di corrente y_1 (in tensione), misura di posizione angolare y_2 (in radianti) fornita da un encoder ottico.

Il valore nominale dei parametri sia il seguente.

$$A_m = 15, R_m = 1\Omega, R_s = 0.5\Omega, L_m = 0.5mH, L_s = 2mH, \phi = 0.2\,\mathrm{Wb}$$

$$J_m = 0.001kgm^2, \beta_m = 0.001Nms, \tau = 150, K = 100000Nm/rad, J_2 = 22.5kgm^2, \beta_2 = 11.25Nms$$

Alcune variabili siano limitate: $|u| \le u_{\max} = 5V, |I| \le I_{\max} = 10A, |\theta_2| \le \theta_{\max} = \pi$ rad

Il sistema di controllo sia gerarchico con un anello interno (regolatore PI) che regoli la corrente del motore ed un anello esterno (regolatore PID) che asservisca y_2 ad un riferimento r e abbia come uscita il riferimento I_r del regolatore di corrente. Gli algoritmi di controllo e i loro guadagni siano progettati dapprima a tempo continuo, siano poi convertiti in tempo discreto assumendo per semplicità un'unica frequenza di campionamento $f_c = 5$ kHz.

Il tema deve essere sviluppato in tre passi: A) modellistica, B) regolatore di corrente e C) asservimento di posizione.

Passo A): modellistica

1) Si riporti lo schema a blocchi nella variabile s (trasformata di Laplace) dell'assieme elettromeccanico di Figura 1, ponendo in evidenza ingressi e uscite.
2) Si calcolino in forma simbolica le funzioni di trasferimento (FDT): a) $P_1(s)$ tra tensione di comando u e corrente I assumendo che il riduttore sia ideale, b) $P_{2,ideale}(s)$ tra corrente I e angolo θ_2 assumendo riduttore ideale e forza controelettromotrice nulla $(E = 0)$.
3) Si calcolino i poli di entrambe le FDT di cui al punto 2) in modo simbolico e numerico, si riportino i risultati in apposita tabella.

4) Si tracci il diagramma di Bode in modulo, su carta logaritmica allegata, della FDT $P_{2,reale}(s) = \theta_2 / I$ nel caso di riduttore reale, che, sempre ponendo $E = 0$, si scrive come

$$P_{2,reale} = P_{2,ideale} \frac{1}{s^2/\omega_r^2 + 2\zeta_r s/\omega_r + 1}, \omega_r = \sqrt{K\left(J_2^{-1} + \left(J_m \tau^2\right)^{-1}\right)}, \zeta_r = 0.075$$

Passo B) Regolatore PI di corrente, requisiti e vincoli.

1) Requisiti di accuratezza e prontezza. Il regolatore di corrente in risposta ad un riferimento di corrente I_r ad onda quadra a valor medio zero con periodo $P_r \geq 50ms$ deve garantire che dopo ogni cambio di segno del riferimento la corrente misurata y_1 / R_s ripeta il riferimento entro il 4% del valore di picco con un ritardo di 5 ms, come in Figura 2.
2) Il riferimento di corrente deve rispettare $|I_r| \leq I_{\max}$ e il regolatore deve rispettare $|u| \leq u_{\max}$ per la classe dei riferimenti di cui al punto 1.

Metodo e risultati del progetto

1) Si scriva in forma simbolica la funzione di trasferimento del regolatore PI progettato, si indichi e si sviluppi un metodo per il calcolo dei guadagni che consenta di rispettare requisiti e vincoli di cui ai punti precedenti, si riportino i valori e le unità di misura dei guadagni in apposita tabella. Il metodo deve fare riferimento alla FDT $P_1(s) = I(s)/u(s)$ calcolata al passo A. Se necessario si traccino i diagrammi di Bode in modulo su carta logaritmica allegata. Si verifichi numericamente che il contributo di E alla misura di corrente y_1 / R_s rispetti i requisiti.
2) Si converta il regolatore PI a tempo discreto tramite equazioni di stato, scrivendole in modo simbolico. Si riportino i valori dei guadagni e le loro unità di misura in un'apposita tabella. Si assuma la frequenza di campionamento f_c di cui sopra.
3) Si riporti lo schema a blocchi simbolico del regolatore PI discreto che riceve in ingresso la misura digitale di corrente e il riferimento di corrente (non digitale) e fornisca in uscita il comando digitale.
4) Si dimostri che nel caso ideale in cui valga $I = I_r$ (errore d'inseguimento nullo) e nell'ipotesi di riduttore ideale, la FDT $P_2(s) = \theta_2 / I_r$ è uguale a $P_{2,ideale}(s)$.
5) Si proponga il numero di bit μ_u di DAC (Digital to Analogue Converter) e μ_1 di ADC (Analogue to Digital Converter). Si riportino i valori insieme con i livelli di quantizzazione in apposita tabella.
6) Si proponga e si dimostri la minima frequenza di commutazione f_a dell'amplificatore di potenza PWM.

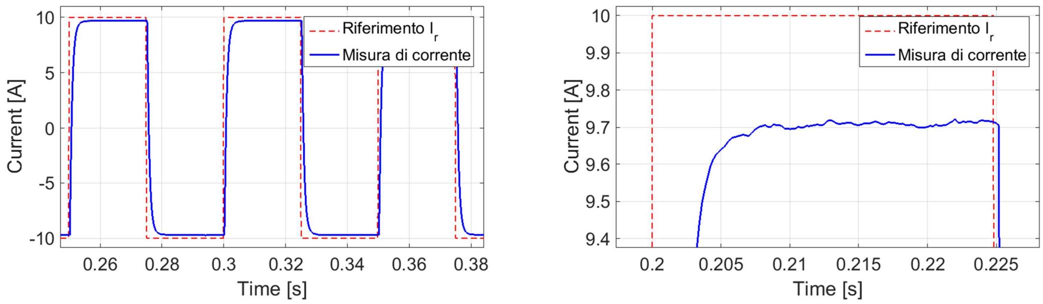

Figura 2. Sinistra: riferimento e corrente misurata. Destra: raggiungimento del requisito

Passo C. Asservimento PID di posizione. Requisiti e vincoli.

1) Classe di riferimento a): riferimento sinusoidale $r(t) = r_0(1 - \cos(2\pi t / P_r))$ con $|r_0| \leq \theta_{\max}$ e $P_r \geq 5s$. Il ritardo temporale τ_r a regime tra y_2 ed r deve essere $\tau_r \leq 0.3s$ e l'attenuazione picco-picco deve essere inferiore all'1% come in Figura 3.
2) Classe di riferimento b): riferimento ad onda quadra $|r(t)| < 0.1$ rad, $P_r \geq 10s$. La misura y_2 deve ripetere il riferimento con un errore inferiore al 2% del valore di picco entro 1 s dal cambio di segno come in Figura 4.
3) L'asservimento deve rispettare $|I| \leq I_{\max}$ e $|u| \leq u_{\max}$ per le classi dei riferimenti di cui ai punti precedenti.

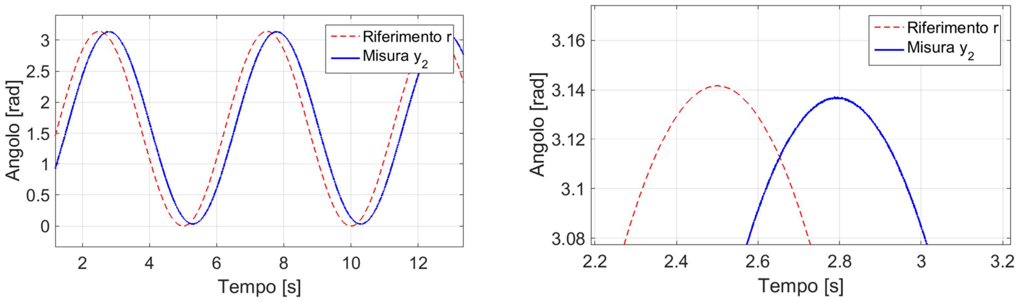

Figura 3 Risposta a riferimento sinusoidale.

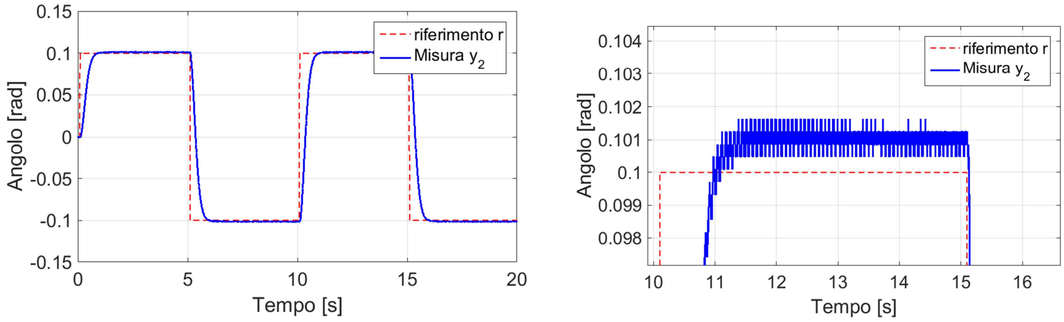

Figura 4 Risposta a riferimento ad onda quadra.

Metodo e risultati del progetto

1) Si scriva in forma simbolica la funzione di trasferimento del regolatore PID progettato, si indichi e si sviluppi un metodo per il calcolo dei guadagni che consenta di rispettare requisiti e vincoli di cui ai punti precedenti, si riportino i valori e le unità di misura dei guadagni in un'apposita tabella. Il metodo deve fare riferimento a entrambe le FDT $P_{2,ideale}(s)=\theta_2(s)/I(s)$ e $P_{2,\mathrm{reale}}(s)=\theta_2(s)/I(s)$ calcolate al passo A. Se necessario si traccino i diagrammi di Bode in modulo su carta logaritmica allegata. Si ponga attenzione al fatto che la coppia di poli complessi in $P_{2,\mathrm{reale}}(s)$ possa rendere instabile l'anello chiuso. A tale scopo si garantisca che la funzione di anello $G_2(s)=P_{2,reale}(s)F(s)$ essendo $F(s)$ la FDT della retroazione PID, abbia un sufficiente margine di guadagno η_m il cui valore sia dimostrato dal candidato in forma simbolica e numerica.
2) Si converta il regolatore PID nella forma a tempo discreto tramite equazioni di stato, scrivendole in modo simbolico. Si riportino i valori dei guadagni e le loro unità di misura in un'apposita tabella. Si assuma la frequenza di campionamento di cui sopra.
3) Si riporti lo schema a blocchi simbolico del regolatore PID discreto che riceva in ingresso la misura digitale di posizione angolare e il riferimento di posizione (digitale) e fornisca in uscita il riferimento di corrente (non digitale).
4) Si proponga un'espressione simbolica per calcolare la massima corrente $I_{r,\max}$ richiesta da entrambe le classi di riferimento di cui sopra. Tramite essa si calcolino sia il periodo P_r della classe a) sia l'ampiezza $r_{\max}$ della classe b) che richiedono $I_{r,\max}=I_{\max}$.
5) Si proponga un'espressione simbolica per calcolare il valore massimo $M_{e,\max}$ della coppia M_e trasmessa dal riduttore reale, e con tale espressione si calcoli $M_{e,\max}$ per i riferimenti di entrambe le classi a e b. Si verifiche che valga $M_{e,\max}\le 150Nm$.
6) Si proponga e si dimostri il numero di bit μ_2 dell'encoder ottico.

Allegati: tre fogli di carta logaritmica

Custom Graph™

Tema n. 3

Il candidato consideri un canale di comunicazione ad antenne multiple in cui sono presenti n_T antenne di trasmissione e n_R antenne di ricezione (detto "canale MIMO" – *multiple input multiple output*). Il modello tempo-discreto di questo canale è caratterizzato dal seguente sistema di equazioni lineari:

$$y_i = \sum_{j=1}^{n_T} H_{ij} x_j + z_i\,, \quad i = 1, \dots, n_R$$

In queste equazioni, x_j rappresenta il simbolo trasmesso dalla j-esima antenna di trasmissione, H_{ij} rappresenta il guadagno tra la j-esima antenna di trasmissione e la i-esima antenna di ricezione, z_i rappresenta la componente di rumore all'i-esima antenna di ricezione e y_i rappresenta il campione di segnale ricevuto campionato all'uscita del demodulatore dell'i-esima antenna di ricezione.

Le equazioni precedenti possono essere scritte in forma matriciale nel modo seguente:

$$\boldsymbol{y} = \boldsymbol{Hx} + \boldsymbol{z}$$

In questa equazione, $\boldsymbol{x} = \left(x_1, \dots, x_{n_T}\right)^T$, $\boldsymbol{y} = \left(y_1, \dots, y_{n_R}\right)^T$, $\boldsymbol{z} = \left(z_1, \dots, z_{n_R}\right)^T$ e $\boldsymbol{H} = \left(H_{ij}\right)_{i=1,j=1}^{n_R,n_T}$ è la *matrice di canale,* con n_R righe e n_T colonne.

Assumiamo inoltre che le componenti del vettore di rumore, z_i, siano variabili casuali indipendenti, gaussiane complesse a valor medio nullo con simmetria circolare e varianza unitaria (in altri termini, se $z_i = z_{i,R} + \mathrm{j}\, z_{i,I}$, allora $z_{i,R}$ e $z_{i,I}$ sono variabili casuali reali gaussiane indipendenti a valor medio nullo e con varianza uguale a $\frac{1}{2}$).

1. Supponendo che il vettore $\boldsymbol{x}$ sia a valor medio nullo e che $\boldsymbol{Q_x} = E[\boldsymbol{xx}^H]$ sia la matrice di covarianza del segnale, si indichi la capacità di Shannon del canale MIMO con matrice di canale $\boldsymbol{H}$ nota esattamente al ricevitore. Si discuta il significato e la rilevanza di questa ipotesi (matrice di canale $\boldsymbol{H}$ nota al ricevitore) ai fini della realizzazione del ricevitore. Si dica inoltre quali sono le caratteristiche generali della matrice di covarianza.
2. Assumendo un vincolo sulla potenza media del segnale trasmesso da tutte le antenne del trasmettitore del tipo $E\left[||\boldsymbol{x}||^2\right] \leq P$,descrivere in modo <u>dettagliato</u> la procedura di calcolo della capacità del canale basata sul metodo detto di *waterfilling* dopo avere applicato le opportune trasformazioni alla matrice di canale.
3. Supponendo che $n_T = n_R = 3$ e che i valori singolari della matrice $\boldsymbol{H}$ siano $(1.5, 0.9, 0.3)$, calcolare la capacità di canale per potenze P variabili da 0 a 5 con passo 0.25. Per ogni valore di P indicare il rango della matrice ottima di covarianza $\boldsymbol{Q_x}$. Giustificare correttamente i vari passaggi e le ipotesi fatte.
4. Indicare il valore massimo di potenza P per cui la tecnica detta di *beamforming* consente di raggiungere la capacità di canale.
5. Calcolare la potenza P minima richiesta per raggiungere una efficienza spettrale di 4 bit/s/Hz.
6. Calcolare la capacità di canale con allocazione uniforme e indipendente di potenza in corrispondenza al valore numerico di potenza ottenuto al passo precedente.
7. Discutere dettagliatamente i requisiti di disponibilità dell'informazione di stato del canale (la matrice $\boldsymbol{H}$) al trasmettitore e/o al ricevitore in funzione dell'ottimizzazione della capacità spiegando quando questa sia possibile e cosa fare in assenza di tale informazione.

Tema n. 4

Progettare un sistema di acquisizione dati da un insieme di 3 sensori piezoelettrici di forza orientati secondo i tre assi coordinati di un sistema di riferimento. Ad ogni sensore è associato un canale di acquisizione. Le specifiche di ogni sensore sono fornite in allegato.

Il sistema deve interfacciarsi con un sistema a microcontrollore responsabile per il calcolo della forza risultante espressa in coordinate sferiche rispetto all'origine degli assi. Le comunicazioni tra il microcontrollore ed il sistema di acquisizione avvengono attraverso porte di comunicazione digitali parallele.

Le specifiche del sistema di acquisizione dati sono:

- Valore dell'accelerazione di ogni singolo canale espresso come intero con segno su 14 bit e con fondo scala corrispondente a 30 m/s^2. L'errore massimo deve essere inferiore a 2 LSB.

- Curva di risposta in frequenza di ogni singolo canale di tipo passabanda massimamente piatta con frequenza di taglio inferiore a 3 dB pari a 20 Hz e frequenza di taglio superiore a 3 dB di 1 kHz con attenuazione minima di 23 dB alla frequenza di 2 kHz.

- Campionamento sincrono dei tre canali. Il segnale di campionamento è fornito dal microcontrollore e la frequenza dello stesso è compresa tra 4 kHz e 8 kHz.

- Alimentazione da batteria da 24 V

Progettare:

- Lo schema a blocchi dettagliato dell'intero sistema indicando tutti i segnali di comunicazione tra i vari blocchi e verso il controllore ed il protocollo di comunicazione tra il sistema di acquisizione ed il microcontrollore. Per ogni blocco funzionale non specificamente progettato devono essere fornite le specifiche dettagliate.

- In dettaglio:

    - Il sistema di alimentazione di ciascun sensore secondo le specifiche fornite nel datasheet dello stesso

    - L'amplificatore di condizionamento di ciascun sensore.

    - La routine che deve venire eseguita dal microcontrollore per ottenere l'espressione della forza risultante a partire dai dati dei tre accelerometri. (Può venire scritta nel linguaggio di programmazione che il candidato desidera. Nel caso di linguaggio C si ipotizzi la disponibilità della libreria <math.h>.

In allegato è fornito il datasheet dei sensori da utilizzare, tabelle per la progettazione di filtri e il datasheet aggiuntivo di un diodo regolatore di corrente.

1.4.5 Data for low pass filter design

The following tables allow the design of lowpass filters with order from 2 to 10 of the Bessel, Butterworth, Chebyshev 1 dB and Chebyshev 0.5 dB types.

n.	cella 1		cella 2		cella 3		cella 4		cella 5	
poli	Q	f_0	Q	f_0	Q	f_0	Q	f_0	Q	f_0
2	0.577	1.732								
3	I ord.	2.322	0.691	2.542						
4	0.522	3.023	0.806	3.389						
5	I ord.	3.647	0.564	3.778	0.917	4.261				
6	0.510	4.336	0.611	4.567	1.023	5.149				
7	I ord.	4.972	0.532	5.066	0.661	5.379	1.126	6.050		
8	0.506	5.655	0.560	5.825	0.711	6.210	1.226	6.959		
9	I ord.	6.297	0.520	6.371	0.589	6.607	0.760	7.056	1.322	7.877
10	0.504	6.976	0.538	7.112	0.620	7.405	0.810	7.914	1.415	8.800

Table 1.1: Bessel filters, normalized for a unit phase delay at $f = 1$

n.	cella 1		cella 2		cella 3		cella 4		cella 5	
poli	Q	f_0	Q	f_0	Q	f_0	Q	f_0	Q	f_0
2	0.7071	1.0000								
3	I ordine	1.0000	1.0000	1.0000						
4	0.5412	1.0000	1.3066	1.0000						
5	I ordine	1.0000	0.6180	1.0000	1.6180	1.0000				
6	0.5176	1.0000	0.7071	1.0000	1.9319	1.0000				
7	I ordine	1.0000	0.5550	1.0000	0.8019	1.0000	2.2470	1.0000		
8	0.5098	1.0000	0.6013	1.0000	0.9000	1.0000	2.5629	1.0000		
9	I ordine	1.0000	0.5321	1.0000	0.6527	1.0000	1.0000	1.0000	2.8794	1.0000
10	0.5037	1.0000	0.5612	1.0000	0.7071	1.0000	1.1013	1.0000	3.1962	1.0000

Table 1.2: Butterworth filters, normalized for a $-3dB$ attenuation at $f = 1$

n.	cella 1		cella 2		cella 3		cella 4		cella 5	
poli	Q	f_0	Q	f_0	Q	f_0	Q	f_0	Q	f_0
2	0.9565	1.0500								
3	I ordine	0.4942	2.0177	0.9971						
4	0.7845	0.5286	3.5590	0.9932						
5	I ordine	0.2895	1.3988	0.6552	5.5565	0.9941				
6	0.7609	0.3531	2.1980	0.7468	8.0037	0.9954				
7	I ordine	0.2054	2.6169	0.4801	3.1559	0.8084	10.8987	0.9963		
8	0.7530	0.2651	1.9564	0.5838	4.2661	0.8506	14.2406	0.9971		
9	I ordine	0.1593	1.2600	0.3773	5.5266	0.6622	5.5266	0.8806	18.0287	0.9976
10	0.7495	0.2121	1.8645	0.4761	3.5605	0.7215	6.9367	0.9025	22.2628	0.9980

Table 1.3: Chebyshev filters with $1dB$ ripple in pass band normalized for a corner frequency $f = 1$

1N5283 THRU 1N5314

SILICON CURRENT LIMITING DIODES

DO-35 CASE

Central Semiconductor Corp.

www.centralsemi.com

DESCRIPTION:

The CENTRAL SEMICONDUCTOR 1N5283 series types are silicon field effect current regulator diodes designed for applications requiring a constant current over a wide voltage range. These devices are manufactured in the cost effective DO-35 double plug case which provides many benefits to the user, including space savings and improved thermal characteristics. Special selections of I_P (regulator current) are available for critical applications.

FEATURES:

- High Reliability
- Special Selections Available
- Superior Lot To Lot Consistency
- Surface Mount Devices Available

MAXIMUM RATINGS: (T_L=75°C)	**SYMBOL**		**UNITS**
Peak Operating Voltage	P_{OV}	100	V
Power Dissipation	P_D	600	mW
Operating and Storage Junction Temperature	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS: (T_A=25°C)

Type	Regulator Current (Note 1) I_P @ V_T=25V			Minimum Dynamic Impedance Z_T @ V_T=25V	Minimum Knee Impedance Z_K @ V_K=6.0V	Maximum Limiting Voltage V_L @ I_L=0.8 x I_P MIN
	MIN mA	NOM mA	MAX mA	MΩ	MΩ	V
1N5283	0.187	0.22	0.253	25	2.75	1.0
1N5284	0.204	0.24	0.276	19	2.35	1.0
1N5285	0.230	0.27	0.311	14	1.95	1.0
1N5286	0.255	0.30	0.345	9.0	1.60	1.0
1N5287	0.281	0.33	0.380	6.6	1.35	1.0
1N5288	0.332	0.39	0.449	4.1	1.00	1.05
1N5289	0.366	0.43	0.495	3.3	0.87	1.05
1N5290	0.400	0.47	0.541	2.7	0.75	1.05
1N5291	0.476	0.56	0.644	1.90	0.56	1.10
1N5292	0.527	0.62	0.713	1.55	0.47	1.13
1N5293	0.578	0.68	0.782	1.35	0.40	1.15
1N5294	0.638	0.75	0.863	1.15	0.335	1.20
1N5295	0.697	0.82	0.943	1.00	0.29	1.25
1N5296	0.774	0.91	1.05	0.88	0.24	1.29
1N5297	0.850	1.00	1.15	0.80	0.205	1.35
1N5298	0.935	1.10	1.27	0.70	0.18	1.40

Notes: (1) Pulsed Method: Pulse Width (ms) = 27.5 divided by I_P NOM (mA)

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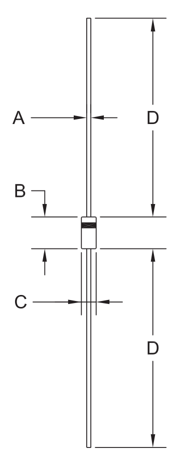
SILICON CURRENT LIMITING DIODES

ELECTRICAL CHARACTERISTICS - Continued: (T_A=25°C)

Type	Regulator Current (Note 1) I_P @ V_T=25V			Minimum Dynamic Impedance Z_T @ V_T=25V	Minimum Knee Impedance Z_K @ V_K=6.0V	Maximum Limiting Voltage V_L @ I_L=0.8 x I_P MIN
	MIN mA	NOM mA	MAX mA	MΩ	MΩ	V
1N5299	1.02	1.20	1.38	0.640	0.155	1.45
1N5300	1.11	1.30	1.50	0.580	0.135	1.50
1N5301	1.19	1.40	1.61	0.540	0.115	1.55
1N5302	1.28	1.50	1.73	0.510	0.105	1.60
1N5303	1.36	1.60	1.84	0.475	0.092	1.65
1N5304	1.53	1.80	2.07	0.420	0.074	1.75
1N5305	1.70	2.00	2.30	0.395	0.061	1.85
1N5306	1.87	2.20	2.53	0.370	0.052	1.95
1N5307	2.04	2.40	2.76	0.345	0.044	2.00
1N5308	2.30	2.70	3.11	0.320	0.035	2.15
1N5309	2.55	3.00	3.45	0.300	0.029	2.25
1N5310	2.81	3.30	3.80	0.280	0.024	2.35
1N5311	3.06	3.60	4.14	0.265	0.020	2.50
1N5312	3.32	3.90	4.49	0.255	0.017	2.60
1N5313	3.66	4.30	4.95	0.245	0.014	2.75
1N5314	4.00	4.70	5.41	0.235	0.012	2.90

DO-35 CASE - MECHANICAL OUTLINE



R1

DIMENSIONS				
	INCHES		MILLIMETERS	
SYMBOL	MIN	MAX	MIN	MAX
A	0.018	0.022	0.46	0.56
B	0.120	0.200	3.05	5.08
C	0.060	0.090	1.52	2.29
D	1.000	-	25.40	-

DO-35 (REV: R1)

R4 (7-February 2013)

Model M352C68

High sensitivity, miniature (2 gm), ceramic shear ICP® accel., 100 mV/g, 0.5

Installation and Operating Manual

For assistance with the operation of this product,
contact PCB Piezotronics, Inc.

Toll-free: 800-828-8840
24-hour SensorLine: 716-684-0001
Fax: 716-684-0987
E-mail: info@pcb.com
Web: www.pcb.com

Warranty, Service, Repair, and Return Policies and Instructions

The information contained in this document supersedes all similar information that may be found elsewhere in this manual.

Total Customer Satisfaction – PCB Piezotronics guarantees Total Customer Satisfaction. If, at any time, for any reason, you are not completely satisfied with any PCB product, PCB will repair, replace, or exchange it at no charge. You may also choose to have your purchase price refunded in lieu of the repair, replacement, or exchange of the product.

Service – Due to the sophisticated nature of the sensors and associated instrumentation provided by PCB Piezotronics, user servicing or repair is not recommended and, if attempted, may void the factory warranty. Routine maintenance, such as the cleaning of electrical connectors, housings, and mounting surfaces with solutions and techniques that will not harm the physical material of construction, is acceptable. Caution should be observed to insure that liquids are not permitted to migrate into devices that are not hermetically sealed. Such devices should only be wiped with a dampened cloth and never submerged or have liquids poured upon them.

Repair – In the event that equipment becomes damaged or ceases to operate, arrangements should be made to return the equipment to PCB Piezotronics for repair. User servicing or repair is not recommended and, if attempted, may void the factory warranty.

Calibration – Routine calibration of sensors and associated instrumentation is recommended as this helps build confidence in measurement accuracy and acquired data. Equipment calibration cycles are typically established by the users own quality regimen. When in doubt about a calibration cycle, a good “rule of thumb” is to recalibrate on an annual basis. It is also good practice to recalibrate after exposure to any severe temperature extreme, shock, load, or other environmental influence, or prior to any critical test.

PCB Piezotronics maintains an ISO-9001 certified metrology laboratory and offers calibration services, which are accredited by A2LA to ISO/IEC 17025, with full traceablility to N.I.S.T. In addition to the normally supplied calibration, special testing is also available, such as: sensitivity at elevated or cryogenic temperatures, phase response, extended high or low frequency response, extended range, leak testing, hydrostatic pressure testing, and others. For information on standard recalibration services or special testing, contact your local PCB Piezotronics distributor, sales representative, or factory customer service representative.

Returning Equipment – *Following these procedures will insure that your returned materials are handled in the most expedient manner*. Before returning any equipment to PCB Piezotronics, contact your local distributor, sales representative, or factory customer service representative to obtain a Return

Materials Authorization (RMA) Number. This RMA number should be clearly marked on the outside of all package(s) and on the packing list(s) accompanying the shipment. A detailed account of the nature of the problem(s) being experienced with the equipment should also be included inside the package(s) containing any returned materials.

A Purchase Order, included with the returned materials, will expedite the turn-around of serviced equipment. It is recommended to include authorization on the Purchase Order for PCB to proceed with any repairs, as long as they do not exceed 50% of the replacement cost of the returned item(s). PCB will provide a price quotation or replacement recommendation for any item whose repair costs would exceed 50% of replacement cost, or any item that is not economically feasible to repair. For routine calibration services, the Purchase Order should include authorization to proceed and return at current pricing, which can be obtained from a factory customer service representative.

Warranty – All equipment and repair services provided by PCB Piezotronics, Inc. are covered by a limited warranty against defective material and workmanship for a period of one year from date of original purchase. Contact PCB for a complete statement of our warranty. Expendable items, such as batteries and mounting hardware, are not covered by warranty. Mechanical damage to equipment due to improper use is not covered by warranty. Electronic circuitry failure caused by the introduction of unregulated or improper excitation power or electrostatic discharge is not covered by warranty.

Contact Information – International customers should direct all inquiries to their local distributor or sales office. A complete list of distributors and offices can be found at www.pcb.com. Customers within the United States may contact their local sales representative or a factory customer service representative. A complete list of sales representatives can be found at www.pcb.com. Toll-free telephone numbers for a factory customer service representative, in the division responsible for this product, can be found on the title page at the front of this manual. Our ship to address and general contact numbers are:

PCB Piezotronics, Inc.
3425 Walden Ave.
Depew, NY 14043 USA
Toll-free: (800) 828-8840
24-hour SensorLine℠: (716) 684-0001
Website: www.pcb.com
E-mail: info@pcb.com

General
OPERATING GUIDE

for use with

PIEZOELECTRIC ICP® ACCELEROMETERS

SPECIFICATION SHEET, INSTALLATION DRAWING
AND CALIBRATION INFORMATION ENCLOSED

PCB ASSUMES NO RESPONSIBILITY FOR DAMAGE CAUSED TO THIS PRODUCT AS A RESULT OF PROCEDURES THAT ARE INCONSISTENT WITH THIS OPERATING GUIDE.

1.0 INTRODUCTION

Congratulations on the purchase of a quality, ICP® acceleration sensor. In order to ensure the highest level of performance for this product, it is imperative that you properly familiarize yourself with the correct mounting and installation techniques before attempting to operate this device. If, after reading this manual, you have any additional questions concerning this sensor or its application, feel free to call a factory Application Engineer at 716-684-0001 or your nearest PCB sales representative.

2.0 ICP® ACCELEROMETERS

Powered by simple, inexpensive, constant-current signal conditioners, these sensors are easy to operate and interface with signal analysis, data acquisition and recording instruments. The following features further characterize ICP® sensors:

- Fixed voltage sensitivity, regardless of cable type or length.
- Low-impedance output signal, which can be transmitted over long cables in harsh environments with virtually no loss in signal quality.
- Two-wire operation with low cost coaxial cable, two-conductor ribbon wire or twisted-pair cabling.
- Low-noise, voltage-output signal compatible with standard readout, signal analysis, recording, and data acquisition equipment.
- Low cost per-channel - ICP® accelerometers require only an inexpensive, constant-current signal conditioner to operate.
- Intrinsic self-test feature – monitoring the sensor's output bias voltage provides an indication of proper operation, faulty condition, and bad cables.

In the rear of this manual you will find a **Specification Sheet**, which provides the complete performance characteristics of your particular sensor.

3.0 OPTIONAL FEATURES

Many sensors are supplied with standard, optional features. When listed before the model number, the following prefix letters indicate that the sensor is manufactured or supplied with a particular optional feature: **"A"** option: adhesive mount; **"HT"** option: extended high temperature range; **"J"** option: electrically ground isolated; **"M"** option: metric mounting thread; **"Q"** option: extended discharge time constant; **"T"** option: built-in transducer electronic data sheet (TEDS); and **"W"** option: attached, water-resistant cabling. Other prefix letters, such as **"K"**, **"KR"**, **"GK"**, **"GKR"**, **"KL"**, and **"GKL"**, indicate that the sensor is ordered in kit form, including interconnect cabling and signal conditioner. If you have any questions or concerns regarding optional features, consult the Vibration Division's product catalog or contact a PCB factory representative.

4.0 INSTALLATION OVERVIEW

When choosing a mounting method, consider closely both the advantages and disadvantages of each technique. Characteristics like location, ruggedness, amplitude range, accessibility, temperature, and portability are extremely critical. However, the most important and often overlooked consideration is the effect the mounting technique has on the high-frequency performance of the accelerometer.

® ICP is a registered trademark of PCB Group, Inc., which uniquely identifies PCB sensors that incorporate built-in microelectronics.

Shown in figure 1 are six possible mounting techniques and their effects on the performance of a typical piezoelectric accelerometer. (Note that not all of the mounting methods may apply to your particular sensor). The mounting configurations and corresponding graph demonstrate how the high-frequency response of the accelerometer may be compromised as mass is added to the system and/or the mounting stiffness is reduced.

NOTE: *The low-frequency response is unaffected by the mounting technique. This roll-off behavior is typically fixed by the sensor's built-in electronics. However, when operating AC-coupled signal conditioners with readout devices having an input impedance of less than one megohm, the low frequency range may be affected. If necessary, contact a factory representative for further assistance.*

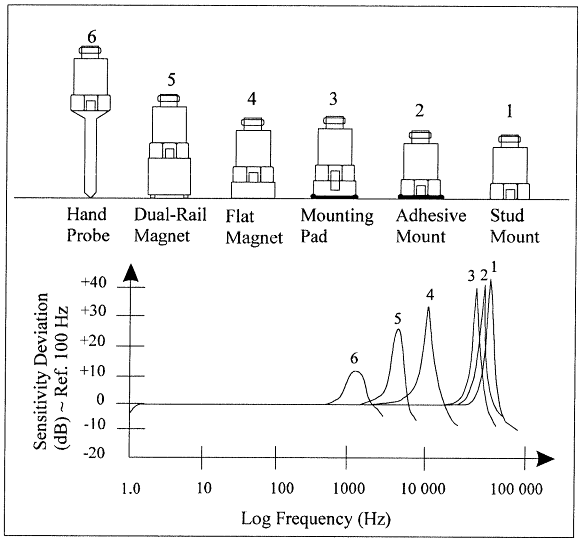


Figure 1. Assorted Mounting Configurations and Their Effects on High Frequency

4.1 STUD MOUNT

This mounting technique requires smooth, flat contact surfaces for proper operation and is recommended for permanent and/or secure installations. Stud mounting is also recommended when testing at high frequencies.

NOTE: *Do NOT attempt mounting on curved, rough, or uneven surfaces, as the potential for misalignment and limited contact surface may significantly reduce the sensor's upper operating frequency range.*

STEP 1: First, prepare a smooth, flat mounting surface, then drill and tap a mounting hole in the center of this area as shown in Figure 2 and in accordance with the enclosed **Installation Drawing**.

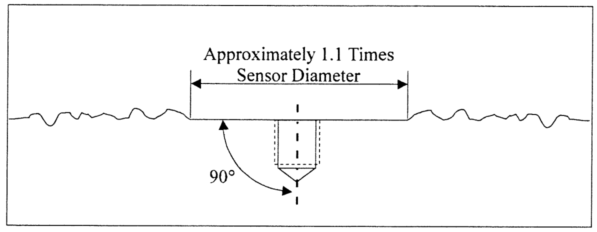


Figure 2. Mounting Surface Preparation

A precision-machined mounting surface with a minimum finish of 63 μin (0.00016 mm) is recommended. (If it is not possible to properly prepare the test structure mounting surface, consider adhesive mounting as a possible alternative). Inspect the area, checking that there are no burrs or other foreign particles interfering with the contact surface.

STEP 2: Wipe clean the mounting surface and spread on a light film of grease, oil, or similar coupling fluid prior to installation.

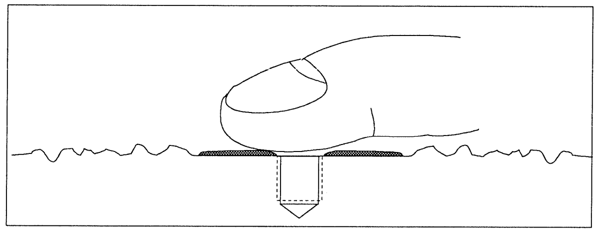


Figure 3. Mounting Surface Lubrication

Adding a coupling fluid improves vibration transmissibility by filling small voids in the mounting surface and increasing the mounting stiffness. For semi-permanent mounting, substitute epoxy or another type of adhesive.

STEP 3: Screw the mounting stud into the base of accelerometer and hand-tighten (this step is unnecessary for units having an integral mounting stud). Then, screw the sensor into the tapped hole that was prepared in the test object. Tighten the unit in place by applying, with a torque wrench, the recommended mounting torque, as listed on the enclosed **Installation Drawing**.

NOTE: *It is important to use a torque wrench during this step. Under-torquing the sensor may not adequately couple the device; over-torquing may result in stud failure.*

4.2 ADHESIVE MOUNT

Adhesive mounting is often used for temporary installation or when the test object surface cannot be adequately prepared for stud mounting. Adhesives like hot glue and wax perform well for temporary installations whereas two-part epoxies and quick-bonding gels (super glue) provide a more permanent installation. Two techniques are used for adhesive mounting; they are via an adhesive mounting base (method 1 below) or direct adhesive mounting (method 2 below).

NOTE: *Adhesively mounted sensors often exhibit a reduction in high-frequency range. Generally, smooth surfaces and stiff adhesives provide the best high frequency response.*

METHOD 1 - Adhesive Mounting Base

This method involves attaching a base to the test structure, then securing the sensor to the base. This allows for easy removal of the accelerometer. Also, since many bases are manufactured of "hard-coated" aluminum, they provide electrical isolation to eliminate ground loops and reduce electrical interference that may propagate from the surface of the test object.

STEP 1: Prepare a smooth, flat mounting surface. A minimum surface finish of 63 µin (0.00016 mm) generally works best.

STEP 2: Stud-mount the sensor to the flat side of the appropriate adhesive mounting base according to the guidelines set forth in **STEPS 2** and **3** of the Stud Mount Procedure presented above.

STEP 3: Place a small portion of adhesive on the underside of the mounting base (the underside is discernable by the concentric grooves which are designed to accept the adhesive). Firmly press down on the assembly to displace any extra adhesive remaining under the base.

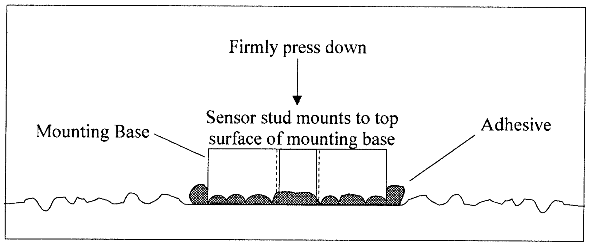


Figure 4. Mounting Base: Adhesive Installation

METHOD 2 - Direct Adhesive Mount

For restrictions of space or for convenience, most sensors can be adhesive-mounted directly to the test structure (an exception being units having integral mounting studs).

STEP 1: Prepare a smooth, flat mounting surface. A minimum surface finish of 63 µin (0.00016 mm) generally works best.

STEP 2: Place a small portion of adhesive on the underside of the sensor. Firmly press down on the top of the assembly to displace any adhesive. Be aware that excessive amounts of adhesive can make sensor removal difficult. Also, adhesive that may invade the tapped mounting hole in the base of the sensor will compromise future ability to stud mount the unit.

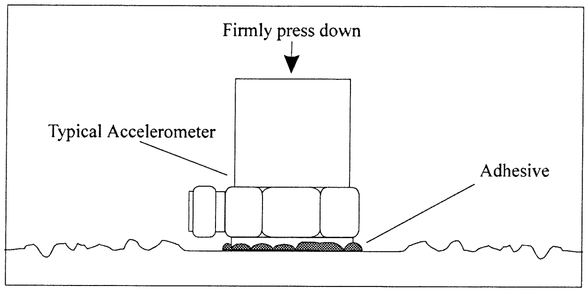


Figure 5. Direct Adhesive Mounting

4.2-1 ADHESIVE MOUNT REMOVAL (other than wax)

NOTE: *A debonder should always be used to avoid sensor damage.*

To avoid damaging the accelerometer, a debonding agent must be applied to the adhesive prior to sensor removal. With so many adhesives in use (everything from super glues, dental cement, epoxies, etc), there is no universal debonding agent available. The debonder for the Loctite 454 adhesive that PCB offers is Acetone. If you are using anything other than Loctite 454, you will have to check with the individual manufacturers for their debonding recommendations. The debonding agent must be allowed to penetrate the surface in order to properly react with the adhesive, so it is advisable to wait a few minutes before removing the sensor.

After the debonding agent has set, you can use an ordinary open-end wrench if the accelerometer has a hex base or square base, or the supplied removal tool for teardrop accelerometers. After attaching either, use a gentle shearing (or twisting) motion (by hand only) to remove the sensor from the test structure.

4.3 MAGNETIC MOUNT

Magnetic mounting provides a convenient means for making quick, portable measurements and is commonly used for machinery condition monitoring, predictive maintenance, spot checks, and vibration trending applications.

NOTE: *The correct magnet choice and an adequately prepared mounting surface are critical for obtaining reliable measurements, especially at high frequencies. Poor installations can cause as much as a 50% drop in the sensor frequency range.*

Not every magnet is suitable for all applications. For example, rare earth magnets are commonly used because of their high strength. Flat magnets work well on smooth, flat surfaces, while dual-rail magnets are required for curved surfaces such as motor housings and pipes. In the case of non-magnetic or rough surfaces, it is recommended that the user first weld, epoxy, or otherwise adhere a steel mounting pad to the test surface. This provides a smooth location for mounting and a target to insure that subsequent measurements for trending purposes are taken at the same location.

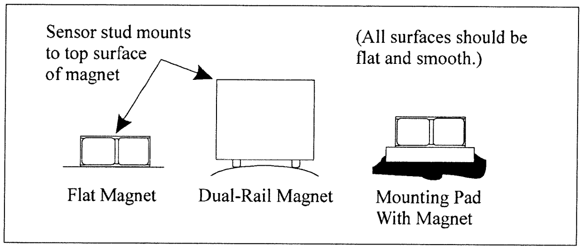


Figure 6. Magnet Types

STEP 1: Prepare a smooth, flat mounting surface. A minimum surface finish of 63 μin (0.00016 mm) generally works best. After cleaning the surface and checking for burrs, apply a light film of silicone grease, machine oil, or similar-type coupling fluid.

STEP 2: After choosing the correct magnet type, inspect the magnet, verifying that its mounting surfaces are flat and smooth.

STEP 3: Stud-mount the accelerometer to the appropriate magnet according to the guidelines set forth in **STEP 3** of the above Stud Mount Procedure.

STEP 4: To avoid damage to the sensor, install the magnet/sensor assembly to the prepared test surface by gently "rocking" or "sliding" it into place.

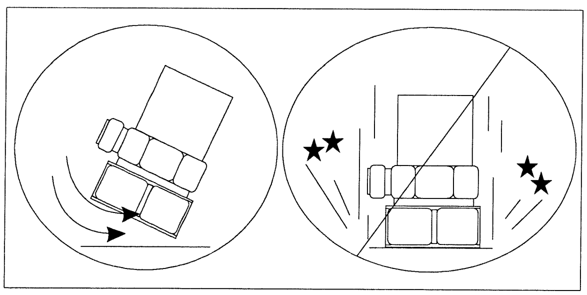


Figure 7. Magnet Mounting

CAUTION: *Magnetically mounting of an accelerometer has the potential to generate very high (and very damaging) acceleration (g) levels. To prevent such damage, exercise caution and install the assembly gently by rocking it into place. If shock is expected to be a particular concern, use a sensor with built-in shock protection. For further assistance, contact a factory representative.*

4.4 HANDHELD OR PROBE TIP MOUNT

This method is NOT recommended for most applications. Both the accuracy and repeatability at low (<5 Hz) and high frequency (>1 kHz) ranges are questionable. It is generally used only for machinery condition monitoring, when installation space is restricted, or other portable trending applications. The technique, however, can be useful for initially determining locations of greatest vibration to establish a permanent sensor installation point.

5.0 CABLING

Care and attention to cable installation and cable condition is essential as the reliability and accuracy of any measurement system is no better than that of its weakest link. Do to the nature of vibration measurements, all sensor cables will ultimately fatigue and fail. Good installation practice will extend the life of a cable, however, it is highly recommended to keep spare cables on hand to enable continuation of the test in the event of a cable failure.

STEP 1: Ascertain that you have the correct cable type.

One cable type cannot satisfy all applications. ICP® sensors can be operated with any ordinary two-wire or coaxial cable. Special, low-noise cables that are typically recommended for use with high-impedance, charge-output sensors can also be used. For applications requiring conformity to CE, low noise cables are essential. Industrial applications often require shielded, twisted-pair cables to reduce the effects of EMI and RFI that is present near electrical motors and machinery. Teflon-jacketed cabling may be necessary to withstand corrosive environments and higher temperatures. Consult the Vibration Division's product catalog for more information about cables or feel free to contact a factory representative for a specific recommendation on cables that are best suited for your application.

STEP 2: Connect the cable to the accelerometer.

A small amount of thread-locking compound placed on the connector threads prior to attachment helps secure the cable during testing. In wet, oily, or dirty environments, the connection can be sealed with silicone rubber sealant, O-rings, and flexible, heat-shrink tubing.

Coaxial Cables: Make connection by inserting the cable's connector pin into the sensor's mating socket. Then thread the connector into place by turning the cable connector's outer shell onto the accelerometer's electrical connector.

NOTE: *Do not spin the accelerometer while holding the cable connector stationary, as this will cause undue* *friction on the center pin of the cable connector and lead to premature fatigue.*

Multi-pin connectors: Make connection by inserting the sensor's mating pins onto the cable connector's mating sockets. Then thread the connector into place by turning the cable connector's outer shell onto the accelerometer's electrical connector.

Pigtail Connections: Certain miniature accelerometers and shock sensors are provided with lightweight cables attached to "Pigtail" connections. This type of connection reduces overall weight and incidence of connection intermittency under shock conditions. In the event of a cable or connection failure, the cables may be repaired in the field simply by re-soldering the stripped leads to the exposed pins on the sensor. (Check the **Installation Drawing** to determine signal and ground pins). In many cases, it is also helpful to protect the solder joint with heat-shrink tubing or epoxy.

NOTE: *If you do not have the experience or resources to attach pigtail leads, consult PCB to discuss factory attachment. Damage to internal electronics may be caused by excessive heat during soldering and such failure is not covered by warranty.*

STEP 3: Route the cable to the signal conditioner, making certain to relieve stress on the sensor/cable connection. Also, minimize cable motion by securing it with tape, clamps or ties at regular intervals.

Common sense should be used to avoid physical damage and minimize electrical noise. For instance, avoid routing cables near high-voltage wires. Do not route cables along floors or walkways where they may be stepped on or become contaminated. To avoid ground loops, shielded cables should have the shield grounded at one end only, typically at the signal conditioner.

STEP 4: Finally, connect the remaining cable end to the signal conditioner. It is good practice to dissipate any electrical charge that may have accumulated in the cable by shorting the signal pin to the ground pin or shell prior to attachment.

6.0 POWERING

All ICP® sensors require constant current excitation for proper operation. For this reason, use only PCB constant-current signal conditioners or other approved constant-current sources. A typical system schematic is shown in Figure 8.

NOTE: *Damage to the built-in electronics resulting from the application of incorrect power, or the use of an unapproved power source, is NOT covered by warranty.*

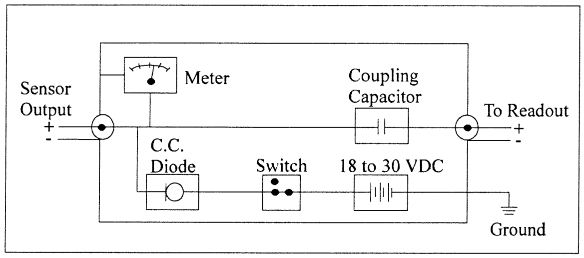


Figure 8. Typical System Schematic

The power supply consists of a current-regulated, 18 to 30 VDC source. This power is regulated by a current-limiting circuit, which provides the constant-current excitation required for proper operation of ICP® sensors. In general, battery-powered devices offer versatility for portable, low-noise measurements, whereas line-powered units provide the capability for continuous monitoring. Consult the Vibration Division's product catalog for more information about signal conditioners.

NOTE: *Under no circumstances should a voltage be supplied to an ICP® accelerometer without a current-regulating diode or equivalent electrical circuit. This may include ohmmeters, multi-meters and continuity testers.*

Meters or LEDs are used on PCB signal conditioners to monitor the bias voltage on the sensor output signal, to check sensor operation, and detect cable faults. Normally, a "yellow" reading indicates an open circuit; "green" indicates normal operation; and "red" indicates either a short or overload condition. Finally, a capacitor at the output stage of the device removes the sensor output bias voltage from the measurement signal. This provides a zero-based, AC-coupled output signal that is compatible with most standard readout devices.

NOTE: *Units having a low bias voltage may be in the "red," when actually they are working properly. If suspect, the bias voltage can be checked with a voltmeter attached to a "T" connector installed on the input connector to the signal conditioner.*

Note: *For readout devices having an input impedance near one gigohm (as encountered with some A to D converters), it may be necessary to place a one megohm resistor in parallel to the readout input to eliminate slow turn-on and signal drift.*

Today, many FFT analyzers, data acquisition modules, and data collectors have the proper constant-current excitation built-in for direct use with ICP® sensors. Before using this feature, however, check that the supply voltage and constant current are within acceptable limits for use with your particular sensor. (Check enclosed **Specification Sheet**). Please contact the respective signal conditioner manufacturer or check the product manual for more information.

7.0 OPERATING

After completing the system setup, switch on the signal conditioner and allow 1 to 2 minutes for the system to stabilize. The meter (or LED) on the signal conditioner should be reading "green." This indicates proper operation and you may begin taking measurements. If a faulty condition is indicated (red or yellow reading), first check all system connections, then check the functionality of the cable and signal conditioner. If the system still does not operate properly, consult a PCB factory representative.

NOTE: *Always operate the accelerometer within the limitations listed on the enclosed **Specification Sheet**. Operating the device outside these parameters can cause temporary or permanent damage to the sensor.*

8.0 ACCELEROMETER CALIBRATION

Accelerometer calibration provides, with a definable degree of accuracy, the necessary link between the physical quantity being measured and the electrical signal generated by the sensor. In addition, other useful information concerning operational limits, physical parameters, electrical characteristics, or environmental influences may also be determined. Without this link, analyzing data becomes a nearly impossible task. Fortunately, most sensor manufacturers provide a calibration record that documents the exact characteristics of each sensor. (The type and amount of data varies depending on the manufacturer, sensor type, contractual regulations, and other special requirements).

Under normal conditions, piezoelectric sensors are extremely stable, and their calibrated performance characteristics do not change over time. However, the sensor may be temporarily or permanently affected by harsh environments influences or other unusual conditions that may cause the sensor to experience dynamic phenomena outside of its specified operating range. This change manifests itself in a variety of ways, including: a shift of the sensor resonance due to a cracked crystal; a temporary loss of low-frequency measuring capability due to a drop in insulation resistance; or total failure of the built-in microelectronic circuit due to a high mechanical shock.

For these reasons, it is recommended that a recalibration cycle be established for each accelerometer. This schedule is unique and is based on a variety of factors, such as: extent of use, environmental conditions, accuracy requirements, trend information obtained from previous calibration records, contractual regulations, frequency of "cross-checking" against other equipment, manufacturer recommendation, and any risk associated with incorrect readings. International standards, such as ISO 10012-1, provide insight and suggest methods for determining recalibration intervals for most measuring equipment. With the above information in mind and under "normal" circumstances, PCB conservatively suggests a 12- to 24-month recalibration cycle for most piezoelectric accelerometers.

NOTE: *It is good measurement practice to verify the performance of each accelerometer with a Handheld Shaker or other calibration device before and after each measurement. The PCB Handheld Shaker operates at a fixed frequency and known amplitude (1.0 g) to provide a quick check of sensor sensitivity.*

8.1 RECALIBRATION SERVICE

PCB offers recalibration services for our piezoelectric accelerometers, as well as units produced by other manufacturers. Our internal metrology laboratory is certified to ISO 9001, accredited by A2LA to ANSI/IEC 17025 and ANSI/NCSL Z540-1, complies with ISO 10012-1 (and former MIL-STD-45662A), and uses equipment directly traceable to NIST. Our investment in equipment, traceability and conformance to industry standards ensures accurate calibration against relevant specifications, in a timely fashion.

8.2 BACK-TO-BACK CALIBRATION THEORY

Many companies choose to purchase the equipment necessary to perform the recalibration procedure in house. While this may result in both a savings of time and money, it has also been attributed to incorrect readings and costly errors. Therefore, in an effort to prevent the common mistakes associated with customer-performed calibration, this document includes a broad overview of the Back-to-Back Calibration technique. This technique provides a quick and easy method for determining the sensitivity of a test accelerometer over a wide frequency range.

Back-to-Back Calibration is perhaps the most common method for determining the sensitivity of piezoelectric accelerometers. This method relies on a simple comparison to a previously calibrated accelerometer, typically referred to as a reference standard.

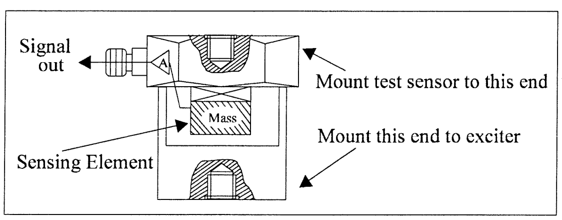


Figure 9. Reference Standard Accelerometer

These high-accuracy devices, which are directly traceable to a recognized standards laboratory, are designed for stability, as well as configured to accept a test accelerometer. By mounting a test accelerometer to the reference standard and then connecting this combination to a suitable vibration source, it is possible to vibrate both devices and compare the data as shown in Figure 10. (Test set-ups may be automated and vary, depending on the type and number of accelerometers being calibrated).

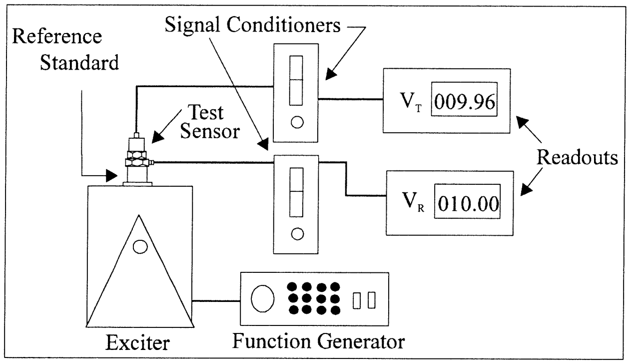


Figure 10. Typical Back-to-Back Calibration System

Because the acceleration is the same on both sensors, the ratio of their outputs (V_T/V_R) must also be the ratio of their sensitivities. With the sensitivity of the reference standard (S_R) known, the exact sensitivity of the test sensor (S_T) is easily calculated by using the following equation:

$$S_T = S_R\,(V_T/V_R)$$

By varying the frequency of the vibration, the sensor may be calibrated over its entire operating frequency range. The typical response of an unfiltered accelerometer is shown in Figure 11.

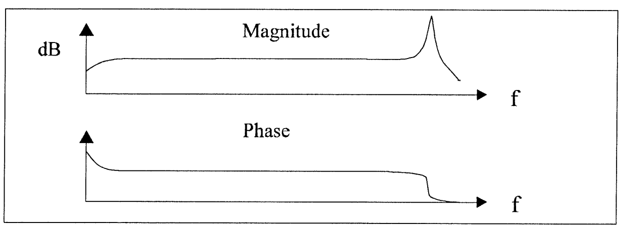


Figure 11. Typical Test Accelerometer Response

8.3 PCB CALIBRATION PROCEDURE

Numerous precautions are taken at PCB to insure accurate and repeatable results. This section provides a brief overview of the primary areas of concern.

Since the Back-to-Back Calibration technique relies on each sensor experiencing an identical acceleration level, proper mounting of the test sensor to the reference standard is imperative. Sensors with mounting holes are attached directly to the reference standard with a stud tightened to the recommended mounting torque. A shouldered mounting stud is typically used to prevent the stud from "bottoming out" in the hole. Both mounting surfaces are precision-machined and lapped to provide a smooth, flat interface according to the manufacturer's specification. A thin layer of silicone grease is placed between the mating surfaces to fill any imperfections and increase the mounting stiffness. The cables are stress-relieved by first routing them to the shaker head, then to a nearby stationary location. This reduces cable motion, which is especially important when testing charge output sensors, and helps to prevent extraneous motion or stresses from being imparted into the system. A typical set-up is shown in Figure 12.

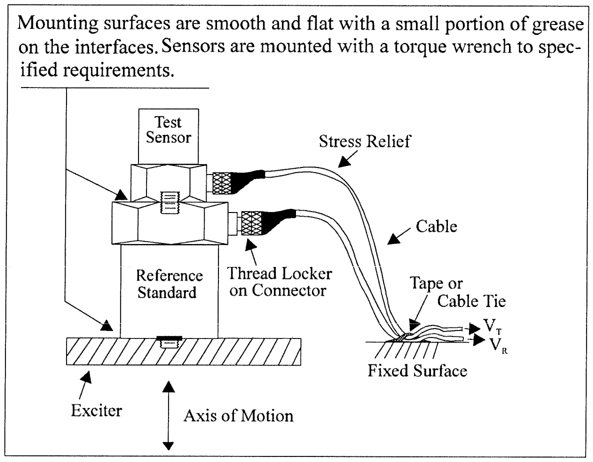


Figure 12. Typical Calibration Set-Up

Adhesively mounted sensors use similar practices. However, in this case, a small portion of quick-bonding gel, or similar temporary adhesive, is used to attach the test sensor to a reference standard designed with a smooth, flat mounting surface.

In addition to mounting, the selection of the proper equipment is critical. Some of the more important considerations include: 1) the reference standard must be specified and previously calibrated over the frequency and/or amplitude range of interest; 2) the shaker should be selected to provide minimal transverse (lateral) motion and minimal distortion; and 3) the quality of the meters, signal generator, and other devices should be selected so as to operate within the limits of permissible error.

8.4 COMMON MISTAKES

Most calibration errors are caused by simply overlooking some of the fundamental principals of dynamics. This section attempts to address some of the more common concerns.

For stud-mount sensors, always mount the accelerometer directly to the reference standard. Ensure that the mounting surfaces are smooth, flat, and free of any burrs. Always use a coupling fluid, such as silicone grease, in the mounting interface to maintain a high mounting stiffness. Mount the sensor according to the manufacturer's recommended mounting torque. DO NOT use any intermediate mounting adaptors, as the mounted resonant frequency may be reduced, and thereby compromise the high-frequency performance. If necessary, use adaptor studs.

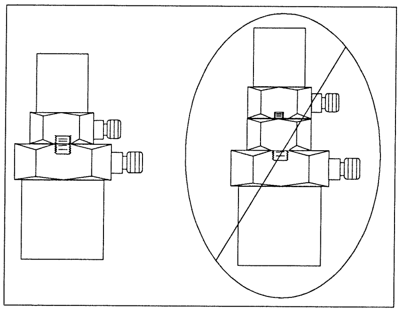


Figure 13. Stud Mounting

For adhesive mount sensors, use a thin, stiff layer of temporary adhesive such as quick-bonding gel or superglue. DO NOT use excessive amounts of glue or epoxy, as the mounting stiffness may be reduced and compromise high-frequency performance. It may also damage the sensor during removal.

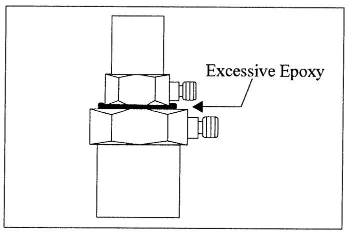


Figure 14. Incorrect Adhesive Mounting

Triaxial accelerometers should always be mounted directly to the reference standard. Unless absolutely required, DO NOT use adaptors to re-orient the sensor along the axis of motion, as the mounting stiffness may be altered. The vibration at the test sensor's sensing element may differ from the vibration at the reference standard due to a "cantilever" effect, seen in Figure 15.

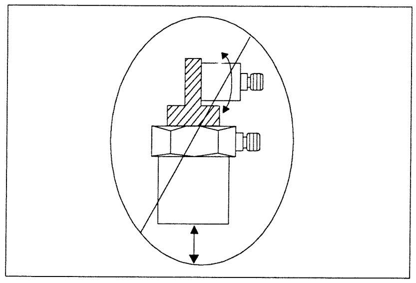


Figure 15. Mounting Triaxial Sensors (Incorrect)

Understand Back-to-Back Calibration limitations. Do not expect the uncertainty of calibration to be any better than ±2%. (In fact, the uncertainty may be as high as ±3% or ±4% for frequencies <10 Hz or >2 kHz.) Since large sensors may affect high-frequency accuracy, verify that the test sensor does not mass load the reference standard. Validate your calibration system with another accelerometer prior to each calibration session. Check with the manufacturer for exact system specifications.

8.5 CONCLUSIONS

Without an adequate understanding of dynamics, determining what, when, and how to test a sensor is a difficult task. Therefore, each user must weigh the cost, time, and risk associated with self-calibration versus utilizing the services of an accredited laboratory.

9.0 SERVICE

See the supplement sheet, contained in this manual, for information on our warranty, service, repair, and return policies and instructions.

When unexpected measurement problems arise, call our 24-hour SensorLine^{SM} to discuss your immediate dynamic instrumentation needs with a factory representative.
Dial 716-684-0001.

PCB PIEZOTRONICS
VIBRATION DIVISION

3425 Walden Avenue, Depew, NY 14043-2495 USA **Vibration Division toll-free** 888-684-0013
24-hour SensorLineSM 716-684-0001 **FAX** 716-685-3886 **E-mail** vibration@pcb.com **Website** www.pcb.com

A PCB GROUP COMPANY ISO 9001 CERTIFIED A2LA ACCREDITED to ISO 17025

Manual Number: 18292
Manual Revision: B
ECN Number: 19829

VIB-ICPMANUAL-0

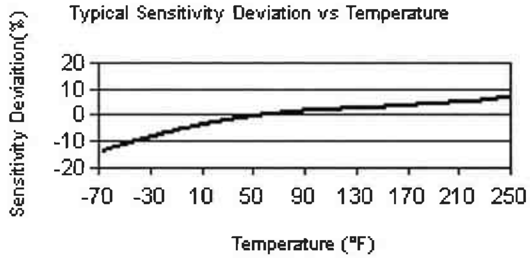
Printed in U.S

Model Number 352C68	ICP® ACCELEROMETER	Revision: N ECN #: 31827

Performance

Performance	ENGLISH	SI	
Sensitivity(± 10 %)	100 mV/g	10.2 mV/(m/s²)	
Measurement Range	± 50 g pk	± 491 m/s² pk	
Frequency Range(± 5 %)	0.5 to 10,000 Hz	0.5 to 10,000 Hz	
Frequency Range(± 10 %)	0.3 to 12,000 Hz	0.3 to 12,000 Hz	
Frequency Range(± 3 dB)	0.2 to 20,000 Hz	0.2 to 20,000 Hz	
Resonant Frequency	≥ 35 kHz	≥ 35 kHz	
Phase Response(± 5 °)(at 70°F [21°C])	2 to 6000 Hz	2 to 6000 Hz	
Broadband Resolution(1 to 10,000 Hz)	0.00016 g rms	0.0015 m/s² rms	[1]
Non-Linearity	≤ 1 %	≤ 1 %	[3]
Transverse Sensitivity	≤ 5 %	≤ 5 %	[4]
Environmental			
Overload Limit(Shock)	± 5000 g pk	± 49,050 m/s² pk	
Temperature Range(Operating)	-65 to +200 °F	-53 to +93 °C	[2]
Temperature Response	See Graph	See Graph	[1]
Base Strain Sensitivity	≤ 0.005 g/με	≤ 0.05 (m/s²)/με	[1]
Electrical			
Excitation Voltage	18 to 30 VDC	18 to 30 VDC	
Constant Current Excitation	2 to 20 mA	2 to 20 mA	
Output Impedance	≤ 300 ohm	≤ 300 ohm	
Output Bias Voltage	8 to 12 VDC	8 to 12 VDC	
Discharge Time Constant	0.8 to 2.4 sec	0.8 to 2.4 sec	
Settling Time(within 10% of bias)	<10 sec	<10 sec	
Spectral Noise(1 Hz)	60 μg/√Hz	588 (μm/sec^2)/√Hz	[1]
Spectral Noise(10 Hz)	16 μg/√Hz	157 (μm/sec^2)/√Hz	[1]
Spectral Noise(100 Hz)	5 μg/√Hz	49 (μm/sec^2)/√Hz	[1]
Spectral Noise(1 kHz)	1.5 μg/√Hz	14.7 (μm/sec^2)/√Hz	[1]
Physical			
Sensing Element	Ceramic	Ceramic	
Sensing Geometry	Shear	Shear	
Housing Material	Titanium	Titanium	
Sealing	Welded Hermetic	Welded Hermetic	
Size (Hex x Height)	9/32 in x 0.73 in	9/32 in x 18.5 mm	
Weight	0.070 oz	2.0 gm	[1]
Electrical Connector	10-32 Coaxial Jack	10-32 Coaxial Jack	
Electrical Connection Position	Top	Top	
Mounting Thread	5-40 Male	5-40 Male	
Mounting Torque	8 to 12 in-lb	90 to 135 N-cm	

Typical Sensitivity Deviation vs Temperature



CE [5]

All specifications are at room temperature unless otherwise specified.
In the interest of constant product improvement, we reserve the right to change specifications without notice.

OPTIONAL VERSIONS

Optional versions have identical specifications and accessories as listed for the standard model except where noted below. More than one option may be used.

A - Adhesive Mount
Supplied Accessory : Model 080A90 Quick Bonding Gel (1) replaces Model 080A15

HT - High temperature, extends normal operation temperatures

Frequency Range(5 %)	5 to 10,000 Hz	5 to 10,000
Frequency Range(10 %)	3 to 12,000 Hz	3 to 12,000
Frequency Range(3 dB)	2 to 20,000 Hz	2 to 20,000
Broadband Resolution(1 to 10,000 Hz)	0.0002 g rms	0.002 m/s² rms
Temperature Range(Operating)	-65 to +250 °F	-54 to +121 °C
Discharge Time Constant	0.08 to 0.24 sec	0.08 to 0.24 sec
Spectral Noise(1 Hz)	75 μg/√Hz	736 (μm/sec^2)/√Hz
Spectral Noise(10 Hz)	25 μg/√Hz	245 (μm/sec^2)/√Hz

J - Ground Isolated

Frequency Range(5 %)	0.5 to 8000 Hz	0.5 to 8000 Hz
Frequency Range(10 %)	0.3 to 10,000 Hz	0.3 to 10,000 Hz
Frequency Range(3 dB)	0.2 to 16,000 Hz	0.2 to 16,000 Hz
Resonant Frequency	≥ 30 kHz	≥ 30 kHz
Electrical Isolation(Base)	≥ 10^8 ohm	≥ 10^8 ohm
Size - Hex x Height	3/8 in x 0.75 in	3/8 in x 19.1 mm
Weight	0.1 oz	2.8 gm

M - Metric Mount

Mounting Thread	M3 x 0.50 Male	M3 x 0.50 Male

Supplied Accessory : Model M080A15 Adhesive Mounting Base (1) replaces Model 080A15

W - Water Resistant Cable

Electrical Connector	Sealed Integral Cable	Sealed Integral Cable
Electrical Connection Position	Side	Side

NOTES:
[1] Typical.
[2] 200°F to 250°F data valid with HT option only.
[3] Zero-based, least-squares, straight line method.
[4] Transverse sensitivity is typically ≤ 3%.
[5] See PCB Declaration of Conformance PS023 for details.

SUPPLIED ACCESSORIES:
Model 080A109 Petro Wax (1)
Model 080A15 Adhesive Mounting Base (1)
Model ACS-1 NIST traceable frequency response (10 Hz to upper 5% point).

Entered: ECB	Engineer: BAM	Sales: WDC	Approved: JB	Spec Number:
Date: 12/10/09	Date: 12/10/09	Date: 12/10/09	Date: 12/10/09	**8337**

PCB PIEZOTRONICS
VIBRATION DIVISION
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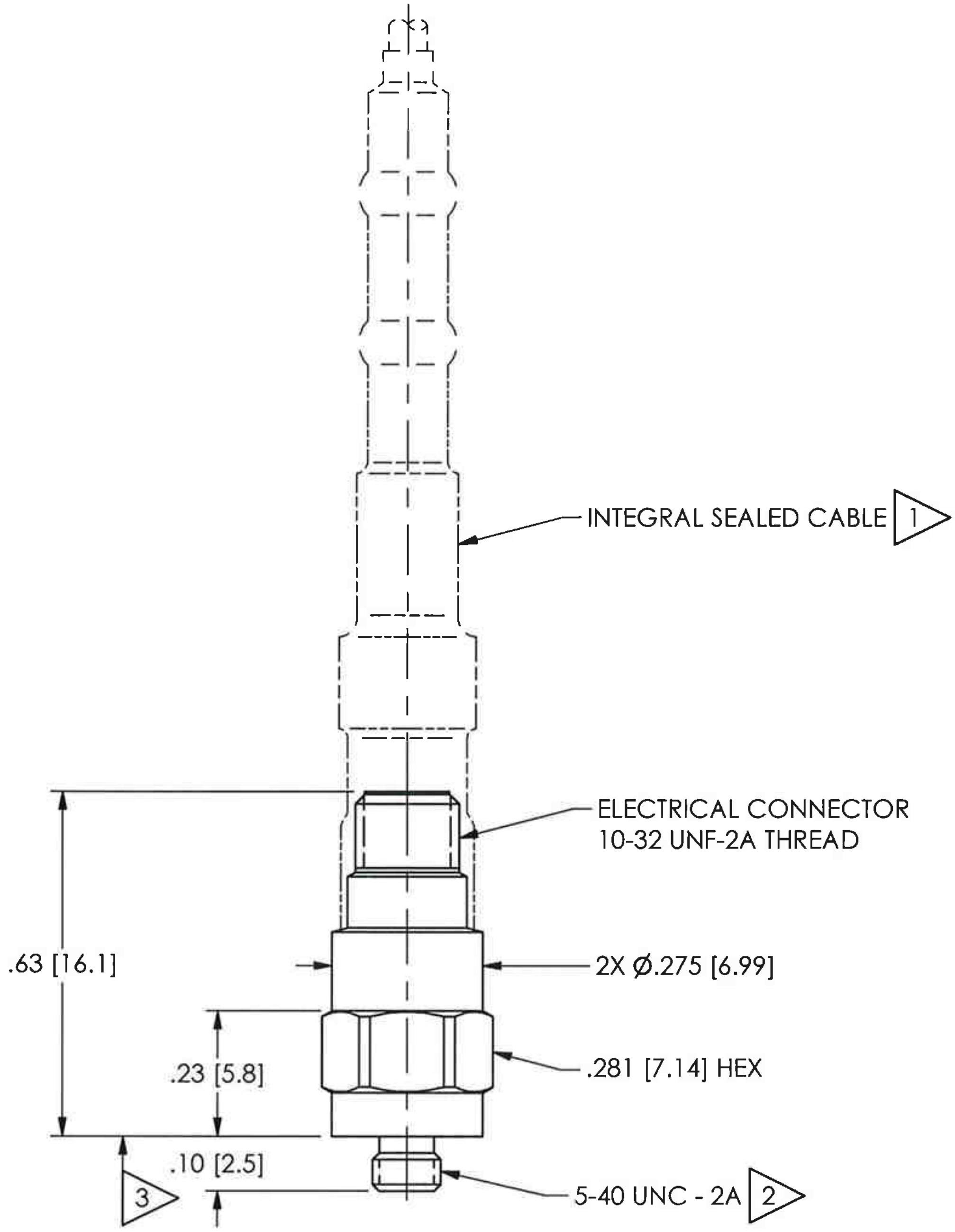
Phone: 716-684-0001
Fax: 716-685-3886
E-Mail: vibration@pcb.com

8244

REVISIONS

REV	DESCRIPTION	ECO
A	CORRECTED OVERALL HEIGHT	8962
B	UPDATED DRAWING	31827



3 STUD REMOVED FOR SENSOR WITH ADHESIVE MOUNT OPTION.

2 M3 X 0.50-6g FOR SENSOR WITH METRIC OPTION.

1 ADD CABLE FOR SENSOR WITH WATER RESISTANT OPTION.

UNLESS OTHERWISE SPECIFIED TOLERANCES ARE:		DRAWN		CHECKED		ENGINEER	
DIMENSIONS IN INCHES	DIMENSIONS IN MILLIMETERS [IN BRACKETS]	SMB	1/4/10	ECB	1-5-09	BAM	1/4/10
DECIMALS XX ±.03 XXX ±.010 ANGLES ± 2 DEGREES	DECIMALS X ± 0.8 XX ± 0.25 ANGLES ± 2 DEGREES	TITLE OUTLINE DRAWING 352C18 & 352C68 SERIES ACCELEROMETER					
FILLETS AND RADII .003 - .005	FILLETS AND RADII 0.07 - 0.13						

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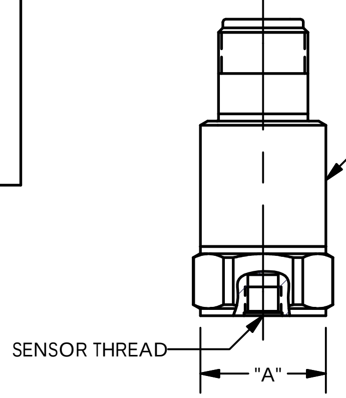
3425 WALDEN AVE. DEPEW, NY 14043
(716) 684-0001 E-MAIL: sales@pcb.com

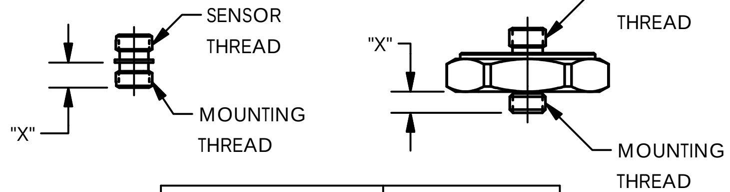
CODE IDENT. NO.	DWG. NO.
52681	8244
SCALE: 3X	SHEET 1 OF 1

081-XXXX-90

REVISIONS		
REV	DESCRIPTION	DIN
P	UPDATE DRAWING	25686

STANDARD STUD MOUNT

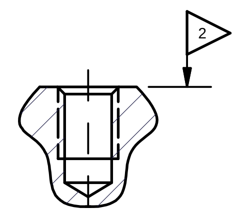




MOUNTING THREAD	SEE DRAWING
5-40	A
M3 X 0.50	B
10-32	C
M5 X 0.80	D
1/4-28	E
M6 X 1.00	F

"A" 5-40 MOUNTING INSTRUCTIONS

(METRIC DIMENSIONS IN BRACKETS)



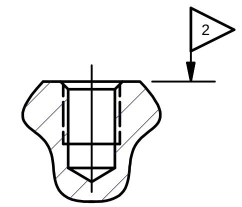
MOUNTING HOLE PREPARATION:

1 Ø.101[Ø2.57]
X .20[5.1]↧ MIN.
5-40 UNC-2B
X .15[3.8]↧ MIN.

4.) RECOMMENDED MOUNTING TORQUE, 4-5 INCH POUNDS [45-55 NEWTON CENTIMETERS].

"B" M3 X 0.50 MOUNTING INSTRUCTIONS

(ENGLISH DIMENSIONS IN BRACKETS)



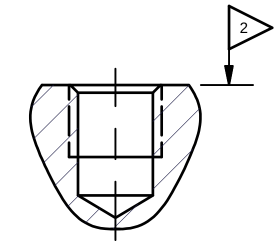
MOUNTING HOLE PREPARATION:

1 Ø2.5[Ø.099]
X 4.6 [1.8]↧ MIN.
M3 X 0.50-6H
X 3.3[.13]↧ MIN.

4.) RECOMMENDED MOUNTING TORQUE, 45-55 NEWTON CENTIMETERS [4-5 INCH POUNDS].

"C" 10-32 MOUNTING INSTRUCTIONS

(METRIC DIMENSIONS IN BRACKETS)



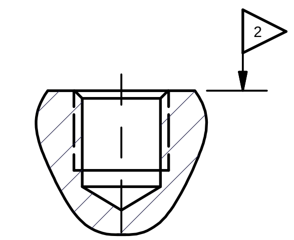
MOUNTING HOLE PREPARATION:

1 Ø.159[Ø4.04]
X .23[5.8]↧ MIN.
10-32 UNF-2B
X .15[3.8]↧ MIN.

4.) RECOMMENDED MOUNTING TORQUE, 10-20 INCH POUNDS [113-225 NEWTON CENTIMETERS].

"D" M5 X 0.80 MOUNTING INSTRUCTIONS

(ENGLISH DIMENSIONS IN BRACKETS)

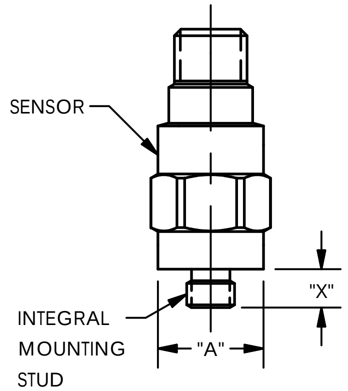


MOUNTING HOLE PREPARATION:

1 Ø4.22[Ø.166]
X 7.62 [.300]↧ MIN.
M5 X 0.8-6H
X 5.08[.200]↧ MIN.

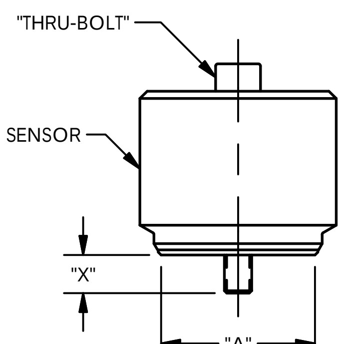
4.) RECOMMENDED MOUNTING TORQUE, 113-225 NEWTON CENTIMETERS [10-20 INCH POUNDS].

INTEGRAL STUD MOUNT



MOUNTING THREAD	SEE DRAWING
5-40	A
M3 X 0.50	B
10-32	C
M5 X 0.80	D
1/4-28	E
M6 X 1.00	F

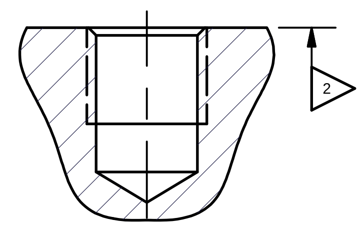
"THRU-BOLT" STUD MOUNT



BOLT THREAD	SEE DRAWING
10-32	C
M5 X 0.80	D
1/4-28	E
M6 X 1.00	F
M8 X 1.25	F

"E" 1/4-28 MOUNTING INSTRUCTIONS

(METRIC DIMENSIONS IN BRACKETS)



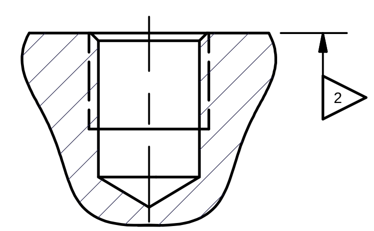
MOUNTING HOLE PREPARATION:

1 Ø.218[Ø5.54]
X .300[7.62]↧ MIN.
1/4-28 UNF-2B
X .200[5.08]↧ MIN.

4.) RECOMMENDED MOUNTING TORQUE, 2-5 FOOT POUNDS [3-7 NEWTON METERS].

"F" M6 X 0.75, M6 X 1.00, M8 X 1.25 MOUNTING INSTRUCTIONS

(ENGLISH DIMENSIONS IN BRACKETS)



M6 X 0.75 MOUNTING HOLE PREPARATION:

1 Ø5.31[Ø.209]
X 7.62 [.300]↧ MIN.
M6 X 0.75-6H
X 5.08[.200]↧ MIN.

M6 X 1.0 MOUNTING HOLE PREPARATION:

1 Ø5.05[Ø.199]
X 8.10 [.320]↧ MIN.
M6X 1.0-6H
X 6.35[.250]↧ MIN.

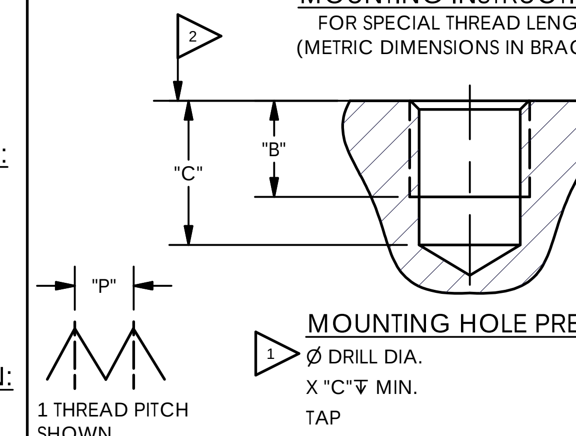
M8 X 1.25 MOUNTING HOLE PREPARATION:

1 Ø6.75[Ø.266]
X 8.64 [.340]↧ MIN.
M8 X 1.25-6H
X 5.00[.197]↧ MIN.

4.) RECOMMENDED MOUNTING TORQUE, 3-7 NEWTON METERS [2-5 FT POUNDS].

"G" MOUNTING INSTRUCTIONS

FOR SPECIAL THREAD LENGTHS
(METRIC DIMENSIONS IN BRACKETS)



MOUNTING HOLE PREPARATION:

1 Ø DRILL DIA.
X "C"↧ MIN.
TAP
X "B"↧ MIN.

THREAD DEPTH : B= X + 1 THREAD PITCH
DRILL DEPTH : C= B + 3 THREAD PITCH
SEE A-F FOR APPROPRIATE DRILL AND TAP
THREAD PITCH= 1/TPI [P]

3.) FOR BEST RESULTS, PLACE A THIN LAYER OF SILICONE GREASE (OR EQUIVALENT) ON INTERFACE PRIOR TO MOUNTING.

2 MOUNTING SURFACE SHOULD BE FLAT TO WITHIN .001(0.03) TIR OVER DIM 'A' WITH A 63[1.61]√ OR BETTER FINISH FOR BEST RESULTS.

1 DRILL PERPENDICULAR TO MOUNTING SURFACE TO WITHIN ± 1˚.

UNLESS OTHERWISE SPECIFIED TOLERANCES ARE:	
DIMENSIONS IN INCHES	DIMENSIONS IN MILLIMETERS [IN BRACKETS]
DECIMALS XX ±.01, XXX ±.005	DECIMALS X ± 0.3, XX ± 0.13
ANGLES ± 2 DEGREES	ANGLES ± 2 DEGREES
FILLETS AND RADII .003 - .005	FILLETS AND RADII 0.07 - 0.13

DRAWN		CHECKED		ENGINEER	
JDM	3/9/07	ECB	3/9/07	JJD	3/9/07

TITLE: INSTALLATION DRAWING FOR STANDARD 081 SERIES MOUNTING

PCB PIEZOTRONICS
3425 WALDEN AVE. DEPEW, NY 14043
(716) 684-0001 E-MAIL: sales@pcb.com

CODE IDENT. NO. 52681 | DWG. NO. 081-XXXX-90

SCALE: N.T.S. | SHEET 1 OF 1

Tema n. 5

Nell'ambito dei dispositivi MEMS (Micro Electro Mechanical System) è possibile identificare i sistemi per l'energy harvesting come componenti che stanno avendo un notevole incremento di interesse.

Il Candidato, basandosi su una o più delle metodologie tipiche della tecnologia MEMS, progetti una struttura per la realizzazione di un dispositivo da utilizzare come harvester per applicazione in network di sensori.

In particolare:

- si indichino i principi di funzionamento del dispositivo citando dei riferimenti quantitativi;
- si riporti uno schematico del dispositivo;
- si descriva il flusso dei passi di processo inquadrandolo nella tecnologia di fabbricazione scelta;

Viene richiesto inoltre di affrontare il problema del packaging del dispositivo e l'integrazione con l'elettronica di gestione.

E' necessaria una trattazione con scelte motivate, precise, schematiche e quantitative.

Tema n. 6

Una società di car sharing vuole realizzare un Sistema Informatico (S.I.) per gestire i propri servizi ed i propri mezzi mediante l'utilizzo delle più moderne tecnologie. Il candidato, che si ipotizza essere stato incaricato (in conformità all'art. 46 del DPR 328/01) per la progettazione di tale sistema, elabori la sua proposta tenendo conto di quanto segue. Il livello di progettazione sia tale da permettere, grosso modo, la stima dei costi, indicandone eventualmente i criteri.

- La società opera in ambito nazionale con un parco iniziale di circa 500 vetture;
- Ogni vettura avrà un computer di bordo dotato di quanto necessario per l'utilizzo previsto, con un display visibile dall'esterno che indicherà lo stato della vettura: disponibile, prenotata, in uso;
- Ogni operazione, sia dei clienti, sia dei gestori del S.I., dovrà essere svolta tramite applicazioni on-line e/o sms, con la massima sicurezza ed affidabilità;
- L'applicazione per la prenotazione fornirà la posizione delle vetture disponibili; la vettura prenotata rimarrà tale per 30 minuti e, se non utilizzata entro quel lasso di tempo, ritornerà disponibile con un addebito al cliente;
- Le tariffe saranno basate sui minuti d'uso, ridotte del 50% per i minuti di sosta, con un massimo giornaliero entro un certo chilometraggio, oltre il quale sarà applicata anche una tariffa a chilometro.
- Ad ogni cliente saranno associate una, o più, carte di credito a garanzia di solvibilità.
- Esisterà comunque un numero verde per l'assistenza emergenziale;

Si richiede che il candidato nel progetto:

1. Esprima e motivi ipotesi addizionali sulle caratteristiche del S.I. ritenute utili per soddisfare i requisiti generali espressi e per garantirne affidabilità, qualità, facilità d'uso, accessibilità, economicità e facilità di gestione;
2. Elenchi e dettagli, tramite diagrammi UML, le funzionalità del sistema, i principali processi e i principali archivi;
3. Definisca tramite diagrammi UML i macro-blocchi del S.I. e di Telecomunicazione nelle diverse componenti centrali e/o distribuite;
4. Definisca e descriva sinteticamente le misure adottate per la sicurezza, la difesa della privacy, la business continuity, il disaster recovery e la difesa da eventuali truffe;
5. Individui eventuali sovraccarichi del S.I. ed indichi misure atte a prevenirli e/o a risolverli;
6. Definisca e descriva sinteticamente applicazioni utili per il controllo di gestione della società, ovvero che forniscano informazioni di riepilogo sull'andamento, nel tempo e per tipologie, dei principali parametri del core business.

Tema n. 7

PARTE A

Il candidato realizzi l'analisi del bilancio della società ALFA SpA (si veda allegato) per l'anno 2013, mettendone in evidenza gli indicatori di redditività operativa, solidità patrimoniale e liquidità.

PARTE B

Un investitore ha investito in un portafoglio costituito da 2 titoli A e B, acquistando 60.000 titoli di tipo A e 35.000 titoli di tipo B. I rendimenti storici dei due titoli presentano un coefficiente di correlazione pari a 0,7. Nell'ipotesi che i titoli siano quotati su un mercato azionario in equilibrio e che soddisfa tutte le assunzioni del Capital Asset Pricing Model (CAPM), il candidato calcoli il rendimento di un portafoglio efficiente.

NB: utilizzare almeno 4 cifre decimali nei conti

Titolo	A	B
Capitalizzazione (Milioni di Euro)	75	180
Numero azioni quotate (Milioni)	12	18
Beta	0,8	0.65
Rendimento	8,8%	7,9%
Varianza dei rendimenti	0,034	0,012
Covarianza con il portafoglio mercato	0,0095	

PARTE C

La società EPSYLON SpA è una impresa non quotata sul mercato azionario. Un fondo di investimento intende realizzare un'analisi per valutare l'opportunità di acquisire tale società. Gli attuali azionisti della società richiedono un prezzo pari a 11.50 Euro per azione.

Nel seguito vengono riportate le informazioni relative alla società EPSYLON:

Numero di azioni: 10 Milioni

Patrimonio netto (book value): 70 Milioni di Euro

Composizione del debito:

- 150 mila obbligazioni ZCB con scadenza a 10 anni con valore di rimborso 100 Euro ed attuale rendimento a scadenza del 7%.
- 10 Milioni di Euro da prestiti bancari a lungo termine su cui l'impresa paga un tasso di interesse pari al 5%.

Elementi del conto economico:
Ricavi operativi: 34 Milioni
Costi Operativi: 14 Milioni
Ammortamenti: 3 Milioni
Aliquota fiscale: 30%.

Si hanno a disposizione le seguenti informazioni sui mercati finanziari:

Rendimento dei titoli di stato per differenti scadenze:

3 mesi: 2,2% 6 mesi 2,5 % 10 anni 4%

Premio per il rischio di mercato: 5,5%

La società EPSYLON opera su un mercato in cui è attiva anche la società quotata GAMMA Spa, simile ad essa sotto il profilo operativo, di cui si hanno a disposizione le seguenti informazioni:

Impresa GAMMA Spa
Numero di azioni: 3 mln
Prezzo di mercato: 23 Euro
P/E: 15
Debito (market value):0
Beta: 0.80

Il candidato calcoli il costo medio ponderato del capitale (rWACC) della società EPSYLON (con ipotesi di stazionarietà dei flussi di cassa).

Allegato – Bilancio della DELTA SPA

Conto Economico 2013

Dati in migliaia di Euro	DELTA Spa
Ricavi vendite e prestazioni	115376
Var. rimanenze prodotti	-441
Variazione lavori	0
Incrementi di immob.	20
Altri ricavi	239
Contributi in conto esercizio	12
TOT. VAL. DELLA PRODUZIONE	115195
Costi Materie prime e consumo	71520
Costi Servizi	11654
Costi Godimento beni di terzi	6982
Totale costi del personale	10023
Salari e stipendi	7127
Oneri sociali	2428
Tratt. fine rapporto	340
Tratt. di quiescenza	0
Altri costi	128
TFR + quiescenza + altri costi	468
TOT Ammortamenti e svalut.	2029
Amm. Immob. Immat.	748
Amm. Immob. Mat.	1087
Altre svalut. Immob.	0
Amm. e svalut. delle immob.	1836
Svalut. Crediti	193
Variazione mag materie	7056
Accantonamenti per rischi	54
Altri accantonamenti	0
Oneri diversi di gestione	912
TOT COSTI DELLA PRODUZIONE	110231
RISULTATO OPERATIVO	4964
TOTALE PROVENTI E ONERI FINANZIARI	-638
Tot. proventi da partecip.	0
TOT Altri Proventi	259
Da Crediti	0
Da titoli iscr. imm.	0
Da titoli iscr. att.circol.	0
Proventi da Titoli	0
Proventi fin. Diversi	259
TOT Oneri finanziari	672
Utili e perdite su cambi	-226
TOTALE RETTIFICHE ATT. FINANZ.	0
TOT Rivalutazioni	0
Rivalut. di partec.	0

Rivalut. di altre imm. fin.	0
Rivalut. di titoli	0
TOT Svalutazioni	0
Svalut. di partec.	0
Svalut. di altre imm. fin.	0
Svalut. di titoli	0
Proventi Straordinari	127
Plusvalenze	0
Oneri Straordinari	76
Minusvalenze	0
Imposte es. prec.	61
RISULTATO PRIMA DELLE IMPOSTE	4377
Totale Imposte sul reddito correnti, differite e anticipate	1819
Imposte correnti	1873
Imposte differite e anticipate	-53
UTILE/PERDITA DI ESERCIZIO	2557
Numero di Dipendenti	195

Stato patrimoniale - Attivo 2013

ATTIVO 2013	DELTA Spa
CREDITI VERSO SOCI	0
TOTALE IMMOBILIZZAZIONI	24712
TOTALE IMMOB. IMMATERIALI	2074
Costi impianto e ampl.	0
Costi ricerca e pubb.	0
Diritti brevetto ind.	0
Concessioni, licenze	5
Avviamento	0
Imm. in corso	0
Altre immobiliz. Immateriali	2069
TOTALE IMMOB. MATERIALI	5143
Terreni e fabbricati	2496
Impianti	1186
Attrez. Industriali	672
Altri beni	789
Imm. in corso/acconti	0
TOTALE IMMOB. FINANZIARIE	17495
TOT Partecipazioni	10307
Imprese controllate	10305
Imprese collegate	0
Imprese controllanti	0
Altre imprese	1
TOT CREDITI Imm. Fin.	7189
Cred. vs Controllate entro	6526
Cred. vs Controllate oltre	0
Cred. vs Collegate entro	0
Cred. vs Collegate oltre	0

Cred. vs Controllanti entro	0
Cred. vs Controllanti oltre	0
Cred. vs Altri entro	10
Cred. vs Altri oltre	653
CREDITI FIN. A BREVE	6536
CREDITI FIN. A OLTRE	653
Altri titoli	0
Azioni proprie	0
ATTIVO CIRCOLANTE	72987
TOTALE RIMANENZE	20912
Materie prime	12539
Prodotti semilav./in corso	4490
Lavori in corso	0
Prodotti finiti	3883
Acconti	0
TOTALE CREDITI	32818
Cred. vs Clienti entro	24130
Cred. vs Clienti oltre	1098
Cred. vs Controllate entro	670
Cred. vs Controllate oltre	0
Cred. vs Collegate entro	0
Cred. vs Collegate oltre	0
Cred. vs Controllanti entro	0
Cred. vs Controllanti oltre	0
Cred. tributari entro	2294
Cred. tributari oltre	63
Cred. per imposte anticipate entro	173
Cred. per imposte anticipate oltre	4
Cred. verso altri entro	3086
Cred. verso altri oltre	1299
Crediti a breve	30353
Crediti a oltre	2465
TOT. DISPON. LIQUIDE	19257
Depositi bancari	19254
Assegni	0
Denaro in cassa	3
RATEI E RISCONTI	731
TOTALE ATTIVO	98430

Stato patrimoniale - Passivo 2013

Passivo 2013	DELTA Spa
Capitale sociale	22000
Riserva da sovrapprezzo	0
Riserva di rivalutazione	2216
Riserva legale	3407
Riserva statutaria	0
Riserva azioni proprie	0
Altre riserve	23853

Utile/perdita a nuovo	0
Utile/perdita di eserci	2557
TOTALE PATRIMONIO NETTO	54033
TOTALE FONDI RISCHI	1215
Fondo di Quiescenza	0
Fondo Imposte anche differite	75
Altri Fondi	1140
TRATTAMENTO DI FINE RAPPORTO	2181
TOTALE DEBITI	40298
Obblig.ni entro	0
Obblig.ni oltre	0
Obblig.ni convert. Entro	0
Obblig.ni convert. oltre.	0
Soci per Finanziamenti entro	0
Soci per Finanziamenti oltre	0
Banche entro	5500
Banche oltre	15298
Altri finanziatori entro	0
Altri finanziatori oltre	0
Acconti entro	80
Acconti oltre	0
Fornitori entro	18107
Fornitori oltre	0
Titoli di credito entro	0
Titoli di credito oltre	0
Imprese Controllate entro	0
Imprese Controllate oltre	0
Imprese Collegate entro	0
Imprese Collegate oltre	0
Controllanti entro	0
Controllanti oltre	0
Debiti Tributari entro	402
Debiti Tributari oltre	0
Istituti previdenza entro	442
Istituti previdenza oltre	0
Altri Debiti entro	469
Altri Debiti oltre	0
DEBITI A BREVE	25000
DEBITI A OLTRE	15298
Total debiti entro l'esercizio	25000
Total debiti oltre l'esercizio	15298
RATEI E RISCONTI	702
TOTALE PASSIVO	98430